The development of social and executive functions in late adolescence and early adulthood

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The development of social and executive functions in late adolescence and early adulthood

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Candidate's statement

This is to certify that the research presented in this thesis is solely my own work.

Signed: STaylor Date: 28/07/14

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Abstract

Executive functions and social cognition develop throughout childhood into adolescence and early adulthood (Blakemore & Choudhury, 2006). These functions are associated with frontal networks showing protracted maturation into early adulthood (Lebel, Walker, Leemans, Phillips & Beaulieu, 2008). Executive function and social cognition studies have previously focused on childhood (Pennequin, Sorel & Fontaine, 2010), adolescence (Magar, Phillips & Hosie, 2010) or broad age ranges in adulthood (Dziobek et al., 2006).

This thesis reports executive function, social cognition, IQ and mood state data in a sequential design with 98 participants aged 17 (Younger group), 18 (Middle group) and 19 years (Older group) at Time 1. Findings indicate non-linear development, with a trough in ability at age 18, on strategy generation and concept formation, assessed with Letter Fluency and Sorting Tests from the Delis Kaplan Executive Function System (Delis, Kaplan & Kramer, 2001). There were no group differences on Time 1 social cognition task scores.

Fifty eight participants were tested at Time 2 (interval between testing M = 14.81 months, SD = 4.01). Again, the Younger group scored significantly higher than the Middle group on strategy generation at Time 2 suggesting that group differences may represent sample characteristics rather than age related change. There were no group differences in concept formation at Time 2, indicating that non-linear development is specific to age 18 in the present sample. Inhibition, rule detection, strategy generation, planning and emotion recognition in dynamic stimuli showed progressively better longitudinal development. IQ, Age, Depression, Anxiety and executive function scores (rule detection, strategy generation, inhibition and planning) predicted performance on social cognition tasks assessing emotion recognition in visual static (Reading the Mind in the Eyes Test; Baron-Cohen et al., 2001), auditory (Reading the Mind in the Voice Test; Golan, Baron-Cohen Hill & Rutherford, 2007), dynamic visual and auditory stimuli (Movie for the Assessment of Social Cognition; Dziobek et al., 2006) and self-report empathy (Interpersonal Reactivity Index; Davies, 1983).

Overall, results indicate linear and non-linear development of functions in late adolescence and early adulthood. Clinical and educational implications of these findings are discussed.

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Chapter 1

Literature Review

1.1 Chapter overview

This chapter will review brain development in late adolescence and early adulthood, focusing on the frontal networks because these undergo protracted development (Lebel, Walker, Leemans, Phillips & Beaulieu, 2008) and are attributed to executive functions (Stuss & Alexander, 2007) and some aspects of social cognition (Carrington & Bailey, 2009). Definitions of executive function and social cognition are included together with their roles in late adolescence and early adulthood. This chapter also discusses theories of executive function and social cognition, followed by a review of behavioural studies of executive function and social cognition in late adolescence and early adulthood.

There is substantial executive function data across the developmental period of childhood (Carroll, Riggs, Apperly, Graham & Geoghegan, 2012: 3-4 year olds; Pennequin, Sorel & Fontaine, 2010: age 4-7), middle adolescence (Prencipe et al., 2011: age 8-15: Anderson, Anderson, Northam, Jacobs & Catroppa, 2001: age 11-17), and adulthood (Ahmed & Miller, 2011: age 18-27; Riccio, Wolfe, Romine, Davis & Sullivan, 2004: age 16-33; Guevara, Martínez, Aguirre & González, 2011: age 26-30; Barker, Andrade, Morton, Romanowski & Bowles, 2010: age 20-59). Similarly, social cognition research has focussed on children aged from 2-12 (Baron-Cohen, Wheelwright, Hill, Raste & Plumb, 2001; Doherty, Anderson & Howieson, 2009; Golan, Baron-Cohen, Hill & Golan, 2008), or adults (Dziobek et al, 2006: age 22-62; Heavey et al., 2000: age 22-45; Dumontheil, Apperly & Blakemore, 2010: age 19-27; Hallerback, Lugnegard, Hjarthag & Gillberg, 2009: age 19-32). Other work has investigated either executive or socio-cognitive functions with atypical groups for example, autism (Golan, Baron-Cohen & Golan, 2008), ADHD (Martel, Nikolas & Nigg, 2007), head-injury (Barker et al, 2010; Barker et al; 2006; Jacobs, Harvey & Anderson, 2011), and schizophrenia (Kravariti, Morris, Rabe-Hesketh, Murray & Frangou, 2003). However, there are scant data particularly with fine-grained age groups on the normative development of social and executive functions across the important maturational period of late adolescence and early adulthood (Herba & Phillips, 2004; Moriguchi, Ohnishi, Mori, Matsuda, & Komaki, 2007).

1.2 Brain maturation in late adolescence and early adulthood

Adolescence is the transition between childhood and adulthood, associated with physical, psychological and social changes (Steinberg & Morris, 2001). Adolescence, spanning from the onset of puberty until the late teenage years, is associated with brain changes as well as hormonal and other physiological changes (Steinberg & Morris, 2001). There is a growing body of evidence showing that brain development continues into adolescence and adulthood with converging evidence for maturational changes from morphological (e.g. Lebel et al., 2008; Sowell et al., 2003), behavioural (e.g. Dumontheil, Apperly & Blakemore, 2010; Romine & Reynolds, 2005; Waber et al., 2007) and neuropathological research (Paus, Keshevan & Giedd, 2008). Until the last few decades, the predominant viewpoint was that brain maturation was complete in childhood. More recently, post mortem histological studies on human brains have provided evidence for structural brain changes occurring in adolescence (e.g. Huttenlocher, 1979; Yakolvlev & Lecours, 1967). Frontal networks undergo a protracted course of development, characterised by synaptogenesis with later synaptic pruning (Huttenlocher, 1979) and myelination of neurons (Yakovlev & Lecours, 1967). Synaptogenesis is the formation of new synapses, resulting in a synaptic density greater than adult levels, whilst synaptic pruning strengthens the frequently used synapses and eliminates the infrequently used synapses. The protracted phase of synaptic pruning in frontal networks leads to more efficient functioning and complex behaviour (Giedd, 2008). Frontal regions are also thought to play an important role in executive functions (Barker et al., 2010; Lebel et al., 2008) and some aspects of social cognition (Carrington & Bailey, 2009; Castelli, Happé, Frith & Frith, 2000; Frith & Frith, 2006; Gallagher et al., 2000) that are crucial to adaptive goal-oriented behaviour.

1.2.1 MRI studies

Understanding of brain maturation was revolutionised by Magnetic Resonance Imaging, a way of investigating brain changes in vivo. This non-invasive technique enables longitudinal studies with living participants and informs the time-course of maturational processes (Toga, Thompson & Sowell, 2006). MRI reveals grey matter, composed of cell bodies, synapses and neuropil, and white matter, myelinated axons.

Sowell, Thompson, Tessner and Toga (2001) conducted an MRI study mapping post-adolescent brain maturation by region; they compared three age groups (7-11 years, 12-16 years and 23-30 years) and reported that grey matter loss predominantly occurred in dorsal frontal and parietal networks between childhood and adolescence. Grey matter loss accelerated in frontal networks between adolescence and adulthood, whilst there was a less pronounced decline in parietal networks. It is likely that parietal networks are associated with visuospatial functions, whereas frontal networks are associated with executive functions, resulting in visuospatial skills maturing earlier than executive functions (Sowell et al., 2001). Brain growth also occurred in the regions of grey matter loss, with the authors suggesting that myelination occurs in the space created by synaptic pruning. These findings show brain changes in late adolescence, specifically in frontal networks, indicating that maturation is dynamic, with both regressive (synaptic pruning) and progressive (myelination) processes (Sowell et al., 2001). The authors noted that synaptic pruning may lead to improved accuracy on cognitive tasks because unused synapses are pruned, leading to a more efficient arrangement of neurons, and myelination may result in faster reaction times due to the myelin sheath increasing transmission speed around brain regions. Sowell et al. (2001) acknowledged that pubertal status may affect brain maturation in adolescence, yet no measure of this was taken.

Gogtay et al. (2004) conducted a longitudinal MRI study with repeat scans every 2 years for 8 to 10 years, resulting in a total age range spanning 4 to 21 years. The authors reported that lower order sensorimotor regions matured earliest, followed by parietal regions (language development and spatial orientation) and then higher order association regions (frontal networks). The protracted development of frontal networks is notable because this region mediates complex cognitive and emotional functions (Stuss & Alexander, 2007). Focusing specifically on the frontal networks, maturation occurred in a posterior to anterior direction, commencing in the primary motor cortex, and then progressing to the superior and inferior frontal gyri, with the prefrontal networks maturing last. In late adolescence, there is loss of grey matter in the dorsolateral prefrontal network, thought to govern executive functions, with the orbitofrontal network maturing until age 21, the oldest age in this study (Gogtay et al., 2004).

1.2.2 Diffusion Tensor Imaging studies

A further advance in imaging is Diffusion Tensor Imaging (DTI); this uses magnetic resonance signals to show water movement in axons, providing a sensitive measure of microstructure changes (Barnea-Goraly et al., 2005). DTI yields measures of fractional anisotropy (FA), the direction of diffusion in water molecules, and mean diffusivity (MD), the average magnitude of water diffusion. Myelin sheath orientation in white matter leads to anisotropic diffusion (movement along one axis), because the myelin sheath prevents water molecules from moving perpendicularly, resulting in water movement along the axon (Thomsen, Henriksen & Ring, 1987). Grey matter shows isotropic diffusion, equal movement in all direction, because it lacks fibre structure (Beaulieu, 2002). DTI research provides evidence for the different maturational rates of brain regions and supports the notion of brain changes occurring in adolescence and beyond. Schmithorst and Yuan (2010) conducted a review of adolescent DTI studies, with the age range of 12 to 18 years, and concluded that white matter continues to develop, particularly in frontal regions, as shown by increases in FA and decreases in MD.

In a large DTI study with 202 participants aged 5 to 30 years, Lebel et al. (2008) reported a significant increase in FA with age in 17 out of 20 brain structures, with most structures showing a sharp increase in FA followed by linear development and levelling off in late teens or twenties. Beaulieu (2002) noted that it is not clear whether the increasing FA values found in development are due to greater coherence of fibre tracts and/or the additional myelin sheath covering. Lebel et al. (2008) found different developmental rates; FA increased early in the corpus callosum, thought to increase the efficiency of communication within frontal networks (Nagy, Westerberg & Klingberg, 2004), whilst fronto-temporal connections displayed a more protracted development. Indeed, the cingulum and uncinate fasciculus, important fronto-temporal connections, show a protracted maturation, reaching 90% of development after age 25 (Lebel et al., 2008). A positive aspect of this study was the large sample size in comparison to other imaging studies. Males and females were analysed together due to only slight differences in developmental trajectories and in accordance with previous research (e.g. Sowell et al., 2003) suggesting that hormones do not greatly impact brain development, although see Chapter 2 section 2.2 for contrasting results. These findings provide support for the protracted development of frontal networks into late adolescence and early adulthood. However, the authors did not elucidate the consequence of protracted maturation in frontal networks on behaviour.

1.2.3 Functional connectivity

Functional connectivity is another aspect of brain structure showing changes during late adolescence. This refers to distributed brain networks showing strongly correlated neural activity patterns due to transmission via long distance white matter tracts (Fingelkurts & Kahkonen, 2005) with the growth of widely distributed, functionally integrated networks leading to efficient higher order cognition (Goldman-Rakic, 1988). Neural constructivism posits that greater interconnection between neural networks leads to age related cognitive development (Stevens, 2009). In addition to the protracted maturation of prefrontal networks, the late expansion of functional connectivity between the prefrontal networks and posterior networks also plays a fundamental role in the development of executive functions (Luna & Sweeney, 2004).

Stevens et al. (2007) compared functional connectivity and performance between adolescents (aged 11 to 17 years) and adults (aged 18 to 37 years) on an inhibition executive function task. Participants completed a go/no go task requiring them to press a button when presented with an "X" on a computer screen and to inhibit this response on presentation of a "K". The authors identified three distinct, functionally integrated networks associated with response inhibition: 1) parietal-premotor network comprising bilateral dorsolateral and right inferior frontal regions, 2) fronto-striatal-thalamic network comprising right inferior frontal, parietal and temporal regions 3) frontal-parietal network comprising right inferior frontal gyrus, right dorsolateral and bilateral frontopolar and bilateral inferior parietal regions. Adolescents displayed less functional connectivity between fronto-striatal-thalamic and frontal-parietal networks compared to adults and took significantly longer to respond than adults. The functional connectivity strength between fronto-striatal-thalamic and frontal-parietal networks negatively correlated with the number of incorrect responses (i.e. not inhibiting a button press on presentation of K) only in the adolescent group. Adolescents showed greater activation in the right ventromedial prefrontal cortex compared to adults, to compensate for less efficient networks undergoing rewiring (Stevens et al., 2007). Together, these findings indicate that adolescents have less functional connectivity in networks associated with inhibition and this manifests behaviourally by adolescents taking significantly longer to respond.

Burnett and Blakemore (2009) demonstrated functional connectivity changes between adolescence and adulthood in a social cognition study. Eighteen adolescents aged 11 to 18 years and ten adults aged 22 to 32 years read scenarios designed to evoke basic emotions (fear or disgust) or social emotions (embarrassment or guilt). Participants were cued with what emotion should be elicited in the scenarios and rated the extent that they would feel the emotion on a scale of one (would not feel emotion) to four (would feel emotion very much). Greater functional connectivity was found between the anterior rostral region of the medial prefrontal cortex and left posterior temporal sulcus / temporo-parietal junction during social relative to basic stimuli in adolescents than adults. Activation of medial prefrontal cortex and posterior temporal sulcus adjacent to the temporal parietal junction provides support for the social cognition network, brain regions activated during social cognition (see Section 1.15). The finding of an age related decrease in functional connectivity is inconsistent with previous research reporting age related increases in functional connectivity, e.g. Stevens et al. (2007). Burnett and Blakemore (2009) argued that this discrepancy could be due to their study being the first to explore functional connectivity during a social cognition task, with previous research restricted to non-social stimuli, e.g. executive function. A possible explanation is that adults utilise a more automatic strategy when considering mental states (Burnett & Blakemore, 2009). A decrease in functional connectivity is consistent with non-linear adolescent brain maturation, for example synaptic pruning. Boersma et al. (2011) proposed that a reduction in functional connectivity could reflect synaptic pruning of unused connections and strengthening of frequently used synapses, leading to a more efficient network, with a developmental shift from diffuse extensive activation to focal activation (Durston & Casey, 2006).

1.3 The association between brain morphology and cognition

This section reviews a range of studies including normative and neuropathological data to illustrate the association between morphology and cognitive function. Blakemore and Choudhury (2006) related morphological findings to behaviour and proposed that the protracted maturation of prefrontal and parietal networks would result in changes during adolescence in social cognition and executive functions mediated by these regions. Synaptogenesis and synaptic pruning, leading to a more coherent and efficient arrangement of neurons in frontal networks, underpin development of social cognition and executive function in adolescence (Blakemore & Choudhury, 2006). This is relevant because studies reviewed in section 1.1 show that frontal regions continue to develop into late adolescence and early adulthood.

In comparison to cross sectional studies, longitudinal designs allow the study of brain maturation over time (Toga et al., 2006). Bava et al. (2010) reported a longitudinal DTI study with participants aged between 16.2 and 20.6 years at time point 1 with follow-up 16 months later. The results show protracted white matter maturation in late adolescence with refinement of association fibres, connecting networks within one hemisphere, and projection fibres, connecting networks in another brain region. A notable aspect of this study is that several behavioural measures were also administered including the Wechsler Abbreviated Scale of Intelligence vocabulary subtest (Wechsler, 1999), assessing Verbal IQ, Delis-Kaplan Executive Function System (D-KEFS) Verbal Fluency and Trail Making Tests (Delis, Kaplan & Kramer, 2001a), measures of strategy generation and sequencing, and Wechsler Adult Intelligence Scale Digit Span (Wechsler, 1997). Despite DTI scans at Time 1 and Time 2, the tasks were administered only at Time 2, resulting in one behavioural assessment. There were no explanations for the selection of specifically the Verbal Fluency and Trail Making Tests to assess executive function. Greater increases in FA in the posterior limb of the internal capsule were associated with higher scaled scores on the D-KEFS Letter Fluency Test, indicating that white matter maturation in late adolescence leads to improved strategy generation (Bava et al., 2010).

Barker, Andrade, Morton, Romanowski and Bowles (2010) compared patients who had frontotemporal head injuries before the age of 25 (early injury group) during a maturationally sensitive period with those injured after the age of 28 (late injury group). This work is based on the latent deficit hypothesis, the notion that early brain injury will result in deficits to functions that emerge later in development. The early injury group were more impaired on functions associated with frontal networks, e.g. on the DEX (Wilson, Alderman, Burgess, Emslie & Evans, 1996), a measure of behavioural insight. The early injury group were also more impaired than the late injury group compared to matched controls on a Serial Reaction Time Task, a measure of implicit cognition. Participants completed the Hayling and Brixton Tests (Burgess & Shallice, 1997), assessing inhibition and rule detection, and the Wisconsin Card Sorting Test (Heaton, 1981), a measure of set shifting. There was a significant relationship between executive functions and insight for the early injury group (low EF score and high DEX insight score showing poor insight) with no significant relationship evident in the late injury group. The relationship between executive and other functions was more impaired in the early injury group compared to the late injury group because the early injury group had endured their head injury in late adolescence / early adulthood when frontal networks are still maturing (Barker et al., 2010). Hierarchical regression analyses with DEX insight (Wilson et al., 1996) as the dependent variables showed that the Behavioural Assessment of the Dysexecutive Syndrome (BADS; Wilson et al., 1996) was a significant predictor, injury group was not a significant predictor and the interaction between BADS and age at injury was significant. The authors suggested that age at injury moderated the relationship between executive function and behavioural insight. This work includes only fronto-temporal head injuries enabling the examination of deficits specific to this region. However, a limitation is that there was variation in the age at injury between the early and late injury group, because of the difficulty in recruiting patients who were the same age at injury (Barker et al., 2010). These results suggest that age at frontal brain injury confers vulnerability to processes associated with frontal regions including executive functions.

To summarise, protracted brain maturation into adolescence and early adulthood is likely to be associated with protracted cognitive development. In a DTI study, Bava et al. (2010) found that higher Fractional Anisotropy values, an index of greater white matter coherence, are associated with better strategy generation (Bava et al., 2010) in adolescence and early adulthood.

1.4 Linear and non-linear development of cognitive functions

Classic theories of development are characterised as either developing continuously, following a smooth curve and adding to existing skills, or developing discontinuously, involving step-like progression through qualitatively different stages (e.g. Piaget, 1952; Erikson, 1950). However, Van Geert (2009) criticised the field of Developmental Psychology for over emphasising linear development. Figure 1.1 presents different developmental trajectories, including linear and non-linear development with peaks and troughs in ability.

Figure 1.1. Different developmental trajectories.

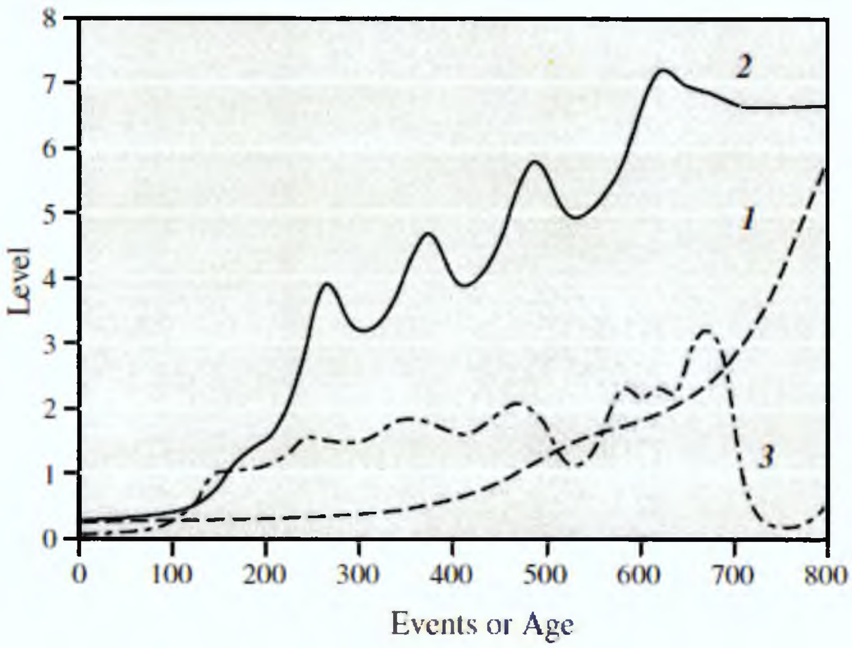


Figure 1.1. Three growth curves based on the same model 1) linear development, 2) stage-like development with peaks and troughs, 3) fluctuating development. Reproduced from Fischer & Biddell (2006).

Line 2 at age 250 in Figure 1.1 shows an example of a peak in ability and at age 300 shows a trough in ability. Non-linear development, troughs in development following a peak in ability (Fischer & Kennedy, 1997), is thought to parallel non-linear brain maturation (Lampl & Johnson, 1998; Lebel et al., 2008; Paus, 2005; Sowell et al., 2003).

1.5 Definition of executive functions

Executive functions initiate, co-ordinate, maintain and inhibit other cognitive functions (Miyake et al., 2000) and are vital for adaptive functioning (Stuss, 1992). Executive functions are recruited in novel or demanding situations to perform goal-directed behaviour when routine behaviour is inadequate (Burgess, 2003). Executive functions include planning, problem solving, attention allocation, abstract thinking, concept formation and inhibitory control (De Luca et al., 2003; Strauss, Sherman & Spreen, 2006; Stuss & Alexander, 2000; Wilson et al., 1996; Burgess, 1997; Shallice & Burgess, 1991). Executive functions control the execution of complex activities and interact with non-executive processes including language, memory and visuospatial abilities (Royall et al., 2002). Executive functions are the capacity to plan and organise ways to solve complex problems, shift problem solving strategies when required, and monitor and evaluate behaviour (Gioia & Isquith, 2004). Goldberg (2001) used an analogy of a conductor to explain executive functions, with the conductor directing and integrating the players of the orchestra.

1.6 Role of executive functions in late adolescence and early adulthood

Whilst research has previously focused on executive function deficits (e.g., Barker et al., 2010; Jacobs, Harvey & Anderson, 2011; Odhuba, van den Broek & Johns, 2005; Robinson et al., 2009), executive functions are also important in normal functioning. Considering late adolescence and early adulthood specifically, executive functions are necessary for completion of academic work and the successful transition to employment or Higher Education. For example, when the goal is writing an essay, the student must generate and implement a plan, monitor their performance, and inhibit distractions so they focus on the task until it is complete. Formation of new friendship groups is another aspect associated with this age range, again requiring executive functions so that inappropriate responses are inhibited. Generally, executive functions are important for independence and autonomy.

1.7 Executive function dysfunction

The following section on executive function deficits, or executive dysfunction, following head injury (HI) emphasises the importance of executive functions. Executive dysfunction has a major impact on a person's ability to attend school or work, also affecting home life and social relationships (Grafman & Litvan, 1999). The most frequently reported symptoms of executive dysfunction by carers of head injured patients are planning problems and distractibility, with patients most commonly reporting distractibility and restlessness (Burgess & Robertson, 2002). These particular deficits may manifest in everyday activities, e.g. distraction by irrelevant environmental stimuli when planning and cooking a meal resulting in the patient focusing less on a particular task. Problems in the school or work place include disorganisation and being unable to prioritise the importance of different tasks (Burgess, 2003).

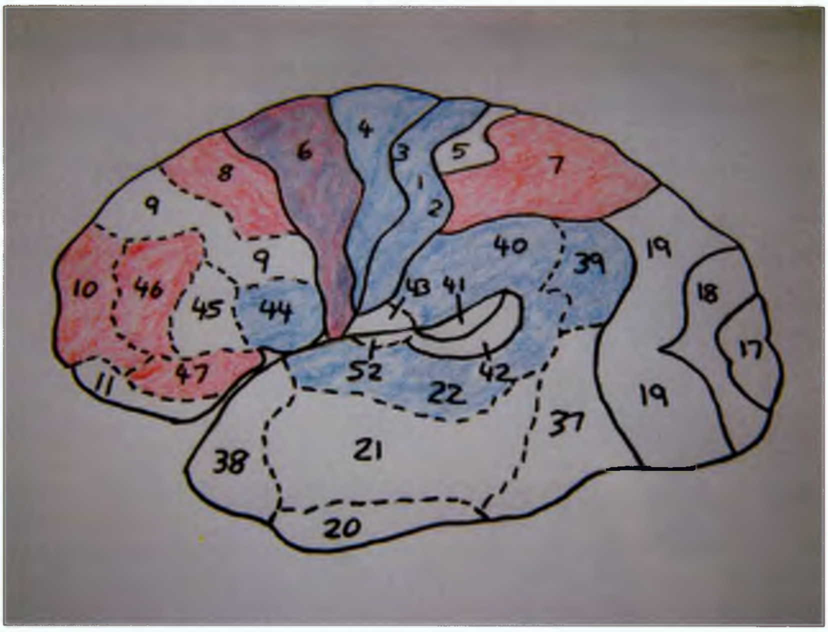
Odhuba, van den Broek and Johns (2005) assessed participants who had sustained a HI with the Hayling Test (Burgess & Shallice, 1997), a measure of inhibition. Sentences with the last word omitted were read aloud and participants were required to complete the sentences with words that made sense (section one) and words that were completely irrelevant (section two). Chapter 3 describes the Hayling Test in more detail. Odhuba et al. (2005) reported a significant positive correlation between job status and response initiation time in section one, indicating how important fast initiation time is for employment. However, Odhuba et al. (2005) did not note whether participants had sustained widespread or localised brain injuries. A quick response initiation time in section one may reflect less severe brain injury or possible impulsivity. Changes in social skills associated with HI include inappropriate or aggressive comments and disobeying social rules (Grafman & Litvan, 1999). Odhuba et al. (2005) reported a significant positive correlation between social integration scale of the Community Integration Questionnaire (Willer, Ottenbacher & Coad, 1994) and number of errors on section two of the Hayling Test (Burgess & Shallice, 1997), reflecting how inhibition is a vital skill in social situations.

1.8 Executive function brain regions

In a review of imaging studies, Collette, Hogge, Salmon and Van der Linden (2006) concluded that executive functions, specifically inhibition, updating and shifting, were associated with activation in both prefrontal and parietal networks. Another study by Collette et al. (2005) examined the unity and diversity of neural networks recruited during executive function tasks. Typically developing participants completed measures of inhibition, updating and shifting. The battery used three measures to index the purported underlying construct, meeting recommendations by Miyake et al. (2000) to use multiple measures. Common areas activated by inhibition, updating and shifting were the left superior parietal gyrus and right intraparietal sulcus, and to a lesser extent, the inferior frontal gyrus (Collette et al., 2006). Updating was associated with activation in frontal regions (frontopolar, superior, middle, inferior and orbitofrontal), intraparietal sulcus and the cerebellum. The shifting tasks recruited the left superior parietal network and to a lower extent, the right intraparietal sulcus and inferior frontal gyrus. Inhibition was associated with activation in the regions common to other executive functions, in addition to the right inferior frontal gyrus. Collette et al. (2005) posited that attentional processes involve posterior regions, whereas executive processes are associated with frontal regions. These findings provide evidence for the recruitment of both frontal and posterior regions in executive function tasks, although an alternative explanation is that executive function tasks are not process pure because the completion of executive function tasks also require non-executive functions, including other cognitive functions.

The next section includes brain regions associated with two executive function tasks often employed in the literature, the Letter Fluency Task, assessing strategy generation, and the Tower of London, assessing planning. Figure 1.2 presents brain regions associated with strategy generation and planning.

Figure 1.2. Brain regions associated with Letter Fluency Task performance (Baldo et al., 2006; blue) and Tower of London (Wagner et al., 2006; red).



Letter fluency requires "an initial mapping of the letter cue to phonologic and/or orthographic information and checking that the orthography of the retrieved word matches the initial letter cue" (Birn et al., 2010, p. 1106). Baldo, Schwartz, Wilkins and Dronkers (2006) used voxel based lesion symptom mapping to determine regions associated with letter fluency in left hemisphere stroke patients. Blue areas in Figure 1.2 indicate that frontal regions (BA 4, BA 6 and BA 44), parietal areas (BA1-3, BA39 and BA40) and anterior temporal regions (BA 22) are associated with strategy generation on the Letter Fluency Task (Baldo et al., 2006). Parietal networks, associated with verbal working memory (Jonides et al., 1998), are crucial for remembering task rules and avoiding repetition of responses.

Wagner, Koch, Reichenbach, Sauer and Schlosser (2006) reported a fMRI study with 17 participants completing the Tower of London task. Participants solved the task mentally and pressed a button to record the minimum number of moves. Red areas in Figure 1.2 indicate that the right ventrolateral prefrontal cortex (BA47), bilateral dorsolateral prefrontal (BA 46), left rostrolateral prefrontal (BA 10), parietal (BA 7) and premotor regions (BA 6, BA 8) are associated with planning on the Tower of London. BA 6, thought to be involved in planning and speech (Petrides et al., 1993), was a common area associated with strategy generation and planning. Newman, Carpenter, Varma and Just (2003) proposed that right dorsolateral prefrontal networks are associated with generation of a plan whereas executing a plan recruits left dorsolateral prefrontal networks. Right superior parietal networks were associated with attention processes and left superior parietal networks are thought to be involved in visuo-spatial processing (Newman et al., 2003).

1.9 Executive functions: conceptual frameworks

Researchers have different views on executive functions; for example, Lezak et al. (2004) considered executive functions to be comprised of volition, planning, purposive action and effective performance. Alternatively, Delis et al. (2001) conceptualised executive functions as planning, problem solving, inhibition, flexibility in thinking, impulse control, concept formation and creativity, operationalised in their Delis Kaplan Executive Function System test battery. Jurado and Rosselli (2007) argued that despite many definitions of executive functions, they all share the following: in a constantly changing environment, individuals are able to plan and persevere with a task while inhibiting inappropriate behaviours. In a review of executive function research, Best, Miller and Jones (2009) noted that there is now a growing interest in typical executive function development, specifically the age at which abilities reach optimal performance.

Issues in executive function research are their operationalisation and measurement because basic domain-specific functions, including memory, language, socio-emotional and visuospatial skills are measured in addition to executive functions, resulting in the need to extract the executive function component (Gioia & Isquith, 2004). Another key debate in this area of research is regarding the unity or diversity of executive functions (Jurado & Rosselli, 2007; Stuss & Alexander, 2007). This is concerned with whether executive functions are conceptualised as a single ability or related, yet distinct components. Collete et al. (2005) conducted a Positron Emission Tomography study and found the left middle frontal gyrus and left inferior frontal gyrus are commonly activated on updating, shifting and inhibition tasks, indicating unity of executive functions. In contrast, behavioural and neuroimaging studies show the multi-faceted nature of executive functions. Double dissociations in performance on executive tasks provide evidence that executive functions are not solely unitary, for example a person performing poorly on the WCST but performing successfully on the Tower of Hanoi (Miyake et al., 2000). The inter-correlations of executive function tasks are often lower than r = 0.4 and not significant (Huizinga et al., 2006). Moreover, Miyake et al. (2000) reported that Confirmatory Factor Analysis produces moderately correlated but separable factors, highlighting both the unity and diversity of executive functions. The finding of executive functions following different developmental trajectories (see Romine & Reynolds, 2005) provides further evidence for executive functions being conceptualised as distinct processes, instead of a unitary process. The next section reviews theories of executive function.

1.10 Theories of executive function

1.10.1 Theory of higher cortical functions (Luria, 1963, 1973)

Luria considered how the interaction of multiple neuroanatomical regions mediates executive functions. Luria proposed three functional units corresponding to different neuroanatomical regions, with the first functional unit of physiological function associated with the brain stem and subcortex. The second unit is comprised of temporal, parietal and occipital networks, which receive, analyse and store visual, auditory and tactile information. According to Luria's integrative theory of cognitive function, the anterior region of the brain acts as a controlling agent, regulating higher cognitive functions and comprises the third functional unit.

Luria (1966) proposed that the interaction between typical brain maturation, social, historical and cultural environmental stimuli lead to the development of executive functions. Development of higher cognitive functions follows five stages (Luria, 1980). The stage most relevant to the age group in this study is the final stage, proposed to begin from age eight throughout adolescence. In this stage, the continued maturation of frontal networks leads to executive function development. Andrés (2003) criticised the methods used because only clinical observations with no control participants informed the theory and the lack of imaging data may have resulted in inaccurate lesion localisation.

1.10.2 Theory of willed and automatic action (Norman & Shallice, 1986)

This model makes a distinction between automatic (routine) and controlled (non-routine or novel) behaviour. The process of contention scheduling, selecting the most appropriate automatic schema and inhibiting competing schemas, completes routine tasks. This theory suggests that schemas are methods for achieving goals and there is a schema network composed of nodes that activate when excitation exceeds a threshold. Novel tasks require more complex cognitive processing, e.g. a general planning component. According to this model, the Supervisory Attentional System (SAS) is engaged in novel or uncertain contexts instead of relying on schemas. The SAS also monitors behaviour. Norman and Shallice (1986) associated the SAS with the frontal networks and contention scheduling with the basal ganglia. Andrés (2003) criticised Norman and Shallice's (1986) theory for not acknowledging that posterior brain regions are also important in novel behaviour.

Cooper and Shallice (2000) developed a computational model to test Norman and Shallice's (1986) theory when applied to the control of action in typically developing participants and Action Disorganisation Syndrome, associated with disorganised goal directed behaviour and frequent errors. The model accounted for the control of action in typically developing participants and the presence of omissions, perseveration, additions and substitutions in head-injured patients. However, this model was criticised for relating to simple tasks e.g. making a cup of coffee (Cooper et al., 2005).

1.10.3 Hierarchical feedback feed forward model (Stuss, 1992)

Alternatively, Stuss (1992) proposed a three level model: the first level of processing is concerned with automatic, routine daily activities, the second level describes executive functions and the third level is self-awareness. The first level of processing is thought to be associated with basal regions and parallels contention scheduling. The second level, executive control, integrates information and directs lower systems leading to goal directed behaviour. The third level, self-awareness refers to "the ability to be aware of oneself and the relation of self to the environment" (p. 12). Incoming information is assessed by a comparator at each level and compared to values developed from previous experience and training. Change is triggered e.g. more information from the environment or direction from higher levels if incoming information is different to existing comparator values. Stuss (1992) suggested that the first level of processing (automatic routine activity) matures earlier than executive functions, which develop at different rates. Morphological and behavioural data support this model. For example, Gogtay et al (2004) reported that phylogenetically older basal regions, associated with automatic routine activity, matured before frontal regions, thought to be involved in executive functions. Furthermore, executive function studies in late adolescence and early adulthood show that executive functions develop at different rates (Magar, Phillips & Hosie, 2010; Romine & Reynolds, 2005; Waber et al., 2007).

1.10.4 Multi-component model of working memory (Baddeley & Hitch, 1974; Baddeley, 1986)

Baddeley and Hitch (1974) suggested a working memory model composed of a central executive, phonological loop and visuo-spatial sketchpad. The central executive is thought to switch attention and co-ordinate the functions of the slave systems, the phonological loop and visuo-spatial sketchpad (Baddeley & Logie, 1999). The phonological loop processes speech-based information and the visuo-spatial sketchpad processes visual and spatial information. In the original model, the central executive was thought to be associated with frontal regions, although Baddeley (1998) suggested that the central executive was likely to involve other brain regions in addition to frontal regions. Baddeley (2000) added an episodic buffer to the model that stores and integrates information from various sources. The central executive is able to influence the content of the episodic buffer by focusing attention on a particular source.

1.10.5 Multiple domain model (Goldman-Rakic, 1996)

Goldman-Rakic (1996) proposed a multiple domain model through studies with primates. According to this model, different regions of the frontal networks process different types of information (spatial, object or semantic), with each network including parietal and temporal, premotor and limbic networks. Whilst Baddeley and Hitch (1974) viewed the central executive as one processor served by two slave systems, Goldman-Rakic (1996) proposed that the central executive might govern the interaction of multiple domain-specific processors. An important point about this model is that it is consistent with the anatomical connections of the frontal networks that extend to posterior regions. Research by Collette et al. (2006) in section 1.8 supports this model and the importance of both frontal and posterior brain regions.

1.10.6 Cascade model of cognitive control (Koechlin & Summerfield, 2007)

Koechlin and Summerfield (2007) criticised existing executive function theories for not fractionating executive function into location-specific subsystems that enable functional integration within and between these regions and sensory areas. The cascade model suggests that executive function fractionates into contextual, episodic and sensorimotor control and these are associated with specific lateral prefrontal regions. Koechlin, Ody and Kouneiher (2003) conducted an imaging study with participants completing an inhibition task that varied by manipulating the context, episodic and stimulus factors. Contextual control refers to signals in the immediate context that guide behaviour and is thought to be associated with the posterior lateral prefrontal cortex. Koechlin et al. (2003) suggested that the anterior lateral prefrontal cortex is associated with episodic control that guides action selection based on previous events. Sensorimotor control selects motor actions based on signals from contextual control, episodic control and the stimulus and is thought to be associated with premotor regions. A strength of the cascade model is that it is more detailed than previous models by associating contextual, episodic and sensorimotor control with distinct regions in the lateral prefrontal network. However, future research should aim to understand how the lateral prefrontal cortex interacts with the medial prefrontal cortex in the model and the role of bottom-up processing (Koechlin & Summerfield, 2003).

1.10.7 Summary of executive function theories

Ward (2010) identified a number of similarities and differences between the models. These models concur that processes must be flexible to cope with changes and novel situations require automatic behaviour to be overridden. The models differ in how they conceptualise executive functions, for example unitary vs. modular. Strengths of the Goldman-Rakic (1996) and Koechlin and Summerfield (2007) models are that they are more detailed compared to Baddeley's (2000) working memory model and Norman and Shallice's (1986) model in terms of how information is processed and anatomical regions. A criticism of existing theories is that they are unable to explain the broad range of behaviour of executive dysfunction. The only models to include the development of executive functions are Luria (1980) and Stuss (1992), with other models not elucidating when executive functions reach adult levels of performance.

1.11 Development of executive functions in late adolescence and early adulthood: Behavioural studies

Romine and Reynolds (2005) conducted a meta-analysis of cross sectional executive function studies and proposed a model for the development of executive functions by analysing effect size differences across age groups (5-8 years, 8-11 years, 11-14 years, 14-17 years and 17-22 years). The meta-analysis included measures of planning (Tower of London, Tower of Hanoi and the NEPSY Tower), inhibition of perseveration measures (perseverative responses and errors from the Wisconsin Card Sorting Task; WCST), set maintenance measures (categories achieved on the WCST), Verbal and Design Fluency. Studies in the meta-analysis used different measures of planning; Anderson et al. (2001) administered a Tower of London Task that consisted of 12 problems requiring 2 to 5 moves, with participants allowed a second attempt if they could not achieve the target pattern with three beads. Welsh, Pennington and Groisser (1991) administered Tower of Hanoi tasks with three and four discs, with repeat attempts until completion. On the NEPSY Tower (Korkman, Kirk & Kemp, 1998), suitable for 3 to 12 year olds, participants moved three balls on pegs to a target pattern with only 2 to 6 moves permitted.

Romine and Reynolds (2005) concluded that executive functions follow divergent developmental trajectories, with some executive functions such as inhibition of perseverative responses, showing optimal performance before other executive functions. Rapid development of planning, verbal fluency, design fluency and inhibition of perseveration occurs between 5 to 8 years and 8 to 11 years. Two executive functions showing protracted development are verbal fluency and planning (indexed by Tower of Hanoi), which continue to mature between 17 and 22 years (Romine & Reynolds, 2005). Figure 1.3 presents the developmental trajectory of executive functions of planning, verbal fluency, design fluency, inhibition of perseveration and set maintenance. Whilst this meta-analysis presents a linear developmental trajectory of executive functions, it is plausible that some functions may be temporarily diminished during brain maturation in late adolescence and early adulthood.

Figure 1.3. Developmental course of executive functions based on average effect sizes.

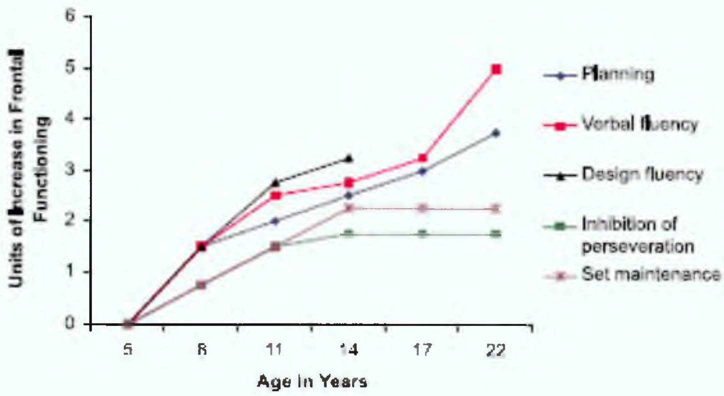


Figure 1.3. From Romine and Reynolds (2005). This depicts the different developmental trajectories of executive functions showing the continued development of verbal fluency and planning into late adolescence and early adulthood.

Romine and Reynolds (2005) reported that inhibition of perseverative responses, measured with the WCST, continued to develop between 11 and 14, but showed no further improvements up to 22 years, the oldest age included in the study. Research with the WCST has found inconsistent results. Chelune and Baer (1986) assessed 6 to 12 year olds and an adult group and reported that 10 year olds showed similar performance to adults, with no significant improvements after age 10, on mean perseverative errors and failure to maintain set. Welsh et al. (1991) supported this and found adult performance on perseverative errors was again evident by age 10 in a sample of 3 to 12 year olds. A conflicting finding proposed that number of categories, perseverative responses and failure to maintain set continued to improve in 9 to 14 year olds and had not attained adult levels (Paniak, Miller, Murphy, Patterson & Keizer, 1996). The authors did not explain why their results may contrast with Chelune and Baer (1986), but noted that their sample size of 685 participants was much larger than the sample size of 105 in the Chelune and Baer (1986) study.

Normative data from the D-KEFS supports Romine and Reynold's (2005) model for executive function. Performance on the Verbal Fluency Task improves rapidly between 8 and 19 years, with performance peaking in the 30-39 year age group illustrating continued development into adulthood (Delis, Kaplan & Kramer, 2001b). For the Tower Task, normative data showed that accuracy peaked in the 16-19 age group remaining relatively constant in the twenties, and rule violations were lowest in the 13-19 age group (Delis et al., 2001b). The D-KEFS normative data and the studies in the meta-analysis by Romine & Reynolds (2005) utilised cross sectional designs. Romine and Reynolds (2005) recommended the use of other executive function measures and longitudinal designs in future research to identify individual differences. Romine & Reynolds (2005) questioned whether the slowing of maturation of executive functions in adolescence and early adulthood was due to the actual neurocognitive development or limitations of the tests, such as ceiling effects. The authors noted that as the model is based on specific executive function tasks the developmental trajectory of each function might not be fully represented e.g. development of inhibition of perseveration might not be fully captured by performance on the WCST. The use of wide age ranges in the meta-analysis by Romine and Reynolds (2005) might mask non-linear development (i.e. peaks and troughs in ability) occurring during late adolescence and early adulthood. Non-linear development would correspond to dynamic brain maturation in late adolescence, including synaptic pruning (e.g. Gogtay et al., 2004), increased white matter connectivity (Lebel et al., 2008; Paus, 2005; Sowell et al., 2003) and non-linear functional synchronisation (Uhlhaas et al., 2009).

Magar, Phillips and Hosie (2010) examined the development of inhibition (go-no go task; Hooper, Luciana, Conklin & Yarger, 2004), updating (n-back task; Cohen et al., 1997) and switching (number–letter switching task; Rogers & Monsell, 1995) in a sample of 149 participants aged between 11 to 17 year olds (65 males and 84 females). In the computerised version of a Go-no Go Task, participants pressed the space bar on presentation of a number that was not a four or a nine. The n-back task required participants to decide whether a number presented on the computer was the same as the number presented immediately before (one back condition) or two numbers earlier (two back condition). In the number-letter switching task, participants decided if the number was odd or even in number-letter pairs presented at the top corners of a computer screen, or whether the letter was a vowel or a consonant in stimuli presented in the lower corners. Results showed that inhibition, associated with orbitofrontal networks, did not significantly change across the age range, whilst updating and switching, underpinned by dorsolateral prefrontal networks, continue to improve over adolescence (Magar et al., 2010). The authors suggested that the earlier development of inhibition might be due to the earlier maturation of orbitofrontal networks. This finding conflicts with work by Gogtay et al. (2004), reviewed in section 1.2.1, who reported synaptic pruning continues in orbitofrontal networks until the age of 21.

Age was a significant predictor of updating and switching, but not for inhibition, accounting for approximately 7% of variance in task performance (Magar et al., 2010). Stage of pubertal development did not explain any additional variance and there were no significant gender differences on any tasks. This study supports the findings by Romine and Reynolds (2005) of executive functions following divergent developmental trajectories, with some continuing to develop into adolescence. However, as no graphs were included showing the developmental trajectories of executive functions, the precise nature of development is unclear. The authors did not assess possible confounding variables, including IQ and drug use. With the oldest participant aged 17, this omits the development of executive functions in late adolescence and early adulthood.

Magar et al. (2010) employed the go-no go task to assess inhibition. The Hayling Test is an alternative task, assessing verbal inhibition instead of motor inhibition, and is associated with activation in medial orbitofrontal networks in the initiation section and left dorsolateral prefrontal networks in the inhibition section (Nathaniel-James & Frith, 2002). Inhibition of a prepotent response develops in preschool years and continues to progress into adolescence, when improvements are noticeable in speed and accuracy (Best, Miller & Jones, 2009). Developmental studies mainly extend to middle childhood and have shown that response inhibition continues to improve to this age, but the oldest participants often do not attain adult levels of performance so it is unknown when maturation is complete (Luna & Sweeney, 2004).

Using a sequential design, Waber et al. (2007) investigated brain structure and neuropsychological task performance in a sample of 385 typically developing participants aged between 6 and 18 years. The sample size of the six-year-old age group was 64; however only 21 17 year olds and six participants aged 18 years were included in the sample. The authors recruited more participants at ages when they expected rapid developmental changes and fewer at ages when they thought development was more stable. However, imaging research has demonstrated that dynamic brain maturation continues into late adolescence and early adulthood (e.g. Gogtay et al., 2004; Lebel et al., 2008; Sowell et al., 2001), suggesting that these age ranges were under-represented in this study.

The test battery used in the Waber et al. study included the WASI (Wechsler, 1999), a modified version of the NEPSY Verbal Fluency Task (Korkman, Kirk & Kemp, 1998), spatial span, working memory tasks, the Intradimensional / Extradimensional Shift Task from the Cambridge Neuropsychological Test Battery (CANTAB; CeNeS, 1998) and the Behaviour Rating Inventory of Executive Functions (Gioia et al., 2000). Standardised scores give the performance of a participant in relation to peers of the same age and despite portraying individual differences, they are not sensitive to developmental differences. Therefore, Waber et al. (2007) analysed raw scores because they correlate with absolute task performance. The authors reported the effects of age, gender and socioeconomic status on task performance. Socioeconomic status was based on family income and classified into three groups: low (less than $35,000 per year), medium ($35,000 to $75,000 per year) and high (over $75,000 per year). Age was a highly significant predictor for verbal fluency and number of shifts on the CANTAB intradimensional/extradimensional task, whereas gender and income were not significant predictors.

Performance on tasks assessing basic information processing, e.g. digit span and spatial span developed linearly between 6 to 18 year olds (Waber et al., 2007). Phonemic, semantic and total verbal fluency showed a linear increase into late adolescence (see Figure 1.4 left), supporting the findings reported by Romine and Reynolds (2005). Other tasks, e.g. female performance on ID/ED task, showed non-linear trajectories, with development increasing from age 6, levelling off around age 10 with a decline for females, followed by another spurt of development at approximately age 14 (see Figure 1.4 right). Waber et al. noted that the cross sectional results must be considered preliminary data because it is not clear whether non-linear trajectories are typical or whether some adolescents diverge, with some levelling off while others continue to develop. The authors suggested that longitudinal data would elucidate these findings and show the natural development of performance on these tasks.

Figure 1.4. The development of performance on Verbal Fluency and Intradimensional/Extradimensional shift task

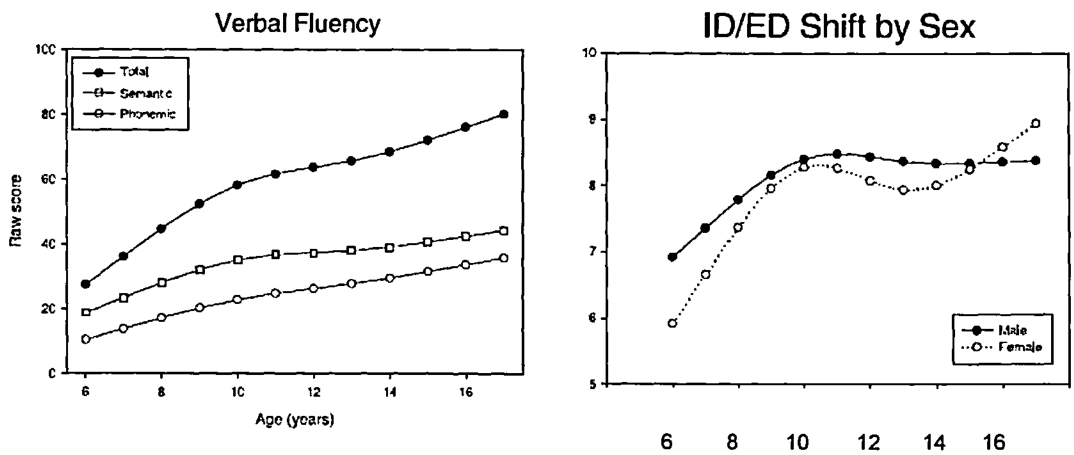


Figure 1.4. Left: The development of verbal phonemic, semantic and total verbal fluency in a sample of 6 to 18 year olds. Right: an example of a non-linear developmental trajectory for performance by females on Intradimensional/Extradimensional shift task. Reproduced from Waber et al. (2007).

Dumontheil, Houlton, Christoff and Blakemore (2010) demonstrated non-linear development on a relational reasoning task with a dip in accuracy in middle adolescence. Relational reasoning requires inhibition and cognitive flexibility (Diamond, 2013) and is associated with activation in the rostrolateral prefrontal cortex (Kroger et al., 2002). Shapes that varied by either shape or texture were presented on a computer. Participants aged between 7.3 and 27.5 years identified whether the top two shapes differed by the same dimension as the lower two shapes. Dumontheil et al. (2010) reported that performance peaked at 9-11 years with the attainment of adult levels, followed by a dip in ability at age 11-13 and 14-17 years, with performance of 19 year olds returning to adult levels.

The authors conducted fMRI scans to investigate the relationship between functional, structural and behavioural development. They found a combination of linear and non-linear age-related changes in prefrontal activity. There was significantly greater activation in the posterior part of the rostrolateral prefrontal cortex in the mid adolescent group (14.8 to 18.6 years) compared to the adult group (22.5 to 30.4 years), indicating non-linear changes in rostrolateral prefrontal cortex activation, which the authors argued are possibly due to performance and brain maturation with age. There were no group differences for IQ, although this was assessed differently in the behavioural and imaging studies, with Verbal IQ and no assessment of Performance IQ reported for the behavioural data, and Full IQ reported for the MRI data. In the behavioural study, adults completed the vocabulary subtest from the WASI (Wechsler, 1999) and children completed the British Picture Vocabulary Scale (Dunn, Dunn, Whetton & Burley, 1997), whereas participants in the MRI study completed the Vocabulary and Matrix Reasoning subtests from the WASI (Wechsler, 1999).

Kalkut, Han, Lansing, Holdnack and Delis (2009) analysed the development of set shifting from childhood to adulthood using D-KEFS normative data (Delis et al., 2001). Trail Making, Design Fluency, Verbal Fluency, Colour-word interference and Card Sorting Task data were analysed for the following age groups: 8-9, 10-11, 12-13, 14-15, 16-17, 18-24 and 25-30 year olds. The Trail Making Test, assessing visual scanning, sequencing and motor speed, requires participants to connect numbers, letters and a combination of numbers and letters in a visual array. In the Design Fluency Test, participants join filled dots, unfilled dots and a combination, providing an assessment of non-verbal fluency and cognitive flexibility. The Verbal Fluency Task assesses strategy generation and comprises of letter fluency (generating words beginning with a particular letter), category fluency (words belonging to a category e.g. naming animals) and category switching (fruits and furniture). The Colour-word Interference Task assesses inhibition with four sections to the task: naming colours, colour words, ink colour of incongruent stimuli and switching between naming incongruent ink colour and word. In the Card Sorting Test, a measure of concept formation, participants sort cards into groups (free sorting) or describe how the examiner has sorted the cards (sort recognition) based on verbal or perceptual features of the cards.

The authors conducted five regression analyses, with IQ entered in step one, any component task data in step two (e.g. time taken to connect filled and unfilled dots on the Design Fluency Task), age and gender in step three and age-gender interaction in step four. IQ and age significantly predicted performance on each task. Gender was a significant predictor for four tasks; females outperformed men on trail making switching, design fluency switching, verbal fluency switching and Card Sorting Tests indicating that females are more cognitively flexible than males (Kalkut et al., 2009). Figure 1.5 shows the development of sort descriptions, with the 18 to 24 year old group scoring more poorly compared to the 16 to 17 year old group, indicating non-linear development.

Figure 1.5. The development of Description Score on the D-KEFS Card Sorting Test between childhood and adulthood. Reproduced from Kalkut et al. (2009).

The authors suggested, given equivocal previous research regarding gender differences, that gender differences may only be apparent on the more complex executive function tasks involving switching. Post-hoc comparisons between age groups indicated that switching ability continued to develop until middle adolescence, with no further improvement after the age of 15. Kalkut et al. (2009) recommended future research should investigate other executive functions, including inhibition, utilise a longitudinal design and assess pubertal development. Table 1.1 summarises studies indicating when executive functions mature.

Table 1.1. Maturation of executive functions

Executive function	Task	Age of maturity	Reference
Set maintenance	WCST – categories achieved	14	Romine & Reynolds (2005)
Inhibition of perseveration	WCST – perseverative errors	14	Romine & Reynolds (2005)
Task switching	D-KEFS Trail Making switching, Design Fluency switching and Verbal Fluency switching	15	Kalkut et al. (2009)
Strategy generation	Semantic Fluency Test	14-15	Matute, Rosselli, Ardila & Morales (2004)
Planning	Tower Test	Continues into early adulthood	Romine & Reynolds (2005)
Strategy generation	Verbal Fluency Test	Continues into early adulthood	Romine & Reynolds (2005)

Table 1.1 shows that research suggests some executive functions, such as set maintenance, task switching and strategy generation (Semantic Fluency) do not develop further after age 14 to 15. Romine and Reynolds (2005) reported that planning, assessed with the Tower Test, and strategy generation, assessed with the Verbal Fluency Test continue to develop into early adulthood.

To summarise, behavioural studies have shown that executive functions follow different developmental trajectories, with some showing no development after age 14 (e.g. set maintenance; categories achieved on the WCST) while planning and letter fluency continue developing into late adolescence and early adulthood (Romine & Reynolds, 2005). There is evidence of non-linear development of some executive functions; 18 to

24 year old males and females scored lower on D-KEFS Sorting Test description score, indicating poorer performance relative to 16-17 year olds (Kalkut et al., 2009) and relational reasoning in middle adolescence (Dumontheil et al., 2010). Gender differences are inconsistent, with females outperforming males on switching (Kalkut et al., 2009), whilst Magar et al. (2010) reported no gender differences on updating, switching and inhibition.

1.12 Definition of social cognition

Social cognition encompasses the perception and interpretation of social situations (Fiske & Taylor, 2008). Scourfield, Martin, Lewis and McGuffin (1999) defined social cognition as "aspects of higher cognitive function which underlie smooth social interactions by understanding and processing interpersonal cues and planning appropriate responses" (p. 559). Another definition by Carrington and Bailey (2009) specified that the consideration of facial expressions, body postures and prosody are important in understanding others' behaviour. The broad term social cognition incorporates a range of abilities including emotion recognition, empathy and perspective taking (Frith, 2007). Theory of Mind, the ability to impute a range of mental states, including beliefs, desires and intentions to self and others (Premack & Woodruff, 1978), is also a key component of social cognition (Carrington & Bailey, 2009; Kalbe et al., 2010; Vollm et al., 2006). Empathy, an important element of adaptive social cognition, is the "the tendency to be aware of and react to the mental or emotional states of other people." (Davis & Franzoi, 1991, p. 72).

1.13 Role of social cognition in late adolescence and early adulthood

Social cognition is vital in late adolescence and early adulthood because it allows individuals to conduct themselves appropriately at school or work and with friends (Rubin et al., 2005). An example of when adolescents require social cognition skills in school and university is group work. An individual may need to employ his or her Theory of Mind skills to understand another group member's perspective. Late adolescence to early adulthood is an important transition phase, accompanied with changes in education, e.g. sixth form to university, or commencing employment. Another situation when social cognition skills are important is in job interviews, when a person must behave in an appropriate manner. Social cognition skills are in demand during adolescence when peer influence replaces parental influence. If social cognition skills are weak, this could impede success at school, university or work and making friendships, possibly leading to isolation, anxiety and depression (Ahmed & Miller, 2011).

1.14 Social cognition dysfunction

The next section discusses the transition between adolescence and adulthood for participants with Asperger's Syndrome, because this emphasises how impairments in social cognition affect everyday life. Asperger's Syndrome is associated with impairments in social cognition (e.g. Dziobek et al., 2006; Heavey et al., 2000) and the diagnostic criteria for Asperger's Syndrome are impairment in social interaction and restricted, repetitive behaviour or interest (APA, 1994). However, see section 2.5.2 for discussion of recent changes in DSM V (APA, 2013).

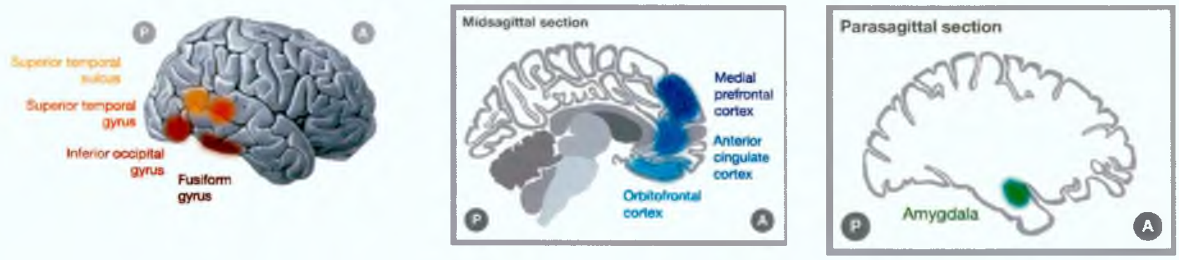
Portway and Johnson (2005) interviewed 25 participants aged between 18 and 35 years with Asperger's Syndrome. Of these, seven participants were in employment, although the authors did not specify full time or part time, four attended college and 14 were unemployed, indicating how Asperger's Syndrome may affect employment prospects. Only one participant lived independently; other living arrangements included living with parents, alone with daily support, in care homes or hostels. Difficulty in making friendships, due to participants not understanding others and being misunderstood themselves, led to loneliness. These findings illustrate how impaired social cognition manifests in a lack of understanding with peers and this can result in isolation or bullying (Attwood, 2006).

To summarise, social cognition is essential at all ages, but particularly in demand in late adolescence and early adulthood, during the transition to independence and autonomy including changes in friendship groups, education and employment. Knowledge of social cognition generally stems from studies of abnormal functioning. Considering the consequences of Asperger's Syndrome has illustrated the effect of impairments in social cognition on everyday life.

1.15 Neural regions associated with social cognition

Brain imaging studies have consistently implicated the medial prefrontal cortex, superior temporal sulci and temporal poles, termed the social cognition or mentalising network, in social cognition task performance (Blakemore, 2008a; Frith & Frith, 2006; Gallagher & Frith, 2003; Moriguchi et al., 2007). Figure 1.6 presents the social cognition network.

Figure 1.6. The social brain network. Reproduced from Golan, Baron-Cohen, Hill & Golan (2006)



In a review of social cognition MRI studies, Carrington and Bailey (2009) reported that the medial prefrontal and orbitofrontal regions were recruited in 93% of studies, followed by the temporo-parietal junction in 58%, anterior cingulate cortex in 55% and superior temporal sulcus in 50% of studies. Several studies have shown that different social cognition tasks recruit the 'social brain network.' The tasks used in these studies include stories and non-verbal cartoons requiring mentalising ability (Gallagher et al., 2000), animations of shapes (Castelli, Happé, Frith & Frith, 2000), film clips from the Movie for the Assessment of Social Cognition (Dziobek et al., 2006), sentences about social or basic emotions (Burnett & Blakemore, 2009) and intentions (Blakemore, den Ouden, Choudhury & Frith, 2007). These studies have included adult participants, with the exception of the studies by Burnett and Blakemore (2009) and Blakemore et al. (2007), who included an additional adolescent group. This highlights the lack of social cognition data in late adolescence.

Carrington and Bailey (2009) concluded that the wide range of tasks employed in imaging studies is unlikely to account for the differences in recruitment of different regions of the social brain network. It is likely that each region of the social cognition network contributes to social cognition in a particular way (Carrington & Bailey, 2009). For instance, Gallagher and Frith (2003) suggested that the medial prefrontal cortex is activated when determining a person's mental state (e.g. a belief) that may be different from reality. The anterior cingulate cortex is thought to be involved in understanding intentions specifically in social interaction (Walter et al., 2004). The orbitofrontal network, located in the ventral region of the prefrontal network (Kringelbach & Rolls, 2004), is implicated in social decision making with negative facial emotions (Willis, Palermo, Burke, McGrillen & Miller, 2010). The superior temporal sulcus is thought to be associated with the interpretation of others' actions and intentions by analysing biological motion, including eye and body movements, together with static images of eyes and faces (Allison, Puce & McCarthy, 2000). The perception of faces is associated with activation in the fusiform face area, part of the fusiform gyrus, at the junction of the temporal and occipital lobes (Kanwisher, McDermott & Chun, 1997) and the amygdala seems to be involved in visual emotion processing (Heberlein & Adolphs, 2005).

Figure 1.7 is adapted from Amodio and Frith (2006) and presents regions associated with social cognition. Mentalising (blue diamond), person perception (green triangle) and self-knowledge (yellow circle) are associated with anterior frontal regions. White circles indicate regions activated (Wolf, Dziobek & Heekeren, 2010) during the Movie for the Assessment of Social Cognition (Dziobek et al., 2006) a dynamic social cognition task including social interaction (see Chapter 3 for task description). Wolf, Dziobek and Heekeren (2010) reported that several independent but synchronous networks were associated with task performance including occipito-parietotemporal networks, associated with face processing and recognition, temporal networks, lateral prefrontal networks and precuneus, implicated in language comprehension, and dorsomedial prefrontal networks and precuneus involved in self-referential mental state attribution. Figure 1.7 shows that both frontal and posterior networks mediate social cognition.

Figure 1.7. Regions associated with social cognition.

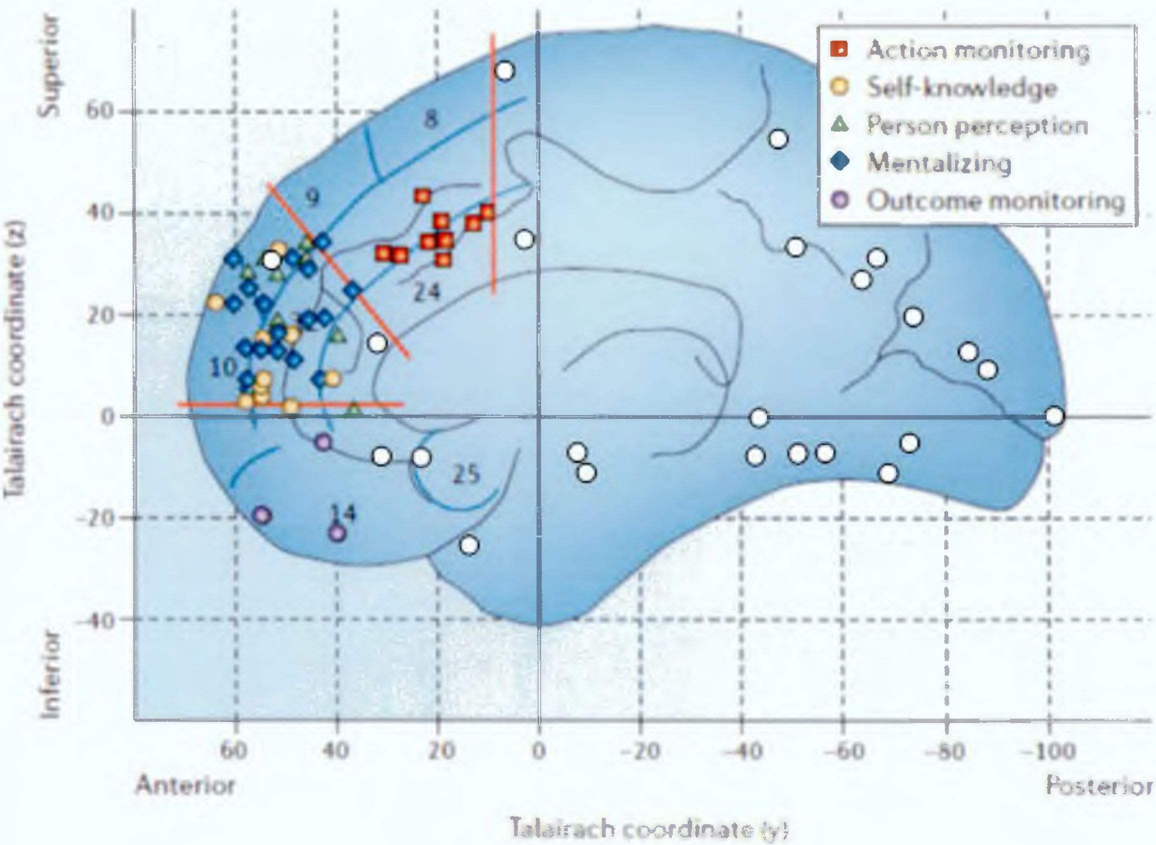


Figure 1.7. The white circles added show regions associated with completing a dynamic social cognition task (Wolf, Dziobek & Heekeren, 2010). Diagram adapted from Amodio and Frith (2006).

Comparing the neural substrates associated with executive function task performance in Figure 1.2 with social cognition task performance in Figure 1.7, common yet distinct neural substrates are involved in executive function and social cognition. Frontal regions are associated with both executive function and social cognition. However, diverse neural substrates, including posterior regions, contribute to performance on the MASC (Wolf et al., 2010). The implication of distinct neural substrates being involved in executive function and social cognition is that they follow different developmental trajectories.

Bird, Castelli, Malik, Frith and Husain (2004) reported a study where findings were not consistent with the importance of medial prefrontal cortex in social cognition. A 62-year-old patient, GT, who had suffered a rare form of stroke resulting in extensive bilateral damage to anterior regions of the medial frontal lobes, completed a range of social cognition and executive function tasks. GT attained an IQ of 102, within the average range, on the Wechsler Adult Intelligence Scale–Revised (Wechsler, 1981). Whilst some studies have found performance on Theory of Mind stories tasks decreases into older age (Maylor, Moulson, Muncer & Taylor, 2002; Slessor, Phillips & Bull, 2007), GT performed at ceiling on the mental state and physical state understanding questions on the short stories task (Happé, 1995), indicating no impairment on this advanced social cognition task. GT scored in the normal range for her age and IQ on the Animations Task (Castelli et al., 2000) requiring the attribution of mental states to moving objects. The Faux Pas test (Baron-Cohen et al., 1999) is comprised of twenty short passages, with half including an inappropriate comment from a character. GT scored at the low end of the normal range, sometimes showing insensitivity to how a character would feel in a scenario.

Regarding executive function, the patient scored in the normal range on the F-A-S Letter Fluency Test (Benton & Hamsher, 1989), Trail Making Test (Army Individual Test Battery, 1944) and the Stroop Test (Trenery et al., 1989). GT attained a moderate-average score on section one of the Hayling sentence completion task (Burgess & Shallice, 1997), but failed to complete section two, requiring inhibition of the correct word and generation of a completely irrelevant word. Given the participant's performance in the normal range on the Stroop Test, Bird et al. (2004) suggested poor performance on Hayling section two was due to a failure in generating an appropriate strategy. The finding of intact social cognition and impaired performance on the Hayling Test indicates that social cognition and executive functions are functionally dissociable.

To summarise, imaging studies with typically developing participants have consistently highlighted the importance of medial frontal regions during social cognition task performance (Carrington & Bailey, 2009 Burnett & Blakemore, 2009; Castelli, Happé, Frith & Frith, 2007; Gallagher et al., 2000; Wolf, Dziobek & Heekeren, 2010). This is inconsistent with the case study of GT, who showed intact social cognition skills following extensive damage to bilateral medial frontal regions. Possible explanations for GT's intact social cognition skills are that the social cognition network was reorganised or the recruitment of other networks during task performance (Bird et al., 2004).

1.16 Theories of social cognition

This section introduces and evaluates theories of social cognition including a model for the development of social cognition (Pelphrey & Perlman, 2009), Social Information Processing Network (Nelson, Leibenluft, McClure & Pine, 2005) and the Socio-cognitive Integration of Abilities Model (Beauchamp & Anderson, 2010).

1.16.1 Ontogeny of social cognition (Pelphrey & Perlman, 2009)

Pelphrey and Perlman (2009) proposed a model for the ontogeny of social cognition from childhood through adolescence underpinned by increases in functional connectivity and aided by myelination and synaptic pruning. Figure 1.8 presents the model for the development of social cognition by Pelphrey and Perlman (2009).

Figure 1.8. Model for the development of social cognition.

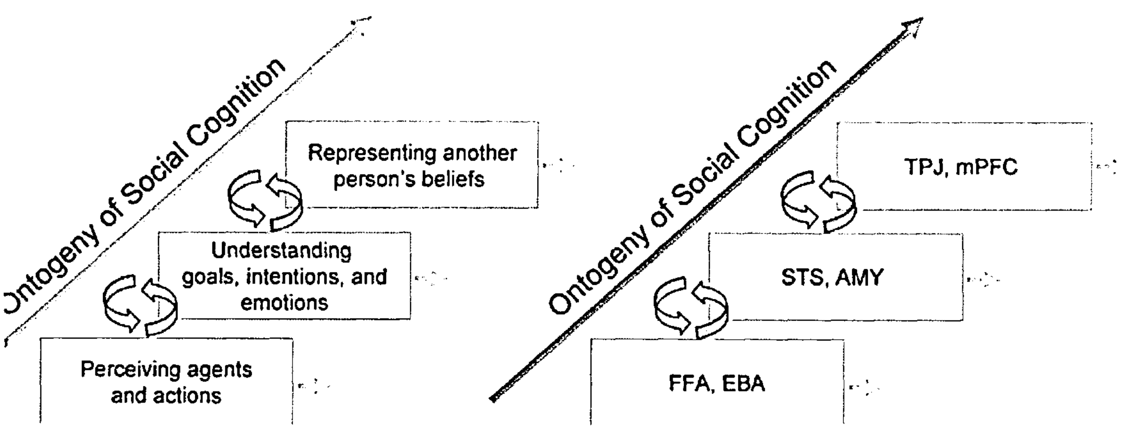


Figure 1.8. FFA = fusiform face area (occipital lobe), EBA = extrastriate body area (occipital lobe), STS = superior temporal sulcus (temporal lobe), AMY = amygdala (temporal lobe), TPJ = temporoparietal junction (temporal / parietal lobes) and mPFC = medial prefrontal cortex (frontal lobes). Reproduced from Pelphrey & Perlman (2009).

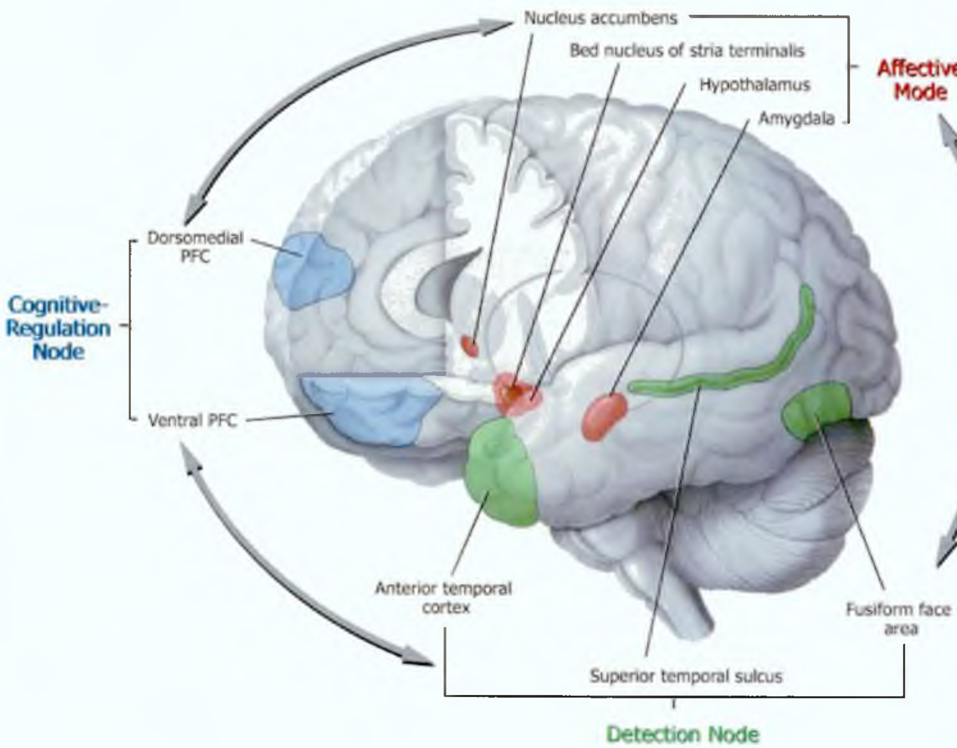
A strength of the model for the development of social cognition presented above (Pelphrey & Perlman, 2009) is that it attempts to match function to brain structure.

There is supporting evidence from neuroimaging studies for the specified regions of interest. The most advanced stage of social cognition denoted in the model is belief representation, commonly assessed with false belief tasks. This seems to be inconsistent with behavioural data indicating that false belief tasks are completed successfully around the age of four (Happé, 1995), yet Pelphrey and Perlmann (2009) suggested belief representation continues to develop into adolescence. Furthermore, the model lacks detail because there are no ages specified for either the development of social cognition stages or brain regions. The model omits some aspects of social cognition e.g., empathy and perspective taking are not included, resulting in the model including a narrow range of abilities.

1.16.2 Social Information Processing Network (Nelson, Leibenluft, McClure & Pine, 2005)

The Social Information Processing network (SIPN) model, as described by the authors, posits that social information processing involves three "nodes" named the detection, affective and cognitive-regulatory nodes. Figure 1.9 presents the Social Information Processing Network (Nelson et al., 2005).

Figure 1.9. Social Information Processing Network. Reproduced from Nelson, Leibenluft, McClure & Pine (2005)



The detection node, thought to be composed of the inferior regions of the temporal cortex, inferior occipital cortex, superior temporal sulcus and fusiform face area, first processes a stimulus. The detection node decides whether a stimulus is animate, a conspecific (of the same species) and considers its actions and intentions. If the stimulus is social, further processing is thought to occur in the affective node, comprised of the amygdala and hypothalamus, and a decision is produced about whether the stimulus should be avoided or approached. The cognitive-regulatory node of the model is considered to be comprised of the medial and dorsal prefrontal networks and the orbitofrontal network; this node is thought to be involved in mental state understanding, inhibition of prepotent responses and generation of goal-directed behaviour. Information processing is primarily thought to lead from the detection node, to affective and cognitive-regulatory nodes, although bi-directional information processing has also been suggested, e.g. mental state monitoring during social interaction would involve both the detection and cognitive-regulatory nodes to detect the actions and mental state of the other person and then act appropriately.

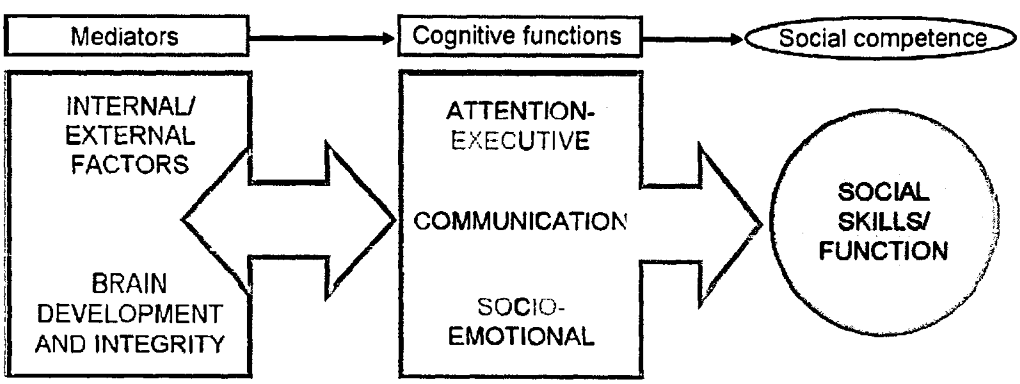
The authors proposed that the detection node matures in the first few years of life, with the maturation of the affective node continuing into adolescence. The protracted maturation of frontal regions (e.g. Gogtay et al., 2004; Sowell et al., 2001) is thought to result in the cognitive-regulatory node developing into late adolescence. Secondary effects of hormones may occur due to the interaction between affective and cognitive nodes. Hormones are thought to influence affective node maturation, whilst cognitive node development is independent of hormonal status, instead being due to myelination and pruning of neural networks. In addition, greater functional connectivity also develops between the components, resulting in greater top-down control. Nelson et al. (2005) suggested rewiring of the affective and cognitive-regulatory nodes leads to changing social behaviour during adolescence, including romantic interest, with more time spent in the company of peers instead of family (Steinberg & Morris, 2001) and an increase in risk taking (Steinberg, 2008).

Strengths of the SIPN model are that it specifies brain regions, when regions mature and how stimuli are processed. Nelson et al. (2005) noted that this model is speculative and needs further behavioural research, for example changes that occur in the SIPN. Choudhury et al. (2006) commented that the SIPN model does not distinguish between emotion processing about the self and another person and suggest an agency node for processing this information before the limbic node. A further limitation of the model is that social information processing is not fragmented into separate components, e.g. visual / auditory information, and some aspects of social cognition, for example empathy, are omitted. The model emphasises the development of social information processing during adolescence being due to brain maturation but does not acknowledge that the environment may also contribute to development. Environmental factors applicable to adolescence may include starting or changing secondary schools or college and different friendship groups.

1.16.3 SOCIAL: Socio-cognitive Integration of Abilities Model (Beauchamp & Anderson, 2010)

This improves on previous models and adopts a multidisciplinary approach by integrating biological and psychological factors; the authors proposed that social cognitive development is dependent on normal brain maturation, cognition and behaviour, together with the influence of environmental and other factors. The SOCIAL model posits that internal and external factors influence social cognition, mediated by the environment and biological factors interacting bi-directionally with brain maturation. The outcome of the model is social function, defined as "overall performance across many everyday domains (e.g. independent living, employment, interpersonal relationships, recreation" (Yager & Ehmann, 2006, p. 48). Figure 1.10 presents components of the SOCIAL model.

Figure 1.10. SOCIAL: Socio-cognitive integration of abilities model. Reproduced from Beauchamp & Anderson (2010)



The first component of the model is comprised of internal and external factors and brain development. Internal factors (e.g. personality, temperament or physical attributes) influence how an individual behaves during social interaction, with external factors affecting the quality and nature of social interactions experienced by an individual, including family environment, socio-economic status or culture. A key aspect of the SOCIAL model is that it includes the development and integrity of brain regions associated with social cognition skills, yet in explaining the model, the authors do not elaborate specific brain regions.

The SOCIAL model differentiates between social cognition and other aspects of cognition, e.g. executive functions. Cognitive functions involved in social cognition form the second component: attention-executive and communication (cold processes) and socio-emotional (hot processes), with cold processes referring to cognitive and rational decision making and hot processes concerned with affective decision making (Séguin, Arseneault & Tremblay, 2007). The authors suggest that the attention-executive component includes attentional control, cognitive flexibility and goal setting, following the definition of executive function by Anderson (2008). The communication component includes various aspects of language thought to be related with social cognitive development, e.g. semantic ability (Slade & Ruffman, 2005), syntactical ability (de Villiers & Pyers, 2002), and pragmatic ability, the use and interpretation of language in communication (Milligan, Astington & Dack, 2007). The socio-emotional component ranges from basic social cognitive skills, the interpretation of facial expressions, to more complex abilities of Theory of Mind and empathy, the ability to infer and share others' emotional experiences (Gallese, 2003).

Beauchamp and Anderson (2010) related the SOCIAL model to atypical social cognition development in Autism Spectrum Disorders, Schizophrenia and TBI. They consider this model as a conceptual framework for understanding typical and atypical social cognition development. The authors suggested that standard psychological measures for clinical utility should assess each component of the SOCIAL model. However, currently there are no data supporting this model.

1.16.4 Summary of social cognition theories

A strength of the model for the development of social cognition (Pelphrey & Perlman, 2009) is that it attempts to match function to brain structure, although the model does not indicate ages when social cognitive development occurs. The Social Information Processing Network (Nelson et al., 2005) omits environmental factors because they are difficult to operationalise and measure, whereas these are included in the SOCIAL model by Beauchamp and Anderson (2010). While Beauchamp and Anderson (2010) provided a descriptive account applying the SOCIAL model to atypical development, at present, no empirical data supports this model. Samson and Apperly (2010) argued that Theory of Mind is not unitary, composed instead of several processes culminating in mental state understanding. However, current models of social cognition do not fully capture this or the diverse range of abilities (i.e. Theory of Mind, empathy, perspective taking etc.) or differentiate between different modalities (visual/auditory, static/dynamic). Furthermore, existing theories do not inform tasks appropriate for use in late adolescence or early adulthood.

1.17 Development of social cognition in late adolescence and early adulthood: Behavioural Studies

Social cognition research has until recently predominantly focused on children e.g. 8 to 12 year olds (Golan, Baron-Cohen, Hill & Golan, 2008) or adults e.g. 22 to 62 year olds (Dziobek et al, 2006), resulting in a dearth of studies investigating social cognitive development in adolescence (Moriguchi et al, 2007; Herba & Phillips, 2004). The following section reviews existing adolescent social cognition studies, with reference to whether development follows linear or non-linear trajectories.

Several studies have investigated emotion recognition development. Thomas, De Bellis, Graham and LaBar (2007) presented morphs of Ekman faces (Ekman & Friesen, 1976) showing neutral to anger, neutral to fear and solely fear to children (mean age = 10.4 years), adolescents (mean age = 15.7 years) and adults (mean age = 39.2 years). Adults showed greater sensitivity to the morphs compared to adolescents, who performed similarly to children. A linear developmental trajectory was reported for fear to anger morphs, whilst neutral to anger morphs showed a quadratic trend, indicating a sharp increase in sensitivity between adolescents and adults. These data provide preliminary evidence for ongoing development of emotion recognition from adolescence to adulthood. This study also assessed pubertal development using a questionnaire (Tanner & Davies, 1985), although correlations with the child and adolescent groups between sensitivity to the morphs and pubertal development were not significant, indicating that emotion recognition is not related to pubertal development. This finding is inconsistent with Burnett, Thompson, Bird and Blakemore (2010) who found that pubertal development in 9 to 16 year old females, assessed with the self-administered rating scale for pubertal development (Carskadon & Acebo, 1993), was positively related to mixed emotion understanding, the ability to acknowledge that several emotions can be experienced in one situation. Thomas et al. (2007) suggested that future research should be conducted with other emotions because only anger and fear were examined in the present study.

Dumontheil, Apperly and Blakemore (2010) found linear improvement when comparing child I (7.3-9.7 years), child II (9.8-11.4 years), adolescent I (11.5-13.9 years), adolescent II (14.0-17.7 years) and adult (19.1-27.5 years) groups on a spatial "Director" Perspective Taking Task. Participants viewed shelves with objects on, with some occluded from the director positioned on the other side of the shelves. In the Director condition, participants were required to move items following the director's rules, taking into account his viewpoint. The No Director condition required participants to ignore objects in slots with a grey background, instead focusing only on the objects in clear slots. Groups did not differ on Verbal IQ, assessed with the British Picture Vocabulary Scale (Dunn, Dunn, Whetton & Burley, 1997) or the WASI (Wechsler, 1999). The group aged 7.3 to 9.7 years made significantly more errors in the Director and No Director conditions compared to the adolescent group aged 14 to 17.7 years, who showed a significant trend with more errors than the adult group aged 19.1 to 27.5 years only in the Director trials. Reaction times were also measured; the group aged 7.3 to 9.7 years took significantly longer to respond than adolescents aged 11.5 to 13.9 years and adults aged 19.1 to 27.5 years.

Dumontheil et al. (2010) suggested that the improvement in perspective taking between late adolescence and early adulthood was due to the maturation of inhibiting a prepotent response. The authors concluded that an interaction between social cognition (perspective taking) and executive functions develops into late adolescence, yet no measure of executive function, a possible confounding variable, was administered. In addition, they proposed an alternative explanation; as reaction times were significantly faster in the Director condition relative to the No Director condition, it is possible that the lower errors rates in adults were not because of an increase in perspective taking efficiency, but rather a greater tendency to consider the directors' perspective. Positive aspects of this study are that Dumontheil et al. (2010) assessed perspective taking ability beyond childhood into adolescence and adulthood utilising a task that avoided ceiling effects. However, a shortcoming of this study is that only Verbal IQ was assessed, with no assessment of Performance IQ, so Full Scale IQ was not calculated; Gore, Barnes-Holmes and Murphy (2010) reported that Full Scale IQ significantly correlated with perspective taking.

Non-linear social cognitive ability is evident in early adolescence on the Reading the Mind in the Eyes Test, a visual assessment of emotion recognition (Baron-Cohen, Wheelwright, Hill, Raste & Plumb, 2001). In this test 36 photographs of eye regions are presented and the participant is required to select one of four mental states that best describes how the person is thinking or feeling. Children aged 11+ significantly outperformed children below 11 years of age, with scores increasing significantly from 59% to 74% between ages 9-11, yet decreasing to 68% for 14 to 15 year olds (Tonks, Williams, Frampton, Yates & Slater, 2007). Vocal prosody tests from the Florida Affect Battery, assessments of auditory emotion recognition, were also administered. Participants heard 20 sentences with neutral content expressing happiness, sadness, anger, fear or neutral emotions and selected the appropriate answer. Nine year olds attained a mean of 78% on this task, and performance improved with age with both 11 and 12 year old groups scoring a mean of 88%. For ages 13 and 14 plus, there was a slight decrease in ability, with a mean score of 83% reported, although there were no significant group differences on the vocal prosody test. However, participants ranged in age from nine to 15 years, so it is not possible to conclude how emotion recognition develops in late adolescence or early adulthood. The authors suggested that the study could be extended by utilising a longitudinal design instead of a cross sectional design. Social cognitive development has previously been considered as linear and occurring in progressive stages (Beauchamp & Anderson, 2010), but the results from Tonks et al. (2007) show a decline in ability during adolescence.

McGivern et al. (2002) found stronger evidence for non-linear development of reaction times to emotional information on a match-to sample task. Participants were presented with stimuli depicting words, faces and a combination of words and faces categorised as happy, angry, sad or neutral, and had to decide whether the stimuli matched the original reference stimulus. The authors found that males and females in early adolescence showed a 10–20% increase in reaction times compared to participants one year younger. McGivern et al. (2002) suggested that the increase in reaction time responses around puberty might reflect inefficient frontal networks prior to synaptic pruning. Although brain morphology was not measured in this study, imaging research provides evidence to support this. For instance, in a cross sectional MRI study previously detailed, Sowell et al. (2001) reported grey matter loss in frontal and parietal networks between ages 7 to

11 and 12 to 16. Furthermore, DTI research also indicates that synaptic pruning begins around puberty (Schmithorst & Yaun 2010).

A study investigating emotional perspective taking by Choudhury, Blakemore and Charman (2006) used a task requiring participants to read sentences presented in the first person perspective, e.g. "You are not allowed to go to your best friend's party. How do you feel?" or third person perspective "A girl is not allowed to go to her best friend's party. How does she feel?" Participants selected their answer from a choice of two cartoon faces showing very happy, happy, neutral, sad, angry and afraid expressions. Children (mean age 8.6 years), adolescents (mean age 12.8 years) and adults (mean age 24.0 years) completed the task. Choudhury et al. (2006) calculated the difference in reaction time between responding to a third person perspective and a first person perspective item. Larger differences for children and adolescents indicated a less systematic processing strategy relative to adults. Reaction time differences approached zero between age 20 and 30, suggesting a more proficient perspective taking strategy develops in adulthood. The authors reported a significant main effect of age, but not of gender, with reaction time decreasing significantly with age. Choudhury et al. suggested that proficient perspective taking ability in adulthood is due to the maturation of the social cognition brain network and greater experience of social situations. Whilst this study provides evidence for linear development of social cognition skills between adolescence and adulthood, the broad age ranges between the adolescent and adult age groups results in a lack of data specifically for late adolescence. In addition, participants selected from a choice of two stimuli, increasing the likelihood of ceiling effects.

The next section reviews empathy, a component of social cognition often measured. Empathy consists of cognitive empathy, intellectual understanding of another person's mental state, and affective empathy, appropriate emotional response after considering the experiences of another person and attributing a mental state to them (Lawrence, Shaw, Baker, Baron-Cohen & David, 2004). Scores on the Interpersonal Reactivity Index (IRI), a widely used measure of empathy (Davis, 1983; see Chapter 3), increased in a sample of 505 participants aged 13 to 15 years old with follow-up testing one year later (Mestre, Samper, Frías & Tur, 2009). The authors reported significant gender differences, with females scoring higher than males on all sub-scales of the IRI. The gender difference increased at Time 2. However, as this study has a cut-off of 16 years, it is not clear if cognitive and affective empathy develops after this age. Extreme Male Brain Theory (Baron-Cohen, 2002) provides a possible explanation for gender differences in empathy based on the concepts of empathising, a drive to understand another person's emotions and respond appropriately, and systemising, a drive to understand rules that govern a system, e.g. syntax, a computer program or a business. Baron-Cohen (2002) argued that male brains are characterised by systemising > empathising whereas female brains are defined by empathising > systemising.

Davis and Franzoi (1991) assessed 205 participants on the IRI (Davis, 1983) aged 15 and 16 years old at Time 1 at one-year intervals over three consecutive years. The authors reported significant increases in Perspective Taking, the tendency to consider another person's point of view, and Empathic Concern, the tendency to experience compassion and sympathy towards others, whereas ratings of Personal Distress, the tendency to experience uneasiness in tense social situations, significantly decreased. These results highlight the multidimensional nature of empathy, with different aspects of empathy showing different developmental trajectories. Davis and Franzoi (1991) explained the results by Hoffman's (1975; 1976) Theory of Empathy. Hoffman posited that during childhood Personal Distress and Perspective Taking develops and then Personal Distress decreases with age because self-oriented distress transforms to other oriented sympathy and compassion, or Empathic Concern. There were significant gender differences on all IRI sub-scales, with females scoring significantly higher than males. Davis and Franzoi (1991) acknowledged that participants may have adhered to demand characteristics specific to their gender, but suggested that the one-year interval between testing was enough time to minimise participants remembering their previous responses. They noted that a limitation of their study was that all the participants were from the same school in America, possibly leading to a narrow demographic range.

1.18 Relationship between executive functions and social cognition

Executive functions and social cognition are commonly considered interrelated (Carlson & Moses, 2001; Charlton et al., 2009; Doherty, 2009; Hughes & Ensor, 2007). Perner and Lang (1999) proposed five theories about the relationship between executive functions and social cognition; social cognition is a prerequisite for executive function, or executive function is a prerequisite for social cognition. Alternatively, social cognition tasks require executive functions, both types of tasks are completed using the same embedded control reasoning, or both types of tasks recruit common brain regions (Perner & Lang, 1999). A limitation of these theories is that they are only relevant to childhood; the suggestion that executive function is a prerequisite for social cognition is inconsistent with the notion that executive functions follow a protracted development into adolescence. Furthermore, it is necessary to understand the relationships between executive functions and social cognition beyond childhood (Best, Miller & Jones, 2009). Carlson and Moses (2001) suggested that executive functions, for example inhibitory control, contribute to the development of social cognition because executive functions and social cognition show similar developmental increases around preschool and are thought to recruit frontal networks. False belief tasks e.g. Sally Anne Test (Baron-Cohen, Leslie & Frith, 1985) require participants to inhibit their own knowledge of the situation and consider the characters' beliefs.

Ahmed and Miller (2011) examined the relationship between executive function and social cognition in participants aged 18 to 27 years. The authors focused on which executive functions predict social cognition because Hughes (1998) found that executive functions predicted social cognition rather than social cognition predicting executive functions. The sample consisted of typically developing participants because the relationships between executive function and social cognition are easier to infer (Ahmed & Miller, 2011). Participants completed all subtests from the D-KEFS (Delis, Kaplan & Kramer, 2001; see Chapter 3 for test descriptions). The Reading the Mind in the Eyes Test (Baron-Cohen et al., 2001), Strange Stories Test (Happé, 1994) and the Faux Pas Test (Stone et al., 1998) assessed social cognition. The Wechsler Test of Adult Reading (Wechsler, 2001) provided an estimation of Full Scale IQ. The researchers collected demographic information about age, gender, ethnicity, United States geographical region and family income. There were no significant correlations between scores on the social cognition tasks. Three separate hierarchical multiple regression analyses were conducted with the social cognition tasks as single dependent variables. Demographic variables that significantly correlated with the dependent variable were entered in the first step as independent variables, followed by any executive function tasks that significantly correlated with the dependent variable. Estimated IQ was the only significant predictor of performance on the Reading the Mind in the Eyes Test, with no executive function scores being significant predictors. No demographic variables were significant predictors of performance on the Strange Stories Task. Scores on the Verbal Fluency Test measure of strategy generation, and the Word Context Test, a measure of deductive reasoning, significantly predicted performance on the Strange Stories Test. Gender was a significant predictor for performance on the Faux Pas Test, with females scoring significantly higher than males. Verbal Fluency and the number of confirmed correct sorts on the Sorting Test, a measure of concept formation, also predicted Faux Pas Test scores.

Ahmed and Miller (2011) concluded that different executive functions are associated with different aspects of social cognition. A positive point about this study was the inclusion of a wide range of executive function tasks and social cognition tasks with different formats (e.g. visual format for the Reading the Mind in the Eyes Test and written format for the Strange Stories and Faux Pas Tests). This study also focused on social cognition and executive function in early adulthood, when the majority of previous research has involved children or older adults. However, the authors noted that participants with Autism Spectrum Disorders (ASD) were not excluded from the study and gave no indication of the number of participants with ASD. This may have had an impact on the results because ASD is associated with deficits in social cognition (Brent, Rios, Happé & Charman, 2004; Dziobek et al., 2006; Golan, Baron-Cohen, Hill & Golan, 2006; Heavey, Phillips, Baron-Cohen & Rutter, 2000).

1.19 IQ

The next sections consider IQ because many studies suggest that executive function, social cognition and IQ are related (Ardila, Pineda & Rosselli, 2000; Charlton et al., 2009; Obonsawin, Crawford, Page, Chalmers, Cochrane & Low, 2002). Spearman (1927) proposed *g* or general intelligence, the notion that cognitive tasks often correlate highly and share a common factor. Duncan, Johnson, Swales and Freer (1997) reported that Cattell's Culture Fair, an assessment of *g*, correlated positively with executive function tasks including the Verbal Fluency Task (Benton & Hamsher, 1978), Six Elements Task (Shallice & Burgess, 1991) and a Letter-monitoring Task (Duncan et al.,

1996) in HI patients, indicating that these tasks share a common element (Duncan et al., 1997). These results have been replicated in studies with typically developing participants (Obonsawin et al., 2002) and HI patients (Wood & Liossi, 2006) with a range of executive function tasks e.g. Hayling and Brixton (Burgess & Shallice, 1997), Card Sorting Test (Milner, 1963) and Tower of London (Shallice, 1982).

Horn and Cattell (1967) proposed the fluid and crystallised intelligence dichotomy. Fluid intelligence continues to increase into the late teens or early twenties, followed by a decline (Wechsler, 1981). The Block Design and Matrix Reasoning sub-tests of the WASI assess fluid intelligence, higher mental abilities including reasoning (Bugg, Zook, DeLosh, Davalos & Davis, 2006). The development of crystallised intelligence is more protracted, peaking around the late twenties with a very gradual decline (Salthouse, 1992). Crystallised intelligence refers to knowledge acquired through education and culture, measured with the Vocabulary and Similarities sub-tests from the WASI.

1.20 Relationship between EF, social cognition and IQ

In a review of studies, García-Molina, Tirapu-Ustarroz, Luna-Lario, Ibáñez and Duque (2010) concluded that executive functions and intelligence overlap but not in all aspects. Ardila, Pineda and Rosselli (2000) examined the relationship between executive function measures and intelligence in 13 to 16 year olds. The authors reported a significant positive correlation of approximately 0.3 between phonological verbal fluency and both Verbal IQ and Full Scale IQ, assessed with the Wechsler Intelligence Scale for Children (Wechsler, 1991). Verbal and Full Scale IQ showed a significant negative correlation with perseverative errors on the Wisconsin Card Sorting Task. The only executive function measure to correlate significantly with Performance IQ was a negative correlation with time on the Trail Making Test. Ardila et al. (2000) noted that the sample was from a region with low socio-economic status, yet no measure was reported.

Friedman et al. (2006) reported further evidence for some executive functions being unrelated to intelligence. Participants, who were 234 twins aged between 16 and 18 years, completed tasks of inhibition, updating and shifting. Inhibition was assessed with the Antisaccade Task (Roberts, Hager & Heron, 1994), requiring participants to inhibit looking at a cue, the Stop-signal Task (Logan, 1994) in which participants attempt to withhold a motor response on particular trials and the Stroop Task (Stroop, 1935), involving the naming of incongruent font colours and inhibiting reading the colour words. The updating tasks required the recall of information previously presented using auditory and spatial tasks. Shifting tasks required participants to switch between classifying numbers and letters, and shapes and colours. Raven's Progressive Matrices Test, a multiple-choice vocabulary test (DeFries, Plomin, Vandenberg & Kuse, 1981) and the Block Design and Information sub-tests from the Wechsler Adult Intelligence Scale (Wechsler, 1997) provided a measure of intelligence. Updating significantly correlated with Performance IQ, whereas inhibition and shifting did not. Updating, shifting and inhibition significantly correlated with Verbal IQ. The authors reported no demographic information about the sample. Plomin et al. (2001) questioned the generalisability of twin studies and whether samples of twins are representative of the human population, given that twins are often born prematurely (Philips, 1993), usually with a lower birth weight compared to single babies (MacGillivray et al., 1988) and are reported to experience language delay (Sutcliffe & Derom, 2006).

There is debate about whether social cognition and IQ are related or independent cognitive domains (Rajkumar, Yovan, Raveendran & Russell, 2008). For example, Golan et al. (2007) reported a significant positive correlation between WASI Verbal IQ and scores on the Reading the Mind in the Voices Test. Dziobek et al. (2006) found a significant positive correlation between the Strange Stories Test and Verbal IQ, assessed with the Shipley Institute of Living Scale (Prado & Taub, 1966). Verbal IQ did not correlate with scores on the Reading the Mind in the Eyes Test (Golan et al., 2007) or the MASC (Dziobek et al., 2006). Performance IQ did not correlate with scores on the Reading the Mind in the Eyes Test and Reading the Mind in the Voices Test (Golan et al., 2007). These findings indicate that performance on some social cognition tasks that require less verbal processing may be independent from general intelligence, although inconsistent findings could be due to different tasks used to assess IQ (Heavey et al., 2000).

1.21 Rationale for present research

A review of the literature reveals a dearth of research into social cognition and executive function development in late adolescence and early adulthood (Moriguchi et al., 2007; Herba & Phillips, 2004), with the majority of studies in this area including children or older adults. Research has predominantly focused on children e.g. 8 to 12 year olds (Golan, Baron-Cohen, Hill & Golan, 2008) or had age cut-offs so that late adolescence and beyond are not included (e.g. executive function in 11 to 17 year olds; Magar et al. (2010), or social cognition in 14 to 18 year olds; Thomas et al., 2007). Given that histological and imaging studies have provided consistent evidence for post-adolescent brain changes, specifically synaptogenesis and synaptic pruning in frontal networks (e.g. Huttenlocher & Dabholkar, 1997; Schmithorst & Yuan, 2010), the present research focuses on the cognitive implications of this protracted maturation. Whilst imaging studies suggest white and grey matter maturation during adolescence, the majority do not report behavioural data.

First-episode psychosis, anxiety, depression and eating disorders often occur in late adolescence, suggesting that a combination of rapid rates of brain maturation, psychosocial, hormonal and environmental factors confer vulnerability at these ages (Paus, Keshevan & Giedd, 2008; Barker et al., 2010). Protracted brain maturation into late adolescence and early adulthood increases susceptibility to neuropathology, summarised in the phrase "moving parts get broken" (Paus et al., 2008, p. 954). Studies of executive function ability have previously included participants with atypical development, such as HI (e.g. Barker et al., 2010; Barker, Andrade, Romanowski, Morton & Wasti, 2006) and schizophrenia (Royer et al., 2009). Social cognition studies have also involved participants with atypical development, e.g. children and adolescents with Asperger's Syndrome (e.g. Kaland et al., 2008) and TBI (e.g. Stronach & Turkstra, 2008). There is a lack of research into the typical developmental trajectory of social cognition and executive functions in late adolescence and early adulthood (Romine & Reynolds, 2005).

Moreover, head injuries are also frequent in this age group. A 25 year longitudinal study into the prevalence of head injuries with an initial cohort of 1,265 found the highest incidence of head injuries were in the 15 to 20 year old group, with approximately 30%

of participants experiencing a head injury by the age of 25 (McKinlay et al., 2008). In addition, head injuries are frequent in childhood; Crowe, Anderson, Catroppa and Babl (2010) reported 406 six to 16 year olds had attended hospital for head injury treatment in one year. The number of head injuries sustained in childhood is important because it is possible that deficits following childhood head injury become evident in late adolescence or early adulthood, defined as the "latent trajectory of impairment" (Tranel & Eslinger, 2000, p. 275). Eslinger, Grattan, Damasio and Damasio (1992) reported a case study of DT, who sustained damage to her left prefrontal network and white matter at age 7, followed by improvement and then a delayed onset of deficits in adolescence, including empathic ability and social development. Currently, it is unknown what social cognition and executive function abilities are typical in late adolescence and early adulthood. It is possible that certain functions go offline temporarily and this would be evident in non-linear trajectories, with a peak in ability followed by a trough and then improvement. It is important to understand the development of executive functions in typically developing adolescents because this has implications for rehabilitation following head injury (Reynolds & Horton, 2008). Therefore, deficits seen in pathology in this age group could then be reliably ascribed as 'deficits' rather than due to typical non-linear developmental trajectories.

1.22 Aims of the Thesis

This thesis examines executive function and social cognition specifically in a typically developing late adolescent and early adulthood group, with participants aged 17 years 0 months – 17 years 8 months, 18 years 0 months – 18 years 8 months and 19 years 0 months – 19 years 8 months at Time 1. De Luca et al. (2003) recommended the use of fine-grained age groups because broad age groups decrease sensitivity. No previous research has concurrently measured executive function and social cognition in this fine-grained age range. As previous research has recommended a longitudinal design (Kalkut et al., 2009; Romine & Reynolds, 2005; Tonks et al., 2007; Waber et al., 2007), this study adopted a sequential design, allowing cross sectional and longitudinal data analyses. It was hypothesised there would be changes in executive functions and social cognition with age, with some functions developing linearly and others following a non-linear developmental trajectory in late adolescence and early adulthood.

Chapter 2 reviews literature on considerations of research in late adolescence and early adulthood. Chapter 3 is a methodology review including the sequential design and task selection. Chapter 4 presents demographic data from Time 1 and Time 2. Chapter 5 presents and discusses cross sectional Time 1 executive function and social cognition data. Chapter 6 includes cross sectional Time 2 executive function and social cognition data and longitudinal analyses. Chapter 7 reports IQ, mood, gender and executive function predictors of social cognition task scores. Chapter 8 summarises and discusses the findings in relation to previous research. Implications of the research are considered together with ideas of future research.

Chapter 2

Considerations of research in late adolescence and young adulthood

2.1 Chapter overview

The rationale for this chapter is to review issues that confound research in late adolescence and early adulthood including the effect of pubertal development and mood on executive function and social cognition. This chapter also reviews how drug use, specifically alcohol, cannabis and ecstasy, affects brain maturation and cognitive function. Statistics are included to indicate the prevalence of drug use in late adolescence and early adulthood. The impact of atypical development, including Head Injury, Autism Spectrum Disorders, Depression, Anxiety and Obsessive-compulsive Disorder on cognitive function is discussed. Participants with head injury and autism spectrum disorders were excluded from the study; executive function and social cognition research in these populations is reviewed to provide a rationale for their exclusion.

2.2 Pubertal development

Whilst there is evidence of sex hormones resulting in neuronal re-organisation during prenatal development (Genazzani et al., 2007), it is now thought that increasing hormones during puberty results in another phase of neuronal re-organisation (Romeo, 2003). In a review of studies into pubertal maturation and white matter development, Ladoucer, Peper, Crone and Dahl (2012) concluded that pubertal hormones influence timing and re-organisation of white matter with gender differences evident. Hormones are also thought to have an organisational effect on grey matter resulting in sexual dimorphism. In a sample of 8 to 15 year olds, Neufang et al. (2009) found that males towards the end of puberty (Tanner stage 4 or 5) had larger grey matter volumes in the left amygdala, whereas females showed higher grey matter volumes in the hippocampus and right striatum, compared to earlier stages of puberty. Testosterone levels positively correlated with grey matter volumes in the hypothalamus, whilst testosterone negatively correlated with grey matter volumes in the left parietal cortex. Neufang et al. (2009) noted that it is not clear whether hormones affect neural organisation directly or whether social experiences are also involved.

The role of hormones and pubertal development is often overlooked in developmental research (Kalkut, Han, Lansing, Holdnack & Delis, 2009; Blakemore, 2008a) due to measurement issues of assessing puberty, a protracted process instead of a single event (Blakemore, Burnett & Dahl, 2010; see Chapter 3 for a review of pubertal development measures). Some researchers have investigated the effects of pubertal development on executive function and social cognition. In one study, 8 to 28 year olds completed the Stroop Task, occulomotor Response Inhibition Task and the 5-move Stockings of Cambridge measure of planning (Olaguni-Jones, Luna & Asato, 2007). Participants completed the Tanner Maturation Scale (Marshall & Tanner, 1970) and rated how similar their bodies were to photographs showing progressive pubertal development. Early maturers were the youngest 25% of participants at each Tanner stage, late maturers were the oldest 25% of participants at each Tanner stage and the 'on time' group were the remaining participants. Early maturing females showed lower response inhibition performance on the Stroop Task and an oculomotor response inhibition task compared to on time and late maturers. In males, there was no relationship between pubertal development and inhibition. There were no pubertal group differences on the spatial planning task, indicating pubertal development does not affect this executive function.

Research indicates that the phase of the menstrual cycle can affect executive function task performance. Maki, Rich and Rosenbaum (2002) assessed females aged 18 to 28 years in their early follicular (lowest oestrogen and progesterone) and midluteal phases (high oestrogen and progesterone). A Rhyme Fluency Task required participants to generate words that rhymed with two difficult cue words (e.g. curls) and a cue word with a large number of possible rhymes (e.g. name). The Phonemic Fluency Test required participants to generate words beginning with the letters C and L and category fluency assessed with the generation of words belonging to a semantic category (e.g. vegetables). For the Mental Rotations Test (Vandenberg & Kuse, 1978) participants selected two out of four 3-D drawings that were mental rotations of an original image.

The Grooved Pegboard Test (Reitan & Davison, 1974) assessed fine motor performance and dexterity. Participants completed the Positive and Negative Affect Scale (Watson, Clark & Tellegen, 1988) to assess possible intra-individual differences in mood. Participants generated significantly more rhymes and performed significantly faster on the Grooved Pegboard Test during midluteal relative to follicular phases. In contrast, mental rotation was significantly better during the follicular phase compared to the luteal phase. Oestrogen positively correlated with scores on the Phonological and Category Fluency Tasks and was negatively related to performance on the Mental Rotations Task. Positive and Negative Affect did not correlate with task scores and did not differ significantly between follicular and midluteal phases. This indicates that menstrual cycle differences in strategy generation, mental rotation and fine motor skills are likely due to oestrogens' effect on the hippocampus and parietal lobes, not due to hormonal effects on mood (Maki et al., 2002).

In a social cognition study, Burnett, Thompson, Bird and Blakemore (2011) found that performance on an emotion-understanding task related to pubertal development instead of age. Participants aged 9 to 16 years were assigned to early, mid or post puberty groups based on their scores on a questionnaire adapted from Carskadon and Acebo's (1993) Rating Scale for Pubertal Development (see Chapter 3). The stimuli were scenarios designed to elicit social emotions requiring representation of mental states (guilt or embarrassment) or basic emotions (fear or anger). Participants rated on visual analogue scales to what extent they would experience guilt, embarrassment, fear or anger in the scenarios. The authors reported an increase in mixed emotion reporting between early and post puberty groups for only social emotion scenarios. However, Burnett et al. (2011) noted that their method for assessing the experienced emotions has not been previously used and requires validation. Moreover it is not clear how mixed emotion reporting relates to more traditional social cognition tasks e.g. the Reading the Mind in the Eyes Test (Baron-Cohen et al., 2001). Contrasting results show that pubertal development measured with the Tanner questionnaire (Tanner & Davies, 1985) in 7-13 and 14-18 year olds was not correlated with performance on an emotion recognition task (Thomas, De Bellis, Graham & LaBar, 2007). Furthermore, Magar, Phillips & Hosie (2010) reported stage of pubertal development in a group of 11 to 17 year olds explained no more variance beyond age on executive function measures of inhibition, updating and switching.

To summarise, pubertal development is often not assessed in adolescent research (Blakemore, 2008a). Pubertal development has been found to affect inhibition (Olaguni-Jones, Luna & Asato, 2007) and emotion understanding assessed with a visual analogue scale (Burnett et al., 2011) although other studies reported pubertal development did not relate to emotion recognition (Thomas et al., 2007) or executive functions (Magar et al., 2010). Equivocal findings might be explained by variability in methodologies and age of participants.

2.3 Mood

Moods are coherent affective states and range in duration from minutes to hours, whereas emotions can be experienced in seconds or less (Lazarus, 1994). Behavioural studies of executive function often fail to examine participants' moods, even though research shows that small changes in mood can affect executive function (Mitchell & Phillips, 2007). Three theories that explain how mood influences executive functions are explained. Capacity limitation theories (e.g. Seibert & Ellis, 1991) suggest that both positive and negative moods utilise cognitive resources resulting in a reduction in available resources and impair executive function task performance. The "mood as information" model posits that positive mood may lead to a heuristic processing style, hindering executive function performance; negative mood leads to a realisation that there is a problem in the environment, increasing motivation resulting in more analytic processing and more effective executive function performance (Park & Banaji, 2000). An alternative theory is that positive mood could facilitate executive functioning through activation of the dopaminergic system (Ashby, Isen & Turken, 1999) although this may be restricted to when tasks are interesting (Isen, 1999).

Oaksford et al. (1996) examined the effect of mood on planning, assessed with a four-move Tower of London Task (Shallice, 1982). Participants attempted to change their mood by using images and memories and viewed a film appropriate to their group (good/happy, bad/unhappy or neutral, together with a control group). Prior to and following the film, participants completed a mood state measure from Isen et al. (1987)

with a 9-point likert scale and five items (calm-anxious, alert-unaware, positive-negative, refreshed-tired and amused-sober). This measure provides a less comprehensive mood assessment than the Positive and Negative Affect Scale (Watson, Clark & Tellegen, 1988). The positive mood group employed significantly more moves compared to the negative mood group and controls, although there was no difference in planning time between the positive mood group and controls. The negative mood group employed the same number of moves as the control group, although there was a non-significant trend with longer planning times in the negative group relative to controls. Oaksford et al. (1996) explained the greater number of moves evident in the positive mood group by depleted central executive resources leading to a less efficient plan. The negative mood group compensated for their depleted cognitive resources by taking longer to formulate their plans. However, caution must be taken in interpreting this finding due to the lack of significant group differences. The authors noted that participants may not fully engage with attempting to create a bad mood. Overall, positive mood had a greater effect on task performance, resulting in less efficient planning. These findings partially support capacity limitation theories (Seibert & Ellis, 1991) and the mood as information model (Park & Banaji, 2000), although there was no significant effect of negative mood on executive function.

In another executive function study, Phillips, Smith and Gilhooly (2002) compared a group of younger adults (aged 19 – 37 years) and older adults (53 – 80 years) who completed three trials of the 5 disk Tower of London planning task (Ward & Allport, 1997) following positive, neutral or negative mood induction procedures consisting of a film clip and music. Participants completed the Positive Affect and Negative Affect Scale (Watson, Clark & Tellegen, 1988) on arrival, following the film clip and five minutes of music and after the Tower of London task. Only the younger group findings are reported here because their age is more similar to late adolescence / early adulthood. The younger group in a positive mood solved fewer trials in the minimum number of moves than the negative mood group, whilst there were no differences between mood conditions in the number of extra moves. The younger positive mood group spent less time planning compared to the neutral mood group. These findings indicate that planning is impaired by positive mood but is unaffected by negative mood in young adults. The finding that positive mood impairs performance on Tower tasks (Phillips, Smith & Gilhooly, 2002; Oaksford et al., 1996) supports a mood as information model. A possible explanation is that happy people are less motivated to employ a systematic approach unless the task directly affects their wellbeing or is interesting (Bodenhauser, Kramer & Susser, 1994).

Phillips, Bull, Adams and Fraser (2002) examined the effects of happy or neutral mood induction on performance on a Letter Fluency Task, with participants (mean age 29 years) producing as many words as possible beginning with "A" in one minute. Mood ratings taken after task completion significantly correlated with number of words produced, with a more positive mood associated with the production of more words. In contrast to planning tasks, there is evidence that positive mood may facilitate Verbal Fluency Task performance. This finding conflicts with the mood as information model (Park & Banaji, 2000) and capacity limitation theory (Seibert & Ellis, 1991) because a broad search space is needed for successful performance on Letter Fluency Tasks.

Mood also affects social cognition; for example, Converse, Lin, Keysar and Epley (2008) induced happy or sad moods with music and then participants, who were university students, completed a modified false belief task. Participants induced to feel happy were less likely to use their Theory of Mind, instead being influenced more by their own private knowledge, than participants in the sad condition. Participants also completed the Director Perspective Taking Task, requiring the consideration of a director's viewpoint when following instructions. Converse et al. (2008) found participants in a happy condition elicited more egocentric behaviour than the sad condition, shown by a participant moving an object visible only to them and not the director. In summary, the groups induced to feel sad were more likely to use knowledge about others when making mental state inferences.

To overcome the problem of short-lived emotion induction lasting for less than 10 minutes, Chepenik, Cornew and Farah (2007) administered an initial emotion induction followed by two further inductions throughout the testing sessions. Using a within participants design, a sad emotion was elicited by thinking of the death of a loved one and a neutral emotion involved thinking about food shopping. The task battery was comprised of an emotion recognition task (the Ekman static photographs portraying anger, afraid, neutral, happy and sad faces), the Stroop, Go/No-Go, digit span and object 2-back tasks. Participants in the neutral condition scored significantly higher in comparison to the sad condition on the emotion recognition task, while there were no group differences on the other tasks. A possible explanation is that the mood induction procedure did not create moods with enough strength to affect executive function or perhaps a broader selection of executive function tasks should have been included (Chepenik, Cornew & Farah, 2007). The finding of the sad participants scoring significantly lower than the neutral condition is inconsistent with the above study by Converse et al. (2008) when a sad mood was associated with higher scores. A possible explanation is the different tasks employed; the Director Perspective Taking task required visuo-spatial skills, whereas the social cognition task in the study by Chepenik et al. (2007) involved mental state attribution.

To summarise, participants in a positive mood made more moves on the Tower of London planning task relative to participants in a negative mood (Oaksford et al., 1996; Phillips et al., 2002). In tasks that are novel, such as innovative word searching in Verbal Fluency Tasks, motivation causes positive mood to improve performance (Phillips, Bull, Adams & Fraser, 2002). Normal fluctuations in negative mood do not greatly affect executive function, but this may be due to negative mood inductions being mild and experienced for a short time (Mitchell & Phillips, 2007). A suggestion for future research is to examine the effects of mood on inhibition, because few studies have focused on this (Mitchell & Phillips, 2007). With regard to social cognition, Converse et al. (2008) found sad mood related to better performance on the Director Perspective Taking Task whereas Chepenik et al. (2007) reported sad mood was associated with lower emotion recognition relative to neutral mood.

2.4 Drug use and impact on brain maturation and cognitive function

2.4.1 Alcohol use in late adolescence / early adulthood

In 2013, alcohol statistics indicated 52% of 16-24 year old males and 50% of 16-24 year old females reported drinking alcohol in the previous week (Office for National Statistics, 2013). In the 16-24 year old age range, 22% of males reported drinking more than eight units of alcohol on one day in the previous week and 19% of females reported drinking more than six units on one day in the previous week. These statistics indicate that alcohol use is prevalent in late adolescence and early adulthood.

In a DTI study assessing the effects of binge drinking on white matter, Mcqueeny et al. (2009) compared scans of 16 to 19 year olds who were binge drinkers (at least 4 drinks for females and at least 5 drinks for males in one sitting during 3 months prior to participation) to controls matched on age, gender, education, ethnicity and Verbal IQ. Binge drinkers had significantly lower FA, an index of white matter coherence, in 18 white matter pathways in frontal, cerebellar, temporal and parietal regions compared to the control group. A study reviewed in Chapter 1 showed that greater FA is associated with more efficient strategy generation (Bava et al., 2010). Therefore, reduced white matter coherence in binge drinkers relative to controls is likely to impact on executive function.

Parada et al. (2012) reported a study investigating the effects of binge drinking in early adulthood. The authors divided first year university students (mean age = 18 years 9 months) into binge drinkers and non-binge drinkers according to scores on the Alcohol Use Disorders Identification Test (Varela, Brana, Real & Rial, 2005). Binge drinkers consumed six or more alcoholic drinks on one occasion, consuming three or more drinks per hour, one or more times per month. Non-binge drinkers never consumed six or more alcoholic drinks on no more than one occasion per month, drinking two or fewer drinks per hour. Participants completed the Spanish version of the Letter Fluency Task (Fortuny, Hermiosillo-Romo, Heaton & Pardee, 1999), a measure of response generation requiring participants to say as many words as possible in one minute beginning with the letters P, M and R. The Zoo Map subtest of the Behavioural Assessment of Dysexecutive Syndrome (Wilson et al., 1996), a measure of planning, required participants to follow a set of instructions and rules to plan a route around a zoo. The Backward Digit Span Test (Wechsler, 1999), an assessment of verbal working memory, required participants to listen to a sequence of numbers and recall them in reverse order. The Self-ordered Pointing Test (Petrides & Milner, 1982) assessed planning and self-monitoring. In this task, participants pointed to a design on each page without repeating their previous responses in a booklet with abstract designs. Participants completed the Wisconsin Card Sorting Test 3 (Robinson, Kester, Saykin, Kaplan & Gur, 1991), a short version of the WCST with 64 cards, assessing concept formation. Binge drinkers scored significantly lower on the backward digit span test, a measure of verbal working memory, and made more perseverative errors on the Self-ordered Pointing Test, a measure of self-monitoring, compared to non-binge drinkers. No group differences were evident on strategy generation, planning or concept formation, assessed with the Letter Fluency Task, Zoo Map and WCST. Parada et al. (2012) summarised the results by suggesting poorer performance of binge drinkers relative to non-binge drinkers was evident on executive function tasks associated with the dorsolateral prefrontal networks. However, no group differences were evident on the Wisconsin Card Sorting Test or Letter Fluency and these tasks are associated with dorsolateral networks (Wang, Kakigi & Hoshiyama, 2001; Baldo, Schwartz, Wilkins & Dronkers, 2006). Parada et al. (2012) suggested future research should employ a longitudinal design because the cross sectional design does not elucidate the directional relationship between executive function and alcohol use.

Other studies have investigated how alcohol affects social cognition. However, social cognition and alcohol studies presently involve older participants beyond late adolescence and early adulthood. One study is reviewed here because the demographic data at the start of this section show that alcohol use is prevalent in late adolescence and early adulthood and this could affect social cognition.

Uekermann et al. (2005) investigated facial and prosodic emotion recognition in alcoholic and control groups (mean age = 42 years) who were similar with regards to age, education level and estimated IQ (alcohol group IQ = 110 and control group = 113). Participants completed the Tubingen Affect Battery, a German version of the Florida Affect Battery Revised (Blonder et al., 1991) comprised of three sections. The facial emotion recognition tasks show anger, happiness, fear, sadness and neutral emotions and include the naming of emotions and matching a stimulus photograph with a reference photograph. The second section assesses prosodic understanding of basic emotions and the tasks involve naming emotions and deciding whether the semantic content is congruent or incongruent with prosody. Participants were also required to match prosody with the correct facial expression and vice versa. The authors hypothesised that the alcohol group would show deficits in both visual and prosodic emotion processing. These findings partly support the hypothesis because the alcohol group only demonstrated impairment in processing prosodic information and not for facial affect processing. The authors proposed that the alcohol group scored lower when naming incongruent semantic prosody compared with the controls because successful completion of this task requires inhibition of semantic information. Uekermann et al. (2005) argued that inhibition is impaired in alcoholics, although Guillot et al. (2010) found no impairment of inhibition in alcoholics compared to controls.

To summarise, both neuroimaging and behavioural data have demonstrated impaired functioning in alcoholics relative to healthy controls. McQueeny et al. (2009) reported lower FA, an index of white matter coherence, in frontal, cerebellar, temporal and parietal regions in binge drinkers relative to controls. Parada et al. (2012) found that binge drinkers made more perseverative errors on a measure of planning and self-monitoring compared to non-binge drinkers. There is also evidence of impaired social cognition in alcoholics. Uekermann et al. (2005) found a deficit in emotion processing only for prosodic information not facial emotion recognition in alcoholics relative to controls. While some studies included older age groups, they can be related to the present study because alcohol use is common in late adolescence and early adulthood.

2.4.2 Cannabis use in late adolescence / early adulthood

The 2011/2012 British Crime Survey stated that 15.7% of 16 to 24 year olds reported using cannabis in the previous year (Home Office, 2012). The most frequently reported age of first cannabis use was 16 years. These statistics illustrate that cannabis use is prevalent in late adolescence and early adulthood.

Heavy cannabis use in adolescence may detrimentally interfere with brain maturation. A PET study showed frontal networks contain high densities of cannabinoid CB1 receptors (Burns et al., 2007). Drugs affect chemical neuromodulation including dopaminergic and serotonergic transmitters in frontal networks (Robbins, 2000); this is notable because frontal networks are associated with executive function (Stuss & Alexander, 2007) and social cognition (Frith & Frith, 2006). Pattij, Wiskerke and Scoffelmeer (2008) proposed that cannabis use in adolescence leads to vulnerability of lasting deficits in executive function because cannabinoid receptors show increased sensitivity and brain maturation is protracted, continuing into late adolescence and early adulthood. In a DTI study, Ashtari et al. (2009) found reduced FA and increased Radial Diffusivity in fronto-temporal connections in adolescents aged between 17 and 21 years with heavy cannabis use compared to controls, suggesting heavy cannabis use leads to myelin deficiencies. However, a limitation of this study is that results could reflect a combination of alcohol and cannabis use because alcohol intake was not controlled for, despite five participants in the drug group previously meeting DSM IV criteria (APA, 1994) for alcohol abuse (Ashtari et al., 2009).

In an MRI study, Lopez-Larson et al. (2011) reported behavioural data showing the effects of cannabis use on neuropsychological task performance with 18 heavy cannabis users, defined as using the drug at least 100 times in the previous year, and 18 non-cannabis users aged 16 to 19 years. Participants completed a Verbal Fluency Task, although it is not apparent which version of the task was administered. Of interest, the cannabis users scored significantly higher on the Verbal Fluency Task compared to non-users, although McHale & Hunt (2008) found the opposite (see below). The cannabis users showed decreased cortical thickness in the bilateral superior frontal cortex and right caudal middle frontal area in comparison to non-users. Lopez-Larson et al. (2011) noted that the reduction in grey matter evident in cannabis users might be due to grey matter not reaching peak thickness in cannabis users, or perhaps the toxicity of cannabis leading to grey matter loss. Cannabis users also showed increased cortical thickness in bilateral lingual, right superior temporal, right inferior parietal and left paracentral regions compared with non-users; the authors proposed this was due to a delay in pruning. Some regions with increased cortical thickness, including the inferior parietal and lingual regions, are associated with performance on Verbal Fluency Tasks (Gauthier, Duyme, Zanca & Capron, 2009) and so it is possible that greater thickness in the cannabis users was an advantage on this task. Furthermore, groups were not matched on IQ at baseline and IQ was not assessed in this study so a possible explanation is that the higher letter fluency in cannabis users was due to higher IQ compared to the control group.

McHale and Hunt (2008) compared performance of recent cannabis users, abstinent cannabis users and a control group, who had never used cannabis, and reported contrasting results. University students completed a phonemic Verbal Fluency Task requiring participants to write down words beginning with "C" in one minute. Inclusion criteria for recent cannabis users were that they had used cannabis during the previous week, but not on the day prior to testing, whilst abstinent cannabis users had smoked cannabis in the last four weeks, but not in the week before testing. Self-report data from the recent cannabis users showed that they smoked cannabis five to six times a week and the abstinent group reported using cannabis twice a week, with both groups smoking an average of two joints per session. The control group scored significantly higher on the Verbal Fluency Task compared to both of the cannabis user groups and the abstinent cannabis user group scored significantly higher than the recent cannabis users. The authors suggested future research should employ a longitudinal design to elucidate whether longer periods of abstinence result in similar executive function performance to non-users, although age cannabis use started and age at test are likely to be crucial variables. The extent to which descriptive statistics for the Verbal Fluency Task performance can be compared to other studies may be limited by different task formats. In the study by McHale and Hunt (2008), participants wrote down their responses to the letter C, whereas other versions of the Verbal Fluency Task use the letters F, A and S, with the examiner recording the items instead of the participant (e.g. D-KEFS Letter Fluency; Delis et al., 2001). The task format may have contributed to group differences because cannabis use is associated with impaired motor control (Ramaekers et al., 2006) possibly resulting in cannabis users writing at a slower rate.

Pope et al. (2003) investigated the effects of commencing cannabis use before age 17 and after. Participants ranging in age from 30 to 35 years formed three groups: current heavy users (smoke daily, used at least 5,000 times), former heavy smokers (used at least 5,000 times but less than 12 times in previous 3 months) and comparison group (used cannabis less than 50 times and no more than once during the previous year). All participants remained abstinent for 28 days prior to completing the study and this was monitored with urine samples. Cannabis users who started using the drug before age 17 attained a significantly lower Verbal IQ (WAIS; Wechsler, 1981) than both users who started after age 17 and the control group (Pope et al., 2003). The early cannabis onset group also scored significantly lower than the control group on the number of semantic categories given on the Controlled Oral Word Association Test, or FAS Task (Lezak, 1995) measure of strategy generation. Pope et al. proposed three explanations for these results; it is possible that early onset cannabis users had a lower innate IQ before they began using cannabis. Alternatively, differences in motivation to complete education (32% of early onset users, 60% of late onset users and 82% of controls had graduated from college) could affect Verbal IQ scores because assessment was with a vocabulary test and vocabulary skills in early onset users may not be fully developed. Another suggestion is that early onset cannabis use is toxic and leads to potentially irreversible deficits (Pope et al., 2003). A limitation of this study is that the authors did not explain why the age of 17 was selected to form the early onset and late onset groups, when the brain continues to mature beyond this age into late adolescence and early adulthood.

There is a lack of research into the effects of cannabis on social cognition in contrast to the many studies into executive function performance of cannabis users. Platt, Kamboj, Morgan and Curran (2010) developed the Dynamic Emotional Expression Recognition Task, showing dynamic stimuli of neutral facial expressions changing to happiness, sadness and anger. Participants were required to identify the emerging emotions as quickly and accurately as possible. The sample consisted of frequent cannabis users, who used the drug at least 15 days per month and had used it over 50 times altogether, and non-cannabis users, who had a lifetime use of less than 10 times. Participants completed the Dynamic Emotional Expression Recognition Task and the Reading the Mind in the Eyes Task (Baron-Cohen et al., 2001). There were no significant group differences on the Eyes Task. Accuracy of emotion recognition for the dynamic emotions was also similar for both the cannabis and non-users; however, the cannabis group was significantly slower at recognising emotions in the dynamic clips compared to non-users. Platt et al. (2010) recommended that future research should examine the remaining basic emotions in different populations of cannabis users including infrequent users and previous chronic users.

To summarise, there is evidence of atypical white matter brain maturation in fronto-temporal connections in cannabis users in comparison to controls (Ashtari et al., 2009). Cannabis users have shown deficits on executive function tasks, for example, Letter

Fluency (McHale & Hunt, 2008), although Lopez-Larson et al. (2011) reported higher performance in cannabis users compared to non-users on a Letter Fluency Task, a measure of strategy generation. Cannabis users and non-users have performed similarly on the Eyes task and the Dynamic Emotional Expression Recognition Task, although the cannabis users took significantly longer than the control group on the latter task (Platt et al., 2010).

2.4.3 Ecstasy use in late adolescence / early adulthood

Ecstasy (3, 4-methylenedioxymethamphetamine, MDMA) is the second most commonly used illegal drug after cannabis in the general population, particularly in adolescence and early adulthood (De Win et al., 2008). The 2011/2012 British Crime Survey reported that 3.3% of 16 to 24 year olds had used ecstasy in the previous year and the most frequently reported age of first use was at age 18 (Home Office, 2012).

De Win et al. (2008) recruited a sample of young adults who had never used ecstasy but were at a relatively high risk of starting to use the drug assessed by an intention to probably or certainly use ecstasy for the first time in the near future and/or having one or more friends who currently use ecstasy. Diffusion Tensor Imaging at 12 and 36 months following baseline showed new ecstasy users had reduced FA in frontoparietal white matter tracts, whereas non-users had an increase in FA, suggesting that ecstasy prevents white matter maturation in frontoparietal tracts (De Win et al., 2008). This could affect executive (Collette et al., 2006) and social functions (Carrington & Bailey, 2009). The authors concluded that a low to moderate dose of ecstasy (1 to 80 tablets) affects brain structure.

Behavioural studies investigating the effects of ecstasy use on executive function ability are inconsistent. De Sola Llopis et al. (2008) compared ecstasy and cannabis polydrug users (mean age = 23.6 years), cannabis users (mean age = 22 years) and non-users (mean age = 22 years) on the Tower of London Task (Shallice, 1982), a measure of planning, and a semantic Verbal Fluency Task requiring the generation of words in the category of animals. Participants were asked to abstain for 72 hours before testing with urine and hair samples used to screen for drugs. No group differences were evident for the total number of moves or first move time on the Tower of London Task. Lifetime ecstasy use positively correlated with number of moves on the Tower of London Task, indicating that greater ecstasy use was associated with a less efficient planning strategy than lower ecstasy use. The ecstasy group scored significantly lower compared to controls on the semantic Verbal Fluency Task. A notable part of this study is the longitudinal design; at a 2-year follow up, both the ecstasy and control groups showed improved performance on the Verbal Fluency Task, although scores for the ecstasy group remained significantly lower than the control group. This indicates development of functions underpinning performance on the Verbal Fluency Task in early adulthood. A confounding variable is the level of cannabis use between groups; the ecstasy and cannabis polydrug group used on average 4,368 joints over their lifetime, compared to the cannabis groups who smoked on average 1,670 joints in their lifetime.

In another study, Piechatzek et al. (2009) administered executive function tasks to participants in four groups with a mean age of 25 years: those who had used ecstasy, individuals with a history of more than five uses of cannabis and no ecstasy use, alcohol use (minimum of a single occasion of 7 drinks for 6 or more months with no more than 5 uses of cannabis and no ecstasy use) and participants who did not excessively consume alcohol or use drugs. The task battery included a Verbal Fluency Task and a Non-Verbal Fluency Task, the Intra/extra Dimensional Shift Task (Owen et al., 1990), an assessment of set shifting and the Stockings of Cambridge, a measure of planning similar to the Tower of London, from the CANTAB (Cambridge Cognition, 2004). Higher error rates in shifting on the Intra/extra Dimensional Shift Task were associated with more prolific cannabis and ecstasy use. There was no relationship between ecstasy use and planning ability measured with the Stockings of Cambridge test or letter and semantic verbal fluency. A possible explanation is that the average dose of ecstasy was too low to cause impairment in executive function (Piechatzek et al., 2009). The authors acknowledged that their data analyses were limited to correlations and suggested future research should employ prospective longitudinal studies.

Other studies have assessed the effects of ecstasy on social cognition. Yip and Lee (2006) assessed abstinent ecstasy users and non users with visual static and prosodic emotion recognition tasks composed of an identification section (saying which emotion a stimulus portrays) and discrimination section (selecting which of two stimuli show a particular emotion). The stimuli portrayed basic emotions of happiness, sadness, anger, surprise, disgust and fear. Abstinent ecstasy users scored significantly lower than non-users on overall facial and prosodic emotion recognition and identification with specific impairments for sadness and disgust. Participants completed category Verbal Fluency Tests with categories of fruit and vegetables, animals and instruments. The Ruff Figural Fluency Test (Ruff, 1996) assessed non-verbal fluency, with participants required to generate unique designs on different configurations of dots. Abstinent ecstasy users scored significantly lower than non-users on these executive function tasks. Time since ecstasy was last taken negatively predicted facial and prosodic emotion recognition and disgust recognition. However, the length of abstinence was not clear because there were no descriptive statistics reported for this variable or participants' age. Another limitation noted by Yip and Lee (2006), applicable to all research on the cognitive effects of ecstasy, is that ecstasy users often take other drugs and ecstasy tablets also contain other substances, with an estimation of tablets containing around 50% MDMA (Cheng, Poon & Chan, 2003). A notable part of this study is that the authors conducted regression analyses to identify whether executive functions significantly predicted social cognition in abstinent ecstasy users. Scores on the animal Verbal Fluency Test measuring strategy generation significantly predicted disgust recognition. Performance on the Figural Fluency Test measuring non-verbal fluency significantly predicted overall facial and prosodic emotion identification and sadness and disgust recognition. These findings suggest that executive functions predict social cognition in these groups, although it is of interest whether other executive functions, beside fluency measures, predict performance on a wider range of social cognition tasks including more complex emotions and dynamic stimuli.

Overall, greater ecstasy use is associated with impaired planning and strategy generation (De Sola Llopis et al., 2008) although other studies have found no planning deficits in ecstasy users compared to non-users (Piechatzek et al., 2009) possibly due to a lower dose of ecstasy. Yip and Lee (2006) found ecstasy users were impaired in overall facial and prosodic emotion recognition and identification, specifically sadness and disgust, compared to non-users. Findings from ecstasy studies are much more clear-cut than cannabis studies indicating that ecstasy use is possibly more detrimental to cognitive functioning overall than cannabis use.

2.5 Brain maturation and atypical development of social cognition and executive function in late adolescence and early adulthood

The combination of rapid rates of brain maturation, psychosocial, hormonal and environmental factors confer vulnerability to mental illness in late adolescence and early adulthood (Paus, Keshevan & Giedd, 2008). This section outlines prevalence of mental illness in late adolescence and early adulthood. More recent statistics that do not include a breakdown of prevalence in late adolescence and early adulthood are omitted. The review includes an evaluation of the exclusion criteria of head injury and autism spectrum disorders, followed by depression, anxiety and obsessive-compulsive disorder.

2.5.1 Head Injury

Head Injuries (HI) are common in late adolescence and early adulthood. Butterworth, Anstey, Jorm and Rodgers (2004) collected self-report HI statistics, defined as at least 15 minutes unconscious, from 7,488 randomly selected Australian residents from cohorts in their 20's, 40's and 60's. Lifetime prevalence of HI and report of multiple HI was highest in the youngest age group. It is plausible that the youngest cohort may be more likely to experience HI through sport or accidents and are more likely to survive a HI compared to older cohorts (Butterworth et al., 2004).

Research has shown that HI affects both executive functions and social cognition. For example, Jacobs, Harvey and Anderson (2011) assessed executive functions in 79 HI participants aged 7 to 16 years including traumatic brain injuries, strokes and tumours. This study is included here because adult HI studies often have broad age ranges with participants much older than adolescence, whereas the age group in this study is nearer to late adolescence. Three groups of HI participants including frontal patients with damage only to prefrontal regions, extra-frontal patients with damage to regions other than frontal areas, and a generalised group with damage to frontal and posterior regions were compared to an age-matched control group on executive function measures. Participants completed the Contingency Naming Test (Taylor et al., 1987), an assessment of attentional control, self-monitoring, response inhibition and cognitive flexibility. The stimuli consisted of three rows of coloured shapes inside another shape. Participants were required to name the colour of the shapes and then name the outside shape. A rule or contingency was introduced specifying colour naming if the inside and outside shapes were congruent and naming the outside shape when incongruent. A further rule required this to be reversed on presentation of an arrow. In addition, participants completed the Tower of London (Shallice, 1982) measure of planning and Controlled Oral Word Association Test (COWAT; Benton & Hamsher, 1989) measure of letter fluency.

Frontal and generalised HI groups made significantly more rule breaks on the Tower of London and more errors on the COWAT Letter Fluency Task than the control group. In comparison to controls, all HI groups generated significantly fewer words on the Letter Fluency Task, a measure of strategy generation, made more failed attempts on the Tower of London planning task and performed worse on the Contingency Naming Test requiring attentional control, self-monitoring, response inhibition and cognitive flexibility. A strength of this study is that the effect of damage to different regions on executive functions was assessed and the finding of deficits, irrespective of pathology region, provides support to the notion that the integrity of the whole brain is crucial to executive function (Jacobs, Harvey & Anderson, 2011). However, confounding factors of age at HI and time since injury could not be examined due to the sample size (Jacobs, Harvey & Anderson, 2011).

In another study, Muller et al. (2010) compared 15 participants (mean age 32 years) who had sustained a HI with a control group matched for age, gender and years of education on social cognition tasks. Despite the participants being marginally older than late adolescence / early adulthood, this study is included because a wide range of social cognition and executive functions were assessed. The interval between injury and testing was wide and ranged from nine to 443 months. Participants completed the following social cognition tasks: the Faux Pas Test (Stone et al., 1998) requiring detection of when a character made a faux pas, first and second order false belief stories (Rowe et al., 2001), an assessment of emotion recognition (Reading the Mind in the Eyes Test; Baron-Cohen et al., 2001) and a self-report measure of empathy

(Interpersonal Reactivity Index; Davis, 1983). The HI group scored significantly lower compared to the control group on the second order false belief tasks, Faux Pas Test and the Eyes Test.

Participants also completed executive function tasks including the Trail Making Test (Reitan & Walfson, 1993), assessing mental flexibility, Verbal Fluency Test (Cardebat et al., 1990), a measure of strategy generation, and the Stroop Test (Bruyer et al., 1995), an assessment of inhibition. The majority of correlations between social cognition and executive function task performance were not significant, with the authors noting that social cognition and executive functions dissociate. This notion is supported by imaging data showing separate neural pathways are recruited in social cognition (Carrington & Bailey, 2009) and executive function tasks (Collette et al., 2006). Muller et al. (2010) commented that future research with a larger sample size would provide results that are more conclusive. The HI group scored lower than standard scores on the executive function tasks; however, Muller et al. (2010) did not note whether these differences were significant or if there were any significant differences between the HI and control group on measures of executive function. A further limitation is that there was no assessment of IQ in the control group so groups could not be compared for this variable. In addition, groups were not matched for IQ, which is common in other HI studies. The HI group had sustained injuries to a variety of brain regions including mostly frontal, sometimes in addition to other regions, and so direct association cannot be made between lesion site and functional impairment.

To summarise, participants with HI show impaired strategy generation and planning relative to a control group (Jacobs, Harvey & Anderson, 2011). Furthermore, deficits are evident on social cognition tasks requiring faux pas understanding, visual emotion recognition and false belief attribution (Muller et al., 2010). Findings from these studies support the idea that executive functions require whole brain integrity and that executive function and social cognition are dissociable. They also indicate a special role of frontal networks to executive function and social cognition. However, confounding variables including lack of IQ assessment, differing age at injury and time since injury should be noted.

2.5.2 Autism Spectrum Disorders

Brugha et al. (2009) reported a prevalence of 1.1% for Autistic Spectrum Disorders (ASD) in 16 to 44 year olds diagnosed by a score of greater than 10 on the Autism Diagnostic Observation Schedule (Lord et al., 2002). However, this statistic is based on the Adult Psychiatric Morbidity Survey of adults living in private households and could underestimate the prevalence of ASD because adults with severe impairment may not participate in the survey. In DSM IV (APA, 2000) ASD could be classified as Autistic Disorder, Asperger's Disorder, Childhood Disintegrative Disorder or Pervasive Developmental Disorder Not Otherwise Specified. The diagnostic criteria for Asperger's Syndrome, at the high-functioning end of the autistic spectrum, are based on impairments in social interaction and repetitive stereotyped behavior or interest (APA, 2000). Impairments in social interaction include a pronounced deficit in non-verbal behaviour, e.g. eye contact and facial expressions and an inability to show emotional or social reciprocity, e.g. impaired or inappropriate responses to others' emotions (APA, 2000). DSM V (APA, 2013) combines all ASD into one category. Wing, Gould and Gillberg (2011) criticised the diagnostic criteria for ASD in DSM V because symptoms must be present from early childhood and in some cases patients may not have anyone who can inform a clinician about childhood behaviour. Mayes, Black and Tierney (2013) found that the DSM V criteria did not identify 25% of children previously diagnosed with ASD, with the authors questioning whether these children will lose support services. ASD are associated with deficits in social cognition (Kaland et al., 2002) and some executive functions (Robinson, Goddard, Dritschel, Wisley & Howlin, 2009).

Robinson et al. (2009) compared 54 participants diagnosed with Asperger's Syndrome or High Functioning Autism to 54 control participants aged 8 to 17 years matched according to age, gender, receptive verbal ability (British Picture Vocabulary Scale; Dunn, Dunn, Whetton & Burley, 1997) and IQ (Wechsler Abbreviated Scale of Intelligence; Wechsler, 1999) in an executive function study. Participants completed a semantic Verbal Fluency Task requiring naming animals, fruit, vegetables and clothes and the Junior version of the Hayling Test (Shallice et al., 2002), a measure of inhibition. Computerised versions of the Tower of London planning test (Culbertson & Zillmer, 2005), Wisconsin Card Sorting Test (WCST; Heaton, 2003) and Stroop Test

(Stroop, 1935) were administered to reduce social demands. The ASD group made significantly more moves to complete towers and made more rule violations on the Tower of London planning Task relative to the control group. The ASD group correctly inhibited significantly fewer items on incongruent trials of the Stroop Test and made more perseverative errors on the Verbal Fluency Test relative to the control participants. There were no significant group differences on the WCST or Hayling Test, although the ASD group showed a trend towards longer response times and incorrect responses on the Hayling Test. Cognitive impairment confounded previous executive function studies (Hill, 2004) but a strength of the Robinson et al. (2009) study is that all participants had IQ in the normal range.

Research with ASD participants has found inconsistent results on social cognition tasks possibly due to different task formats. Kaland et al. (2002) compared performance on a Theory of Mind stories task between ASD and control participants aged 10 to 20 years. Verbal IQ from the Wechsler Intelligence Scale for Children (Wechsler, 1998) was entered as a covariate because the ASD group scored significantly higher than control participants on this variable. The ASD group scored significantly lower on the mental inference stories questions, taking longer to complete the task and showing a tendency to give answers based on physical causation instead of mental states relative to the control group.

Beeger, Malle, Nieuwland and Keysar (2010) reported conflicting findings on the Director Perspective Taking Task, showing ASD participants performed comparably to a control group. There were no group differences for errors or reaction times in participants with a mean age of 16 years. However, the authors commented that these particular findings do not generalise to other social situations and suggested that participants may not have used their Theory of Mind when completing the task, instead possibly employing an alternative strategy and ignoring any objects with a shaded background.

To summarise, behavioural social cognition data is inconsistent, with some studies reporting deficits in ASD (e.g. Kaland et al., 2002) and others finding no impairment (Beeger et al., 2010). An explanation for the conflicting findings is different task demands required to complete the Stories Task compared to the Director Perspective Taking Task. Impairments in planning, inhibition and self monitoring relative to controls can be attributed to autistic symptomatology rather than deficits in IQ or verbal ability (Robinson et al., 2009).

2.5.3 Depression

In a longitudinal study, Franko et al. (2005) reported that 20.3% of 17 year olds and 10.8% of 18 year olds scored above 24 on the Centre for Epidemiological Studies Depression Scale (Radloff, 1977) indicating a diagnosis of depression. The National Comorbidity Survey (Kessler & Walters, 1998) reported a similar epidemiological pattern with 14.3% of 17-18 year olds and 8.8% of 19-20 year olds having a minor lifetime depression diagnosis assessed by the Composite International Diagnostic Interview.

Favre et al. (2009) compared participants with major depression and a control group aged 8 to 17 on set shifting (WCST; Grant & Berg, 1948), strategy generation (Controlled Oral Word Association Test; Benton & Hamsher, 1976), visual scanning, sequencing and motor speed (Trail Making Test; Reitan & Wolfson, 1985) and inhibition (Stroop test; Stroop, 1935). The depression group made slightly more errors on section B of the Trail Making Test requiring the participant to connect alternating numbers and then letters (e.g. 1, A, 2, B etc), although there were no significant group differences for other executive function tasks. These findings were inconsistent with the authors' hypothesis of executive function deficits in major depression. Favre et al. (2009) suggested that their sample of outpatients had less severe depression compared to previous studies including inpatients and bipolar or psychotic depression. The sample had a broad age range spanning late childhood and adolescence when it is likely participants would live with their parents and be less autonomous compared to early adulthood.

In contrast, Uekermann et al. (2008) reported a significant difference in the number of words produced on a semantic Verbal Fluency Task, an assessment of strategy generation, requiring participants to give as many surnames as possible. Depressed participants, selected from inpatients at a hospital, produced significantly fewer words than the control group (mean age = 37 years). Participants also completed a measure of set shifting, the Trail Making Test (Reitan, 1992), requiring participants to connect numbers in ascending order and then alternate between numbers and letters. In a social cognition stories task, participants chose one of four endings that completed the passage to form a joke as a measure of the cognitive component of humour processing. They also rated how funny and logical the four endings were forming an affective index of humour processing. Participants with depression were impaired on the affective and cognitive aspects of humour processing. They completed significantly fewer jokes correctly, instead giving more incorrect slapstick responses, and rated the correct and slapstick responses as being less funny than the control group. Set shifting and strategy generation significantly predicted the number of correct punchlines, providing further support of an association between executive functions and social cognition. Set shifting is relevant to the social cognition stories task because participants shift between alternative answers and meanings (Uekermann et al., 2008). Strategy generation, the ability to flexibly generate responses, might be utilised to consider the alternative responses and whether they reflect a logical answer.

Mild to moderate depression (dysphoria) in university students was found to be associated with greater visual emotion recognition accuracy relative to control participants (Harkness, Sabbagh, Jacobson, Chowdrey & Chen, 2005). Sixteen participants (*M* age = 18 years 11 months, *SD* = 0.61) with a score over 12 on the Beck Depression Inventory (Beck & Steer, 1987) formed the dysphoria group whilst the control group consisted of 27 participants who scored 12 or below on the Beck Depression Inventory. Participants completed the Reading the Mind in the Eyes Test (Baron-Cohen et al., 2001) to assess visual emotion recognition skills together with control tasks requiring participants to state the gender of actors in the Eyes Test and consider which mental state was evident from animal photographs. The dysphoric group scored significantly higher on the Eyes Test compared to control participants. Whilst the dysphoric participants took significantly longer to respond compared to non-dysphoric participants, after controlling for reaction times the higher Eyes Test scores remained showing improved accuracy was not due to longer reaction times. Limitations of the study were the small sample size, participants did not have a formal diagnosis of depression and no measure of anxiety was included (Harkness et al., 2005).

A second study with 92 participants (*M* age = 19.79, *SD* = 3.65) accounted for these limitations by assessing both depression and anxiety symptoms with the Mood and Anxiety Symptom Questionnaire (Watson & Clarke, 1991). Harkness et al. (2005) reported higher dysphoria scores were associated with higher Eyes Test scores after controlling for anxiety, but were not related to accuracy on the animal or gender control tasks. Structural Equation Modelling showed higher anxiety scores were associated with lower Eyes Test scores. A possible explanation for the main finding of dysphoric participants showing improved accuracy on a visual emotion recognition task relative to a control group is that mild to moderate depression is associated with vigilant social information processing due to a drive to understand and control the social environment (Weary & Edwards, 1994).

To summarise, previous research into the effect of depression on executive function and social cognition shows inconsistent results likely due to differences in symptom severity. Favre et al. (2009) reported no significant differences on executive function tasks assessing set shifting, strategy generation and inhibition in 8 to 17 year olds, whereas Uekermann et al. (2008) found a depressed inpatient group scored significantly lower than a control group on a semantic Verbal Fluency Task. Thus, the literature indicates that more extreme deficits in executive function are evident in depressed patients who are hospitalised. Mild to moderate depression, dysphoria, is associated with improved social cognition. Harkness et al. (2005) reported greater accuracy on a visual emotion recognition task in students with mild to moderate depression compared to a control group. In the current study, the Hospital Anxiety and Depression Scale (Zigmond & Snaith, 1983) was included to assess depression because research indicates depression may affect executive function (Uekermann et al., 2008) and social cognition (Harkness et al., 2005).

2.5.4 Anxiety

Wittchen, Nelson and Lachner (1998) assessed 14 to 24 year olds with a computer assisted personal interview of the Munich Composite Diagnostic Interview and found 16.8% had a lifetime prevalence of depression and 14.4% had a lifetime prevalence of anxiety.

Airaksinen, Larsson and Forsell (2005) reported a population-based sample investigating the effects of a range of anxiety disorders on verbal fluency, executive function, episodic memory and psychomotor speed. As previous research reported inconsistent findings, Airaksinen et al. (2005) examined whether cognitive function varied by anxiety subgroup. Demography, health and mental illness questionnaires were sent to 19,742 Swedish citizens aged 20 to 64. The total anxiety group comprised 112 participants with panic disorder with and without agoraphobia, social phobia, generalised anxiety disorder, obsessive-compulsive disorder and specific phobia. Control participants (n = 175) were matched on education. Participants completed the COWAT (Benton & Hamsher, 1989) requiring participants to generate as many words as possible with one minute each for the letters F, A and S. Other measures included an episodic memory test of 32 neutral words and the Trail Making Test measure of visual scanning, sequencing and motor speed (Reitan & Davidson, 1974). Overall, there were no group differences for the total anxiety group compared to the control group on the Letter Fluency Task, indicating that anxiety does not affect strategy generation. Participants with panic disorder and obsessive-compulsive disorder took significantly longer on the Trail Making Test section B requiring participants to join circles and alternate between numbers and letters. Participants with Generalised Anxiety Disorder showed no impairment compared to controls on memory, strategy generation and sequencing. The authors noted that participants who volunteered for the study had high education levels and income, resulting in other groups not being fully represented. Episodic memory is personal memory of past events (Eysenck & Keane, 2001) and so it is questionable whether a memory test of 32 neutral words is a valid assessment of episodic memory. In addition, the Generalised Anxiety Disorder group had a small sample size of seven participants, possibly underestimating the effects of anxiety on executive function. The Hospital Anxiety and Depression Scale (Zigmond & Snaith, 1983) assessed anxiety in the current study.

2.5.5 Obsessive compulsive disorder

A study assessing the prevalence of Obsessive Compulsive Disorder (OCD) in 17 year olds with the Diagnostic Interview Schedule found 2% received a present diagnosis of OCD (Maina, Albert, Bogetto & Ravizza, 1999). Alexander, Crutcher and Delong (1990) argued that the neural connections between the prefrontal region and superior temporal gyrus, thought to underpin social cognition, show abnormal activity in OCD.

Sayin, Oral, Utku, Baysak and Candansayar (2010) reported executive function and social cognition data from 30 participants who had previously been inpatients at a psychiatric hospital and met the DSM IV criteria for OCD matched according to age (M = 34.30, SD = 11.49), gender and education with 30 control participants. Participants completed first and second order false belief cartoon tasks and a Hinting Task comprising a passage about social interaction between people that ends with a character making an obvious hint (Corcoran, Mercer & Frith, 1995). Participants were required to answer a question about what a character really meant by what they said. E.g. Paul has to go to an interview and he's running late. While he is cleaning his shoes, he says to his wife, Jane: "I want to wear my blue shirt but it's very creased." Participants are asked "What does Paul really mean when he says this?" Success on this task requires understanding of intentions behind indirect utterances. Double bluff vignettes from Happé's (1994) Strange Stories Task, a third order Theory of Mind Test (e.g. he knows they think he will lie), were also administered. Participants with OCD scored significantly lower than the control group on the Hinting Task and the Strange Stories Task, but not on the first and second order false belief tasks. Sayin et al. (2010) concluded that basic social cognition remains intact in OCD, but performance on advanced social cognition tasks is impaired. However, the social cognition task battery was limited and the authors suggested future research should also assess IQ and executive function with the D-KEFS or Hayling and Brixton Tests (Burgess & Shallice, 1997). A self-report item was included on the demographic questionnaire to assess for OCD.

In conclusion, this chapter has reviewed literature about the effects of pubertal development, mood and the effects of alcohol, cannabis and ecstasy on executive function and social cognition. Research into executive function and social cognition in HI and ASD has also been reviewed, together with Depression, Anxiety and Obsessive Compulsive Disorder. The Self-Administered Rating Scale for Pubertal Development (Carskadon & Acebo, 1993) was included in the present study to assess pubertal development. The Positive Affect and Negative Affect Schedule (Watson, Clark & Tellegen, 1988) assessed mood and the Hospital Anxiety and Depression Scale (Zigmond & Snaith, 1983) assessed Anxiety and Depression. Participants also reported alcohol, cannabis and ecstasy use. The research reviewed in this chapter provides a rationale for selecting the final task battery, detailed in Chapter 3.

Chapter 3

Methodology review

3.1 Chapter overview

This chapter reviews a range of measures discussed in Chapters 1 and 2 assessing executive function, social cognition, IQ and pubertal development. The chosen task battery for the current study is outlined with rationale underpinning the choice of specific tasks.

3.2 Design: measuring age-related change in neuropsychological research

The present study employed a sequential design that combines cross sectional and longitudinal approaches. The majority of previous research examining social cognition (Dumontheil et al., 2010; Tonks et al., 2007) or executive function development in adolescence (Delis et al., 2001; Romine & Reynolds, 2005) has utilised a cross sectional design. Advantages of this type of design include being faster and easier to conduct compared to longitudinal designs (Moriguchi & Hiraki, 2011). Disadvantages of cross sectional designs include no data on developmental change (Kraemer, Yesavage, Taylor & Kupfer, 2000) and cohort effects, although the latter is not an issue in the present sample because of close age groups.

A sequential design has been recommended to identify how abilities improve and decline over time (De Luca et al., 2003; Romine & Reynolds, 2005; Waber et al., 2007), and allows age-related change in social cognition and executive functions to be examined both cross sectionally and longitudinally. A time frame of 12 to 16 months between testing sessions enabled any subtle linear and non-linear changes to be identified. A 12-month interval between testing sessions conforms to neuropsychological assessment procedures (Lezak, Howieson & Loring, 2004). Shores and Mears (2006) recommended a minimum of six to 12 months between assessments following mild head injury. Furthermore, practise effects due to memory are minimised after an interval of a year (Hausknecht, Halpert, Di Pado & Gerrard, 2007). Previous research outlined in Chapter 1 has used similar testing intervals. For example, in a longitudinal study of self-report empathy, Davis and Franzoi (1991) administered the Interpersonal Reactivity Index (Davis, 1980) with a 12-month interval. Bava et al. (2010) employed a 16-month interval between testing sessions and reported that greater increases in longitudinal white matter maturation were associated with higher scores on the D-KEFS Letter Fluency Test (Delis et al., 2001) in participants with a mean age of 17.8 years at Time 1. A longer interval between testing might not detect non-linear development given the rapid morphological changes occurring in late adolescence, including white matter development and grey matter decreases particularly in frontal networks (Lebel et al., 2008; Paus, 2005; Sowell et al., 2003).

Previous studies have included broad age groups in adulthood e.g. 22-62 years (Dziobek et al., 2006), 22-45 years (Heavey et al., 2000), 19-27 years (Dumontheil et al., 2010) and 19-32 years (Hallerback et al., 2009). A smaller age range of 17 to 19 years at Time 1 in the present study corresponds better to rapid morphological brain changes occurring in late adolescence and early adulthood. Whether executive function and social cognition follow linear or non-linear trajectories corresponding to morphological change at specific ages in late adolescence and early adulthood remains to be established (Gogtay et al., 2004). The current study may establish whether linear and non-linear morphological brain changes correspond to linear and non-linear functional development across narrow age ranges.

3.3 Selected executive function tasks

The meta-analysis by Romine and Reynolds (2005), detailed in Chapter 1, has informed the selection of suitable executive function tasks for participants in late adolescence and early adulthood in the present study. Romine and Reynolds (2005) concluded that verbal fluency and planning continue to develop between 17 years and 22 years, and consequently tasks that measure these executive functions were selected for the task battery. Verbal Fluency Tasks are appropriate for use with typically developing participants because they do not produce ceiling effects (Strauss, Sherman & Spreen, 2006). Previous research has reported the attainment of adult levels by age 14 to 15 on Semantic Fluency Tasks, but not on phonemic Letter Fluency Tasks, suggesting that phonemic letter fluency has a more protracted maturation (Matute, Rosselli, Ardilla &

Morales, 2004); therefore, the (phonemic) Letter Fluency Task from the D-KEFS was selected.

Tower of Hanoi and Tower of London Tasks were not selected as planning measures because ceiling effects are problematic in research with adults (Humes, Welsh, Retzlaff & Cookson, 1997). Huizinga, Dolan and van der Molen (2006) reported that 15 year olds attained adult performance on the 4, 5 and 6 move Tower of London Task measures of first move planning time and number of additional moves required to complete the tower, indicating this task is not appropriate for participants in late adolescence or early adulthood. Instead, the D-KEFS Tower Test was utilised because this avoids ceiling performance in typically developing samples by including progressively more challenging items, culminating in a tower that can be completed in a minimum of 26 moves (Delis et al., 2001).

Previous executive function studies have often included the Wisconsin Card Sorting Test (WCST; Heaton, 1981; Heaton, Chelune, Talley, Kay & Curtiss, 1993) to assess concept formation. For example, Huizinga, Dolan and Van der Molan (2006) reported that performance on the WCST improved up to age 21. The WCST consists of four reference cards and 128 stimulus cards that differ by colour, design and number of items. Participants are required to match the stimulus cards with the reference cards and receive feedback from the examiner about whether the match was correct. The classification rule changes after ten correct sorts requiring participants to flexibly shift to a different sorting rule. Indices of task performance include number of categories completed (set maintenance) and perseverative errors, when a participant sorts according to a previous sorting rule despite a change in sorting rule. The findings of Huizinga et al. (2006) are not consistent with the findings of Romine and Reynolds (2005) who reported that improvement in set maintenance and inhibition of perseveration, assessed with the WCST, improved between ages 5 and 14, followed by no change at ages 17 and 22 in typically developing participants. However, Romine and Reynolds (2005) noted that the tasks included in their review might not completely assess the target executive function, therefore an alternative assessment of concept formation was included in the present task battery. In the present study the D-KEFS Sorting Test was selected instead of the Wisconsin Card Sorting Task because there are

16 conceptual sorting rules in the D-KEFS version, compared to only 3 sorting rules in the WCST, increasing processing demands, minimizing ceiling effects and increasing task sensitivity (Delis et al., 2001a).

The development of prepotent response inhibition is not fully understood in adolescence and lack of inhibition has been attributed to increased risk taking (Luna & Sweeney, 2004) at these age ranges. Examples of adolescent risk taking include drug and alcohol use, dangerous driving and violent behaviour (Steinberg, 2008). Data from The Department for Education (2011) showed that 18 and 19 year olds reported the highest rates of ever using cannabis and alcohol relative to younger age groups. Romine and Reynolds (2005) recommended that future research should include additional tasks; in the present study the Hayling Test assessed inhibition of prepotent responses in the vocal domain and first move time from the Tower task provides a measure of motor inhibition. The Brixton Test (Burgess & Shallice, 1997) was included to assess rule detection using a spatial format, to explore further how this executive function develops during late adolescence and early adulthood.

A diagram of the selected task battery is presented in Figure 3.1. The selected tasks are described in more detail later in the chapter.

Figure 3.1. Summary of the task battery

Executive Function measures

Hayling and Brixton Tests
(Burgess & Shallice, 1997)

Hayling Sentence completion task
Response initiation speed and inhibition of prepotent responses

Brixton spatial anticipation task
Rule detection

D-KEFS (Delis et al., 2001)

Letter fluency
60 seconds in which to say words starting with F, A and S, excluding people, places and numbers

Strategy generation

Card Sort
Free sorting and sort recognition of cards based on semantic and visuo-spatial features

Abstract concept formation, perseveration and problem solving

Tower task
Constructing towers from disks whilst only moving one disk at a time and never placing a large disk on a smaller disk.

Planning, rule learning, problem solving, inhibiting prepotent responses and maintenance of instructional sets

Other measures

Wechsler Abbreviated Scale of Intelligence (Wechsler, 1999)

Positive and Negative Affect Scale (Watson, Clark & Tellegen, 1988)

Hospital Anxiety and Depression Scale (Zigmond & Snaith, 1983)

Self Administered Rating Scale for Pubertal Development
(Carskadon & Acebo, 1993)

Demographics

Key

Black = test

Blue = function measured

Social Cognition measures

Reading the Mind in the Eyes Test
(Baron-Cohen et al., 2001)

Photographs of eye regions

Emotion recognition with static visual stimuli

Reading the Mind in the Voice Test
(Golan, Baron-Cohen, Hill & Rutherford, 2007)

Sound clips

Emotion recognition in the auditory domain

Movie for the Assessment of Social Cognition
(Dziobek et al., 2006)

Film clips

Social cognition in dynamic visual and auditory stimuli with social interaction

Interpersonal Reactivity Index (Davis, 1983)

Self report measure tapping empathic concern, personal distress, perspective taking and fantasy.

Self-report empathy

3.3.1 Description of executive function tasks

In this section, the Hayling and Brixton Tests (Burgess & Shallice, 1997) and D-KEFS (Delis et al., 2001) will be described because literature reviewed in Chapter 1 employed these tasks (e.g. Kalkut et al., 2009; Waber et al., 2007) and they were utilised in the present study.

3.3.1.1 Haying and Brixton Tests (Burgess & Shallice, 1997)

The Hayling Test has previously been employed in adolescent research with atypically developing participants. For example, comparing participants with ASD and control groups in seven to 13 year olds (Ames & White, 2011) and eight to 17 year olds (Robinson et al., 2009). Some studies of executive function in adulthood have employed both the Hayling and Brixton Tests. For instance, Bielak, Mansueti, Strauss and Dixon (2006) examined performance in older adults aged 53 to 90 years and Barker et al. (2010) compared performance between participants who had sustained a head injury before the age of 25 with those injured after the age of 25. Considering previous research in either early adolescence or late adulthood using both the Hayling and Brixton tests, this highlights a gap in the literature, with a need for studies focusing on typically developing participants in late adolescence and early adulthood.

The Hayling Test is a sentence completion task, yielding a measure of response initiation speed and inhibition of prepotent responses. In section one, the participant listens to sentences with the last word missing and is required to produce a word to correctly complete the sentence. Section two requires the participant to generate a word which is completely unconnected to the sentence, e.g. for "Most cats see very well at _____." The participant must first inhibit the expected response of "night" and then produce an unconnected word. A possible strategy is to name objects from the room. There are 30 items in total, with 15 different sentences in each section. When scoring the Hayling Test, Burgess and Shallice (1997) recommended response times for each section are rounded down. A scaled score is calculated based on response times and the number of errors in section two. The scaled score, instead of the raw score, is used most extensively for reporting test results (e.g. Barker et al., 2010; Frangou, Donaldson, Hadjulis, Landau & Goldstein, 2005; Joshua, Gogos & Rossell, 2009; Wood & Liossi, 2005). Burgess & Shallice (1997) reported an overall test-retest reliability of 0.76 when 31 typically developing participants completed the test between two days and four weeks apart.

The Brixton Spatial Anticipation Test assesses rule detection using a visuospatial array and requires the ability to detect rules from a sequence of stimuli. The stimulus for the Brixton Test is a booklet showing ten numbered circles arranged in two lines, with one circle coloured blue. The pattern followed by the coloured circle changes several times; participants are required to identify the pattern and indicate where they consider the blue circle will appear on the subsequent page. The outcome measure is the total number of errors in the 55 trials. The raw score is then converted to a scaled score. Test re-test reliability for 31 typically developing participants tested between two days and four weeks apart was 0.71 (Burgess & Shallice, 1997). The Hayling and Brixton Tests are quick to administer, taking approximately 20 minutes in total.

3.3.1.2 Delis-Kaplan Executive Function System

The D-KEFS (Delis, Kaplan & Kramer, 2001a) includes Trail Making, Verbal Fluency, Design Fluency, Colour-Word Inference, Sorting, Twenty Questions, Word Context, Tower and Proverb Tests. Table 3.1 presents a description of each test.

Table 3.1. Descriptions of D-KEFS Tests and the executive functions assessed

D-KEFS Tests	Description	Executive functions and non executive functions
Trail Making	Certain stimuli from an array of circles are marked in a particular order	Sequencing (ef), visual scanning and motor speed (non efs)
Verbal Fluency	Produce words beginning with a specific letter (Letter Fluency), category (Category Fluency) or alternate categories (Category switching)	Strategy generation (ef), memory, language and processing speed (non efs)
Design Fluency	Connect dots by drawing lines whilst following set rules	Nonverbal fluency, cognitive flexibility (efs) and motor ability (non ef)
Colour-word Interference	Colours are named (condition 1), colour words are named (condition 2), ink colour of incongruent stimuli named (condition 3) and switching between naming incongruent ink colour and word (condition 4)	Inhibition, flexibility (efs) and visual processing (non ef)
Sorting	Sort 6 cards into 2 groups based on a similarity and identify sorts created by the examiner	Verbal and non-verbal concept formation (ef), memory and language (non-efs)
Twenty Questions	Generate "yes/no" questions whilst viewing 30 pictures to identify the target picture	Concept formation (ef) and language (non ef)
Word Context	Generate meaning of novel words using information from 5 clue sentences	Deductive reasoning, verbal abstract thinking (efs) and language (non ef)
Tower	Move disks across pegs to create towers in as few moves possible	Planning, rule learning and inhibition (efs) and processing speed (non ef)
Proverb	Generate meaning of proverbs in a free and multiple choice format	Verbal abstract thinking

Administration of the entire D-KEFS Task battery takes approximately 90 minutes. The D-KEFS is an improvement on existing measures. Kaplan (1988) criticised the use of a single score to index neuropsychological test performance; a strength of the D-KEFS

Sorting and Tower Tests in particular is that several scores are calculated giving a more accurate assessment of executive functions than a single score. On the Sorting Test, the calculation of several components of concept formation provides data on verbal and non-verbal concept formation, abstract expression of concepts and flexibility of behavioural response. The addition of easier and more difficult items in the D-KEFS Tower Test provides a larger range of scores, resulting in improved psychometric properties (internal reliability and lower likelihood of floor/ceiling effects) compared to the Tower of Hanoi or Tower of London (Delis et al., 2001).

The Colour-word Interference Test was not included because participants with colour blindness, estimated at about 10% of the population (Tate et al., 2005) would not be able to complete this task. D-KEFS normative data showed that performance on the Twenty Questions Test, assessing ability to formulate questions and identify categories, peaked in 16-19 year olds followed by little developmental change (Delis et al., 2001b). The Twenty Questions Test was not included because these data indicate performance does not greatly change in late adolescence and early adulthood.

In the test descriptions, references are made to normative data reported by Delis et al. (2001b) from 1750 participants aged between eight to 89 years. The use of broad age categories in the D-KEFS normative data (Delis et al., 2001) e.g.16 to 19 years and 20 to 29 years results in a nebulous picture of executive functions in late adolescence and early adulthood (Taylor, Barker, Heavey & McHale, 2013). Consequently, more fine-grained age groups in the present study will further elucidate development of executive function in these age ranges. Test-retest reliabilities with 9 to 74 days between administration are reported from the manual (Delis et al., 2001) in the following test descriptions.

The following section reviews the Verbal Fluency, Sorting and Tower Tests as these executive function tests are frequently reported in the literature and were employed in the present study. Furthermore, the development of strategy generation, concept formation and planning is considered important during adolescence (e.g. Romine & Reynolds, 2005) and previous research has found that ability on these executive function tasks continues to develop into late adolescence and early adulthood (Delis et al., 2001; Waber et al., 2007; Reynolds & Horton. 2008).

3.3.1.2.1 Verbal Fluency Test

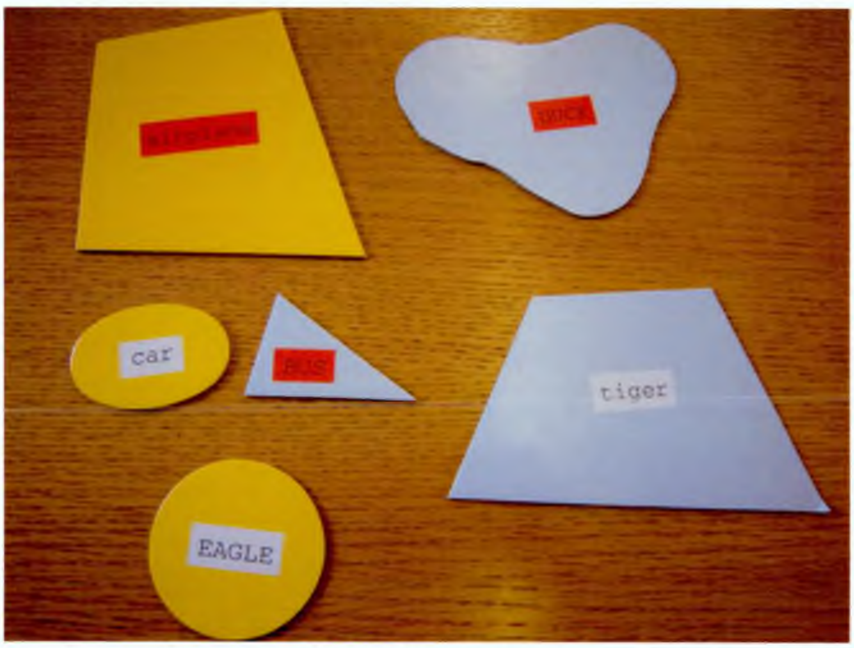
Verbal fluency provides a measure of strategy generation (Barker at al., 2006; Luo, Luk & Bialystock, 2010; Phillips, Bull, Adams & Fraser, 2002) because successful performance requires participants to generate an effective strategy to retrieve words that follow the specified rule. The Verbal Fluency Test comprises three sections: Letter Fluency, Category Fluency and Category Switching. The Letter Fluency Test assesses phonemic fluency and involves a participant speaking as many words as possible in 60 seconds beginning with the letter "F", "A" and then "S" excluding numbers or names of people or places and expletives. Additionally, the same words with different endings are not allowed, e.g. if a participant said "take" they should not then say "takes" or "taking". To score highly on this task a successful strategy must be employed with a systematic search through the mental lexicon, e.g. the generation of words beginning with "Fa" followed by "Fe" for the letter "F". Inhibition is also required to avoid generating words that do not adhere to task instructions (Anderson, Levin & Jacobs, 2002). D-KEFS normative data for Letter Fluency show a rapid improvement in eight to 19 year olds, with performance peaking in the 30 to 39 year old group (Delis et al., 2001b). For the 16 to 19 year old age group, an internal consistency value of 0.80 and test-retest reliability of 0.67 was reported (Delis et al., 2001b).

3.3.1.2.2 Sorting Test

The D-KEFS Sorting Test, previously called the California Card Sorting Test (Delis, Squire, Bihrle & Massman, 1992), and adapted from the WCST (Heaton, 1981), consists of free sorting and sort recognition conditions, providing measures of problem solving, abstract concept formation and perseveration (Delis et al., 2001a). The test authors noted four stages necessary in the completion of concept formation tasks: "a) initiation of effortful and novel thinking, b) isolation of a common feature or attribute from the array of stimuli, c) formation of a higher level concept that captures the defining properties of those common features, d) flexibility of thinking in order to abandon one conceptual relationship in order to apprehend new ones" (Delis et al., 2001a, p. 4). The number of correct sorts assesses the first two stages, description scores assess stage c and d is evident with a low number of repeated sorts. The inclusion of more difficult target sorts, e.g. concave and convex shapes, minimises ceiling effects (Delis et al., 2001a).

The Sorting Test comprises two sets of cards and takes approximately 20 minutes to administer. Card set one is illustrated in Figure 3.2.

Figure 3.2. D-KEFS Sorting Test



In the free sort condition, participants sort six cards, with one word printed on them, into two groups and describe the characteristics of each group. The sort recognition condition requires participants to identify how the examiner has sorted the six cards into two groups. There are eight possible sorts; three sorts use semantic information of the words (e.g. one syllable vs. two syllables) and five sorts use visuospatial features of the cards (e.g. straight edges vs. curved edges). Each description is scored out of two points. The Sorting Test is unique because it assesses description scores for verbal and non-verbal sorts separately.

Table 3.2 shows the scoring criteria for the one syllable (bus, car, duck) and two syllables (airplane, eagle, tiger) target sorts with 0, 1 or 2 points awarded depending on the detail of the participants' response.

Table 3.2. Example of scoring criteria for the D-KEFS Sorting Test

Target sort	2 point answers	1 point answers	0 points answers
One syllable	Single syllable One part per word	Short words	Easy to say
Two syllables	Double syllable Two parts per word	Long words	Hard to say

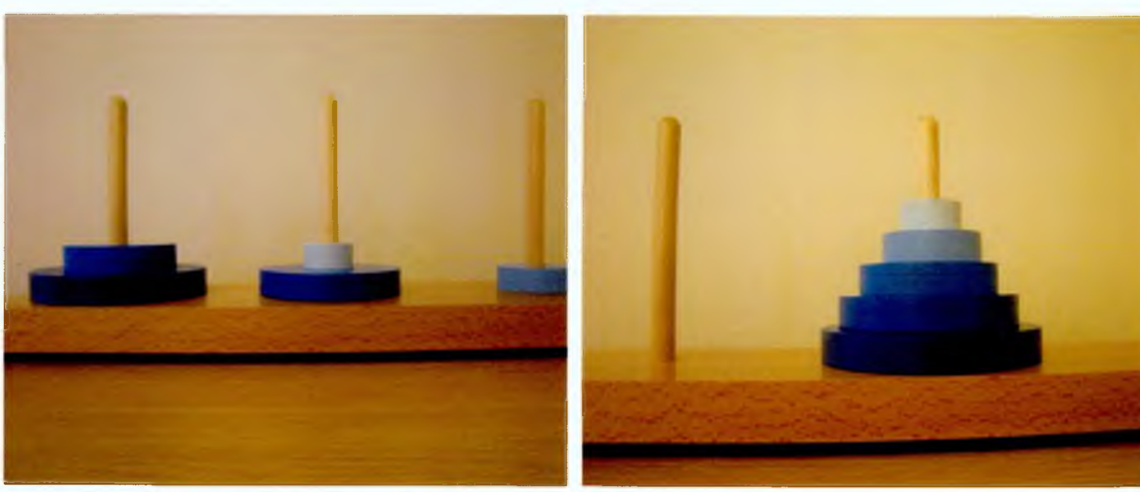
For example, if a participant described the one syllable card group as 'easy to say' they would be awarded 0 points. It is possible to calculate several scores to assess performance on the Sorting Test and the following scores were used in analysis. Number of correct free sorts and free sort description score were calculated from the free sorting section, with the number of repeated free sorts providing an indication of perseveration. Sort recognition description score was calculated from the sort recognition section and description scores for verbal and perceptual sorts were totalled across both sections.

Delis et al. (2001b) reported internal consistency values of 0.72, 0.73 and 0.74 for free sorting, free sorting description and sort recognition scores in 16 to 19 year olds. For the same tasks, Delis et al. calculated test-retest coefficients of 0.49, 0.67 and 0.56. However, in the second testing session, the same cards were administered to the participants; in the present study the use of alternative cards in longitudinal testing minimised the influence of practise effects. The normative data from the D-KEFS showed the number of attempted sorts peaked in the 16 to 19 age group, whilst accuracy of sorts and descriptions peaked in the group aged 20 to 29 years across the whole sample (Delis et al., 2001b).

3.3.1.2.3 Tower Test

The Tower Test provides a measure of rule learning, planning, problem solving, inhibition of prepotent responses and maintenance of instructional sets (Shunk, Davis & Dean, 2006). Participants are shown a diagram of the tower they should aim to build on one of the three pegs, using up to five disks, in as few moves as possible. Only one disk can be moved at a time and a larger disk cannot be placed on a smaller disk. There are nine trials in total becoming progressively more complex to solve. Participants have a specific amount of time to complete each tower (e.g. 30 seconds for the first tower and 240 seconds for the last tower). The test is discontinued if a participant fails to complete three consecutive towers. The total number of moves taken to complete a tower, whether the participant correctly built the tower and the time taken are recorded. Ceiling performance in typically developing samples is avoided by including progressively more challenging items, culminating in a tower which can be completed in a minimum of 26 moves (see Figure 3.3).

Figure 3.3. Tower nine from the D-KEFS Tower Test (starting position on the left and completed position in the right)



The Tower Test can be scored in several ways: number of items completed (total out of 9 trials), achievement score (takes into account if items are completed and also the number of moves), mean first move time (total first move time / items administered), time per move (total completion time / total number of moves) and move accuracy (total number of moves / total minimum number of moves required). Delis et al. (2001b) reported an internal consistency value of 0.60 and test-retest reliability coefficient of 0.51 for the Tower Test. D-KEFS normative data shows the shortest mean first move time was for 13 to 15 year olds, possibly indicating a degree of impulsivity (Delis et al., 2001b). Achievement score peaked in the 16 to 19 year old group, whilst 13 to 19 year olds achieved the lowest rule violations compared to 20 to 29 year olds and beyond.

3.4 Social cognition tasks

Social cognition incorporates a range of abilities including Theory of Mind (Carrington & Bailey, 2009; Frith, 2007; Kalbe et al., 2010), emotion recognition, empathy and perspective taking (Frith, 2007; Vollm et al., 2006). An array of tasks exists for assessing social cognitive development in a range of formats including written format (Strange Stories Task; Happé, 1994), visual static stimuli (Reading the Mind in the Eyes test; Baron-Cohen, Wheelwright, Hill, Raste & Plumb, 2001) and auditory stimuli (Reading the Mind in the Voice test; Golan, Baron-Cohen, Hill & Rutherford, 2007). Tasks utilising a dynamic visual paradigm include the Social Attribution Task (Klin, 2000), Awkward Moments Test (Heavey, Phillips, Baron-Cohen & Rutter, 2000), Empathic Accuracy Paradigm (Roeyers, Buysse, Ponnet & Pichal, 2001), Reading the Mind in Films Test (Golan, Baron-Cohen, Hill & Golan, 2006) and the Movie for the Assessment of Social Cognition (Dziobek et al., 2006).

Research reviewed in Chapter 1 shows that aspects of social cognition continue to develop into adolescence, for example emotion recognition from facial and vocal information (Tonks et al., 2007), perspective taking (Choudhury et al., 2006; Dumontheil et al., 2010) and self-report empathy (Davis & Franzoi, 1991).

3.5 Selected social cognition tasks

The social cognition tasks were selected to encompass a variety of aspects of social cognition using different formats, e.g. static (Reading the Mind in the Eyes Task) and dynamic (Movie for the Assessment of Social Cognition; MASC). The task battery also assessed visual (Reading the Mind in the Eyes Task) and auditory social cognition (Reading the Mind in the Voice Task). The tasks show acceptable levels of internal reliability and are appropriate for participants in late adolescence / early adulthood by avoiding ceiling effects.

Tager-Flusberg (2001) identified a conceptual framework, consisting of social-perceptual and social-cognitive components of Theory of Mind. The social-perceptual component refers to understanding and interpreting information from faces, voices and body posture and attributing mental states, whilst the social-cognitive component refers to the use of information over time and events in the attribution of mental states. The adult version of the Reading the Mind in the Eyes Test (Baron-Cohen et al., 1997) is considered to be a test of the social-perceptual aspect of Theory of Mind (Tager-Flusberg, 2001). It is suggested that the Reading the Mind in the Voice Test assesses social-perceptual skills because this test requires the interpretation of vocal information. Mental state understanding in everyday life consists of both social-perceptual and social-cognitive processes (Tager-Flusberg, 2001). The MASC, a measure approximating ecologically valid social situations, provided a measure of both social-perceptual and social-cognitive processes. Social-perceptual processes are required to interpret facial expressions, speech and body language, whereas social-cognitive skills are utilised in remembering what has happened previously in the film.

Beer and Ochsner (2006) noted that social cognition is composed of processes involved in understanding other people and understanding the self. The component of understanding others was assessed through the inclusion of Reading the Mind in the Eyes, Reading the Mind in the Voice and the MASC. The Interpersonal Reactivity Index (IRI), a self-report measure of empathy, provides an assessment of the self-understanding aspect of social cognition proposed by Beer and Ochsner (2006).

A further comparison can be made between objective assessments (the Reading the Mind in the Eyes Test, Reading the Mind in the Voice Test and MASC), whilst the Interpersonal Reactivity Index is subjective, and includes a perspective taking scale. The selected task battery provides a comprehensive assessment of social cognition compared to other studies assessing social cognition in late adolescence and early adulthood that have administered only one task. For instance, Thomas et al. (2007) administered Ekman faces (Ekman & Friesen, 1976), Davis and Franzoi (1991) utilised the Interpersonal Reactivity Index (Davis, 1980) and Dumontheil et al. (2010) assessed social cognition with the Director Perspective Taking Task.

3.5.1 Reading the Mind in the Eyes Test

In this task a participant views photographs of a person's eye region and chooses one of four mental state terms to best describe what they think that person is thinking or feeling (Baron-Cohen et al., 2001). An example from the Reading the Mind in the Eyes Test is presented in Figure 3.4.

Figure 3.4. An example from the Reading the Mind in the Eyes Test

Arrogant grateful

sarcastic tentative

Note. Correct answer: Tentative

Improvements have been made to the original version of the Reading the Mind in the Eyes Test (Baron-Cohen et al., 1997). In the revised version, there is a forced choice format of four mental states, instead of two mental states in the original version, thus reducing the likelihood of a participant guessing the correct answer. In the original version, the target answer and foil were semantically opposite, e.g. sympathetic and unsympathetic. The emotional valence of the target answer and foils are the same in the revised version to make the task more challenging. Furthermore, only complex mental states are included in the revised version, with basic emotions omitted to make the test more sensitive. The revised version consists of 36 items, whereas the original version had 25 items. These improvements reduce the likelihood of ceiling effects and increase power to detect individual differences (Baron-Cohen et al., 2001). Total test scores range from zero to 36. The Reading the Mind in the Eyes Test (Baron-Cohen et al., 2001) has been used extensively in studies with adolescents and adults involving participants with autism and a typically developing control group. However, there is a gap of data in late adolescence / early adulthood (e.g. 11 to 17 year olds in Demurie, De Corel & Roeyers, 2011; mean age 14 years in Grossman & Tager-Flusberg, 2008; mean age 31 years in Kirchner, Hatri, Heekeren & Dziobek, 2011).

Typically developing adults with a mean age of 46.5 years (*SD* = 16.9) achieved a mean score of 26.2 (*SD* = 3.6) out of a possible 36 on the Reading the Mind in the Eyes Test (Baron-Cohen et al., 2001), indicating that ceiling effects are not likely to be problematic. No significant correlation was found between performance on the Eyes Test and the WAIS – R (Wechsler, 1939), suggesting that task performance is not related to IQ (Baron-Cohen et al., 2001). However, the authors only reported correlations with Full Scale IQ and it is unclear whether Verbal or Performance IQ correlated with performance on the Reading the Mind in the Eyes Test, which is possible given the verbal component of task. There were no significant gender differences on the Reading the Mind in the Eyes Test (Baron-Cohen et al., 2001). DeSoto et al. (2007) administered the Reading the Mind in the Eyes Test to female participants four weeks apart and reported a test re-test reliability of $r=0.67$ with no significant difference in scores between time 1 and time 2 in a typically developing group. Mátyássy, Kelemen, Sárkōzi, Janka and Kére (2006) reported a Cronbach's alpha of 0.81 for abstinent alcoholics and healthy controls (mean age 36 years; 38 males, 22 females), above the acceptable value of 0.7 recommended by Nunnally (1978).

A limitation of the Eyes test is the use of static stimuli, because they are less demanding than real life social situations (Baron-Cohen et al., 2001). The static nature of the stimuli restricts the emotions which can be presented, as some require movement e.g. relief (Golan, Baron-Cohen & Hill, 2006). Despite these criticisms, the Eyes Test is one of the most widely used assessments of visual emotion recognition tasks, being appropriate for use in late adolescence / early adulthood due to the inclusion of complex mental state terms. Moreover, the task is considered a pure assessment of social cognition because executive function is not heavily required (Baron-Cohen et al., 1997). The pen and paper format makes it quick and easy to administer taking about 15 minutes to complete.

3.5.2 Reading the Mind in the Voice Test

The revised version of the Reading the Mind in the Voice Test (Golan, Baron-Cohen, Hill & Rutherford, 2007) comprises 25 sound clips from BBC dramas. The participant is required to select one of four mental states that best describe how the speaker is feeling and requires consideration of both the verbal content and intonation. Total test scores range from zero to 25. Limitations of the original version of the Reading the Mind in the Voice Test (Rutherford, Baron-Cohen & Wheelwright, 2002), comprising of 40 items, were ceiling effects and limited sensitivity. Golan et al. (2007) improved the revised version by increasing the number of possible answer options from two to four for each item using an emotion taxonomy of 412 mental states (Baron-Cohen, Wheelwright, Hill & Golan, 2004) divided into six developmental levels to generate foils that were either in the same developmental level, one above or below the target answer. The proposed developmental levels in the emotion taxonomy and corresponding ages are: level one (understood by typically developing 4 to 7 year olds), level two (8 to 10 year olds), level three (11 to 13 year olds), level four (15 to 16 year olds), level five (17 to 18 year olds) and level six (understood by less than 75% of typically developing 17 – 18 year olds). Baron-Cohen et al. (2004) established these levels by talking to children and adolescents aged between 4 and 18 to ascertain their understanding of mental states. However, information about sample size and the exact method used is omitted. The removal of easier items from the Reading the Mind in the Voice Test and selection of foils matching the target answer for content but not for intonation make the revised task more challenging.

The typically developing control group in the Golan et al. (2007) study, who were aged 17-51 years with a mean age of 24.3 years (*SD* = 7.71), attained a mean score of 18.77 (*SD* = 2.41) from a possible 25 on the Reading the Mind in the Voice Test, showing no evidence of ceiling effects. Golan et al. (2007) reported a significant positive correlation between the Reading the Mind in the Eyes Test (Baron-Cohen et al., 2001) and Reading the Mind in the Voice Test (Golan et al., 2007), providing concurrent validity for the Voices Test. Verbal IQ and scores on the Voices Test were positively correlated, whereas no significant correlation was reported between the Voices Test and Performance IQ or age. Golan et al. (2007) reported a test-retest reliability for 24 participants with Asperger's Syndrome over a 10 week interval of r = 0.8.

3.5.3 Movie for the Assessment of Social Cognition

The Movie for the Assessment of Social Cognition (Dziobek et al., 2006) is a 15-minute film showing social interaction between two male and two female adults aged between 30 and 40 years. The film is paused on 45 occasions and participants answer questions relating to a particular character's emotions, thoughts and intentions. The test authors used a multi-dimensional approach, including first and second order false belief, deception, faux pas, persuasion and sarcasm. To answer questions correctly, verbal content must be considered, including literal and non-literal instances (i.e. containing figurative speech and other pragmatics). The participant must also consider non-verbal content, for example facial emotion recognition and interpretation of body language. The MASC includes positive, negative and neutral emotional valences and scores range from zero to 45, with each question having a four item forced choice answer format. The four answers include the target answer, responses in which the mental state inference is excessive or insufficient and an answer lacking mental state inference, instead referring to physical causation. Administration of the MASC takes approximately 40 minutes.

Roeyers and Demurie (2010) suggested film clips overcome the limitations of static or uni-modal tasks (e.g. Reading the Mind in the Eyes or Voice Tests). Moore (2001) considered the use of static stimuli underestimated participants' abilities to recognise emotion. Wehrle et al. (2000) provided evidence for this and found participants performed more successfully on an emotion recognition task using dynamic faces compared to static faces. The MASC is a closer approximation to real life social situations because there are up to four adults in each scene, whereas the Eyes Test only includes one person per item. The MASC, a dynamic social cognition task, was selected to capture a holistic assessment, following Johnston, Miles and McKinlay (2008) who suggested information from the face and body are necessary for social cognition. The MASC requires consideration of verbal content and non-verbal content (e.g. interpretation of face expressions and body language). Other social cognition tasks, for example the Reading the Mind in the Eyes (Baron-Cohen et al., 2001) or Reading the Mind in the Voice Tasks (Golan et al., 2007) do not involve interpretation of full facial or body language. Erickson (1995) criticised traditional neuropsychological assessments for not considering error responses. A strength of the MASC is that it enables the classification of errors into excessive or insufficient mental state inference errors, or an answer that lacks mental state understanding and instead refers to physical causation. Therefore, error analysis can provide insight into where a participant shows a weakness in this aspect of social cognition. The Reading the Mind in the Eyes Test was included in the task battery to allow for comparison with other groups because this measure has been more widely used than the MASC which is relatively new and the psychometric properties are less well documented than the Eyes Test.

In the Dziobek et al. (2006) study, a group with Asperger's Syndrome and a typically developing control group completed the MASC, Strange Stories Task (Happé, 1994), 24 items from the Reading the Mind in the Eyes Test (Baron-Cohen et al, 2001) and 28 photographs of faces showing basic emotions (happiness, sadness, fear, disgust, anger and surprise). In addition, executive function was assessed with the Stroop Test (Stroop, 1935), a Verbal Fluency Task (Horn, 1962) and Trail Making Test (Reitan & Wolfson, 1993). No significant correlations were found between the MASC and IQ measures from the WAIS (Wechsler, 1955), or between social cognition and executive function. The finding of no significant correlations between the Strange Stories Task (Happé, 1994), the Reading the Mind in the Eyes Test and a basic emotion recognition task indicates "social cognition is a multifaceted construct" (Dziobek et al., 2006, p. 633). The authors found the MASC was the superior social cognition task in discriminating between participants with Asperger's Syndrome and the control group. Dziobek et al. (2006) reported a test-retest reliability of $r = 0.86$, with the second administration of the MASC being one to 12 months after the first completion, with an average of 4.6 months for the group with Asperger's Syndrome and 3.6 months for the control group. A Cronbach's alpha of 0.84 shows the MASC has good reliability (Dziobek et al., 2006).

3.5.4 Interpersonal Reactivity Index

The Interpersonal Reactivity Index (IRI; Davis, 1983) is a 28 item self-report measure tapping four aspects of empathy: empathic concern, personal distress, perspective taking and fantasy (see appendix section 1). The IRI adopts a multidimensional approach by including both affective empathy (Empathic Concern and Personal Distress scales) and cognitive empathy (Perspective Taking and Fantasy scales). The four sub-scales assess different components of empathy, defined as "the reactions of one individual to the observed experiences of another" (Davis, 1983, p. 113). Participants rate statements on a five point scale for how well they describe themselves, ranging from "does not describe me well" to "does describe me well". The Perspective Taking scale relates to the tendency of a person to consider other peoples' viewpoint, whereas the Fantasy scale assesses whether the participant relates to characters in books and films. The Empathic Concern scale explores sympathetic feelings towards other people's misfortune and the Personal Distress scale measures personal feelings of apprehension in stressful situations. Examples from each scale of the IRI are: "I try to look at everybody's side of a disagreement before I make a decision" (Perspective Taking), "I really get involved with the feelings of the characters in novels" (Fantasy), "When I see someone being taken advantage of, I feel kind of protective towards them" (Empathic Concern) and "I sometimes feel helpless when I am in the middle of a very emotional situation" (Personal Distress). Internal reliability statistics for the sub-scales are acceptable and range between 0.71 to 0.77 with test-retest reliabilities between 0.62 and 0.71 (Davis, 1980).

3.6 Review of other measures

In addition to the executive function and social cognition tasks, the following measures were also included in the task battery to assess IQ, anxiety, depression, affect, pubertal development and demographics.

3.6.1 Wechsler Abbreviated Scale of Intelligence

Previous research reviewed in Chapter 1 has found a relationship between IQ and executive functions (e.g. García-Molina et al., 2010) and social cognition (e.g. Charlton et al., 2009). Consequently, an IQ measure was included in the task battery. The

Wechsler Abbreviated Scale of Intelligence (WASI; Wechsler, 1999) was selected due to its shorter administration time compared to the Wechsler Adult Intelligence Scale (Wechsler, 1997).

The WASI is comprised of Vocabulary and Similarities sections, assessing Verbal IQ, and Block Design and Matrix Reasoning, assessing Performance IQ. Examples from the Vocabulary section are "Tell me what transform means" and "Tell me what formidable means." In the Similarities section, participants explain how two words are similar, e.g. "In what way are photograph and song alike?" and "In what way are peace and war alike?" The Block Design section requires participants to create specific patterns out of blocks in a set time-limit, with difficulty ranging from easier patterns comprised of four blocks to more complex nine block patterns. Participants are presented with patterns that have one piece missing and decide from a choice of four answers which piece completes the pattern in the Matrix Reasoning section. The WASI takes approximately 30 minutes to administer. Wechsler (1999) reported test-retest reliability coefficients ranging from 0.79 to 0.90 for an adult sample, who completed the WASI with two to 12 weeks between testing sessions (Wechsler, 1999). The average internal consistency reliability coefficients for each subtest of the WASI range from 0.92 to 0.94 indicating that this measure has good internal consistency.

3.6.2 Pubertal Development Scale

An assessment of pubertal development was included because the possible influence of puberty on functioning is often overlooked in developmental research (Kalkut et al., 2009; Blakemore, 2008). Findings about the effect of pubertal development on executive function and social cognition are inconsistent. Pubertal development has been found to affect inhibition (Olaguni-Jones, Luna & Asato, 2007) and emotion understanding assessed with a visual analogue scale (Burnett et al., 2011), whilst other studies reported pubertal development did not relate to executive functions (Magar et al., 2010) or emotion recognition (Thomas et al., 2007). The Self-Administered Rating Scale for Pubertal Development (Carskadon & Acebo, 1983) was selected because it is more ethically acceptable than picture-based measures when working with adolescents (Bond et al., 2006).

Petersen, Crockett, Richards and Boxer (1988) developed the Pubertal Development Scale, an interview based continuous measure. Both males and females rate on a 4-point scale (1 = not yet started to 4 = seems complete) their stage of development with regard to growth spurt, body hair growth and skin changes. Males complete questions about facial hair growth and voice changes, whilst females answer questions about breast development and the age they started their periods. Instead of interviewing participants, some researchers (e.g. Carskadon & Acebo, 1993) use a self-report version of this measure. This adopts the same questions and rating scale as the interview measures, but allows participants to complete the questions themselves privately.

3.6.3 The Hospital Anxiety and Depression Scale

Literature reviewed in Chapter 2 demonstrated that depression has an equivocal effect on executive functions and social cognition (Favre et al., 2009; Harkness et al., 2005; Uekermann et al., 2008). Therefore, the Hospital Anxiety and Depression Scale (HADS; Zigmond & Snaith, 1983) was included to explore the relationship between task performance with anxiety and depression and assess for age group differences. The HADS is a state measure of anxiety and depression, with seven items scored between zero and three on each subscale. "I feel tense or wound up" is an example from the anxiety subscale and "I feel cheerful" is from the depression subscale. Crawford, Henry, Crombie and Taylor (2001) reported Cronbach's alpha of 0.82 for the anxiety scale and 0.77 for the depression scale indicating the HADS is a reliable measure.

3.6.4 Positive and Negative Affect Scale

Chapter 2 reviewed evidence that positive mood can impair executive function (Phillips, Smith & Gilhooly, 2002) and social cognition (Converse et al., 2008). An assessment of mood is rarely included in executive function or social cognition research despite findings that mood can affect cognitive function. Consequently, the Positive Affect and Negative Affect Scale (PANAS; Watson, Clark & Tellegen, 1988) enabled age group comparisons of mood state and its relationship to task performance to be examined. The PANAS consists of 20 emotion words: ten positive affect (e.g. enthusiastic) and ten negative affect (e.g. scared), which the participants rated on a likert scale indicating to what extent they feel a specific emotion at the present moment. Crawford and Henry

(2004) reported Cronbach's alpha of 0.89 for the Positive Affect scale and 0.85 for the Negative Affect scale indicating good reliability.

3.6.5 Demographics

It has been suggested that young peoples' changing social environment (Blakemore, 2008) and education (Romine & Reynolds, 2005) may affect social and executive development. Other studies of cognitive function in late adolescence and early adulthood (e.g. Dumontheil et al., 2010a; Dumontheil et al., 2010b; Magar, Phillips & Hosie, 2010) provide no data on education, drug and alcohol use or changes to living arrangements and friendship groups. A demography measure (see appendix section 2) was developed to account for the effect of environment on functional change. Participants stated how their living arrangements and friendship groups had changed over the last year. Participants noted whether they drank alcohol and whether they consumed over the weekly limit. Data on cannabis and ecstasy use, including age at first use, frequency and last use was also collected because studies reviewed in Chapter 2 showed impaired executive functions for cannabis users (McHale & Hunt, 2008) and ecstasy users (de Sola Llopis et al., 2008) relative to controls. Data about mental illness was collected because literature reviewed in Chapter 2 indicated inconsistent findings in relation to the effects of mental illness on executive function and social cognition. Participants were asked to report current mental illness by selecting whether they had experienced a Head Injury with 30 minutes unconscious, Autism or Asperger's Syndrome, Depression, Obsessive Compulsive Disorder and Attention Deficit Hyperactivity Disorder.

In summary, the present study utilised a sequential design with participants aged 17 years 0 months – 17 years 8 months, 18 years 0 months – 18 years 8 months and 19 years 0 months – 19 years 8 months at Time 1. A time interval of 12 to 16 months between testing allowed for the identification of any subtle linear or non-linear development of executive functions and social cognition and practise effects were minimised (Hausknecht et al., 2007). Executive function and social cognition tasks appropriate for use with participants in late adolescence and early adulthood were selected. The executive function battery comprised of the Hayling and Brixton Tests (Burgess & Shallice, 1997), measures of response inhibition and rule detection, and D-

KEFS Letter Fluency, Card Sorting and Tower Tests (Delis et al., 2001a), assessing strategy generation, concept formation and planning. The social cognition battery included the Reading the Mind in the Eyes Test (Baron-Cohen et al., 2001) and the Reading the Mind in the Voices Test (Golan et al., 2007) assessing emotion recognition in visual and auditory domains. The MASC (Dziobek et al., 2006) provided a measure of social cognition combining visual dynamic and auditory stimuli showing social interaction and the IRI (Davis, 1983) assessed self-report empathy. Additional measures in the task battery assessed factors that may influence task performance including IQ, pubertal development, mood and demographic information.

Chapter 4

Recruitment, IQ and mood state data

4.1 Chapter overview

This chapter outlines recruitment of participants and then discusses retention in longitudinal studies, examining whether the Time 2 sample is representative of the Time 1 sample. Following this, age group comparisons of IQ and mood state data are reported at Time 1 and Time 2. Mood data include positive affect, negative affect, anxiety and depression scores. Self-report data on employment, education, living arrangements, friendship groups, drug use and pubertal development are reported.

4.2 Participant recruitment

Participants were recruited from a variety of establishments including local schools, colleges, youth organisations and Sheffield Hallam University. Participants received a £10 voucher for taking part at Time 1 and another £10 voucher for participating at Time 2, with Sheffield Hallam University students receiving either a voucher or course credit. It was more difficult to recruit 17 year olds compared to 18 and 19 year olds. Therefore, ethical approval was gained for snowball sampling to increase recruitment of 17 year olds; participants told friends who might be interested in the study and received £10 for each friend who participated.

4.3 Procedure

Testing sessions took place in a quiet room at Sheffield Hallam University and lasted approximately 3 hours each. Rest breaks were participant-determined. Participants first completed the questionnaire measures: Positive and Negative Affect Scale (PANAS; Watson et al., 1988), Hospital Anxiety and Depression Scale (HADS; Zigmond & Snaith, 1983), Drug use and Self-Administered Rating Scale for Pubertal Development (Carskadon & Acebo, 1993). Following these, the Wechsler Abbreviated Scale of Intelligence (WASI; Wechsler, 1999) was administered before the social cognition and executive function battery, which were counterbalanced across testing sessions. The individual tasks within the executive function and social cognition task batteries were also counterbalanced.

4.4 Retention in longitudinal studies

An inherent limitation of longitudinal designs is participant attrition. Participants gave a phone number, email address and postal address at Time 1 to enable contact about participating at Time 2. Participants were contacted twice by email, twice by phone and a voice message recorded to arrange Time 2 testing. Letters were sent to participants who had changed their phone numbers. To increase the number of participants taking part at Time 2 the testing period was extended, participants received £20 for taking part and the researcher offered to travel to test participants. The Time 1 sample consisted of 98 participants and 58 participants took part at Time 2, a 60% retention rate. Of participants who did not take part at Time 2, three did not want to participate again, 17 did not reply, eight were not in Sheffield and six participants were too busy due to academic or work commitments. Six participants did not attend their booked testing session at Time 2 and were not available again.

Other longitudinal studies have reported similar retention rates. Novack, Bergquist, Bennett and Gouvier (1991) reported a retention rate of 60% in a 6-month longitudinal study assessing anxiety and depression in caregivers of Head Injury patients. In another study, Zipparo et al. (2008) conducted neuropsychological assessments including IQ and executive functions tests with 52 participants at Time 1 and 32 participants at Time 2, a retention rate of 60%. As retention in the present study is similar to Zipparo et al. (2008) it is possible some participants did not want to take part because of the testing sessions lasting approximately 3 hours. Davis and Franzoi (1991) reported a longitudinal study with 100% retention rate assessing 205 15 and 16 year olds on two short questionnaires, the Interpersonal Reactivity Index (Davis, 1983) and Self Conscious Scale (Fenigstein et al., 1975), every year over three consecutive years. In the Davis and Franzoi study, it is likely that the shorter testing time and availability of participants who were still at school at follow up testing resulted in a higher retention rate than in the present study. Intervention studies reported lower retention rates; for example, Cabiya et al., (2008) achieved a retention rate of 54% in a Cognitive Behavioural Therapy Intervention 6 months following Time 1. A study investigating parent-child interaction therapy with 120 dyads at Time 1 retained 31% of participants over the 2-year intervention (Lanier et al., 2011).

T-tests were conducted to compare Time 1 data (PANAS Positive Affect and Negative Affect scores, HADS Depression and Anxiety scores and WASI Verbal IQ, Performance IQ and Full IQ) of participants who took part only at Time 1 with participants who took part at both time points. There was a significant difference for Verbal IQ scores (t (96) = 2.27, p = 0.03) with participants who took part at Time 2 (M = 105.60, SD = 8.73) attaining a higher IQ compared to participants who only took part at Time 1 (M = 101.20, SD = 10.43). However, mean scores for both groups fell within the average IQ range indicating that the two groups were not categorically different based on IQ scores. Other t-tests with mood variables were not significant (all p's > 0.30) indicating that the Time 2 sample is representative of the Time 1 sample on mood, depression, anxiety and Full Scale IQ.

Chi square tests were conducted on self-report drug use and changes in living arrangements to ascertain whether the Time 2 sample was representative of the Time 1 sample. Yates's continuity corrections are reported because the contingency tables are 2x2 (Field, 2005). There were no associations between whether participants took part at Time 1 or both time points and whether they reported drinking or not drinking alcohol (χ^2 (1) = 0.01, p = 0.91, phi = 0.04, p = 0.67) and whether they reported drinking under or over the weekly guidelines (χ^2 (1) = 1.19, p = 0.28, phi = 0.13, p = 0.19). There were also no associations between whether participants took part at Time 1 or both time points and whether or not they reported ever using cannabis (χ^2 (1) = 0.01, p = 0.91, phi = 0.03, p = 0.74) or ecstasy (χ^2 (1) = 1.72, p = 0.19, phi = 0.17, p = 0.09). Furthermore, there was no association between whether participants took part at Time 1 or both testing sessions and whether or not they reported changes in living arrangements over the previous 12 months (χ^2<0.01, p = 0.28, phi = 0.13, p = 0.19). These variables were of particular interest because studies reviewed in Chapter 2 showed that alcohol, cannabis and ecstasy use can affect executive function and social cognition (Parada et al., 2012; Uekermann et al., 2005; McHale & Hunt, 2008; De Sola Llopis et al., 2008; Yip and Lee, 2006).

4.5 IQ and mood data at Time 1

The Time 1 sample consisted of 98 participants in total from three age groups: 17 years 0 months – 17 years 8 months (n = 31, M = 17 years 4 months, SD = 2.47 months, 23 females: 8 males), 18 years 0 months – 18 years 8 months (n = 31, M = 18 years 4 months, SD = 2.44 months, 26 females: 5 males) and 19 years 0 months – 19 years 8 months (n = 36, 19 years 2 months, SD = 1.75 months, 28 females: 8 males). The sample consisted of more females (n = 77) than males (n = 21) because females more readily volunteered for the study.

Descriptive statistics for PANAS and HADS scores are presented in Table 4.1. Inferential statistics examining group differences follow the table.

Table 4.1. Means and Standard Deviations for Wechsler Abbreviated Scale of Intelligence, Positive and Negative Affect Scale, Hospital Anxiety and Depression Scale and Pubertal Development Scale for age groups at Time 1

	17 year olds (n = 31)	18 year olds (n = 31)	19 year olds (n = 36)
Verbal IQ	105.35 (7.51)	103.55 (11.78)	102.69 (9.36)
Performance IQ*	105.39 (10.62)	99.97 (9.39)	104.83 (7.93)
Full IQ	106.03 (7.43)	102.13 (10.98)	104.33 (7.65)
Positive affect	30.00 (4.32)	30.87 (7.43)	32.56 (4.75)
Negative affect**	14.68 (5.22)	13.87 (3.31)	11.86 (2.38)
Depression	3.14 (1.64)	2.58 (3.13)	3.21 (2.41)
Anxiety*	8.38 (2.90)	8.38 (3.38)	6.65 (2.80)
Pubertal Development Scale**	3.57 (0.32)	3.77 (0.27)	3.84 (0.21)

* $p < 0.05$, ** $p < 0.01$ Depression and anxiety scores for n = 89

Groups differed on Performance IQ (F (2, 95) = 3.24, p = 0.04), with 18 year olds scoring significantly lower than 17 year olds (t (60) = 21.3 p = 0.04) and 19 year olds (t (65) = 2.30 p = 0.03). However, mean IQ scores for each age group fell within the average range and there were no group differences for Verbal IQ (F(2, 95) = 0.64, p = 0.53, η^2 = 0.01) or Full Scale IQ (F(2, 95) = 1.54, p = 0.22, η^2 = 0.03).

No significant group differences were found between 17 year olds, 18 year olds and 19 year olds on the Positive Affect scale of the PANAS (Watson, Clark & Tellegen, 1988) (F (2, 95) = 1.80, p = 0.17, η^2 = 0.04). There were group differences on the Negative Affect scale of the PANAS (F (2, 95) = 5.04, p<0.01, η^2 = 0.10), with 17 year olds (t (65) = 2.91, p<0.01) and 18 year olds (t (65) = 2.88, p<0.01) scoring significantly higher, indicating greater negative affect, than 19 year olds. No significant differences were evident between 17 year olds and 18 year olds (t (60) = 0.73, p = 0.47) for Negative Affect scores. The PANAS scores are similar to normative data by Crawford and Henry (2004) indicating that group differences did not reflect pathological changes to mood state. Depression scores from the HADS (Zigmond & Snaith, 1983) fell within the normal range with no significant group differences (F (2, 86) = 0.56, p = 0.57, η^2 = 0.01). Group differences were found on the Anxiety scale of the HADS (F (2, 86) = 3.49, p = 0.04, η^2 = 0.08), with scores for 17 year olds and 18 year olds within the mild range and significantly higher, indicating greater anxiety, than 19 year olds whose scores were in the normal range. No significant differences were found between 17 year olds and 18 year olds whose scores fell within the mild range on the Anxiety scale of the HADS (t (53) <0.01, p = 1.00).

Extent of pubertal development differed between groups (F (2, 95) = 9.10, p<0.001, η^2 = 0.16). Seventeen year olds scored lower than 18 year olds (t (95) = 3.03, p<0.01) and 19 year olds (t (95) = 3.06, p < 0.001) indicating that the youngest age group showed less pubertal development than the other groups as might be expected. There were no other group differences for pubertal development.

Data about employment, education, living arrangements and friendship groups per age group is presented in Table 4.2.

Table 4.2. Data on employment, education, living arrangements and friendship groups for 17, 18 and 19 year olds at Time 1

	17 year olds (*n*=31)	18 year olds (*n*=31)	19 year olds (*n*=36)
Job	35%	55%	39%
Education	AS levels 45%	A2 levels 13%	AS levels 3%
	A2 levels 52%	Degree 81%	Degree 97%
	BTEC 3%	BTEC 6%	
Living changed	16%	68%	75%
Live with	Parents 97%	Parents 35%	Parents 25%
	Grandparents 3%	Friends 62%	Friends 75%
		Partner 3%	
New friends	42%	45%	67%
Changed groups	19%	19%	19%
Further apart	10%	13%	6%
Back in contact	3%	0%	0%
No change	26%	23%	8%

Note. Education refers to participants' current course of study. Participants stated whether their living arrangements and friendship groups had changed in the previous 12 months. Friendship changes were categorised into one of five categories: making new friends, changing friendship groups, growing further apart from friends, coming back into contact with friends or no change.

Table 4.2 shows a higher percentage of 18 year olds (55%) reported having a job, in comparison to 39% of 19 year olds and 35% of 17 year olds. Seventeen year olds were studying for AS levels (45%), A2 levels (52%) and BTEC (3%), whilst a higher percentage of 18 and 19 year olds were university students (81% and 97%). The 19-year-old group had greater independence away from family, with 75% reporting living with friends instead of parents compared to 0% of 17 and 62% of 18 year olds. Seventy five per cent of 19 year olds reported their living arrangements had changed in the last year compared to 16% of 17 and 68% of 18 year olds. The percentage of participants living with their parents decreased with age from 97% of 17 year olds, 35% of 18 year olds and 25% of 19 year olds. A similar percentage of participants reported making new friends across 17-year-old (42%) and 18-year-old (45%) age groups; this was greatest in

19 year olds (67%) presumably because of changed living arrangements. These demographic data show the 18 and 19-year-old groups had undergone greater change to their social and living environment than 17 year olds.

4.6 Self-report drug use at Time 1

There was no association between age and self-report cannabis use (χ^2 (2) = 4.62, p = 0.10, phi = 0.22, p = 0.10), ecstasy use (χ^2 (2) = 0.46, p = 0.80, phi = 0.07, p = 0.80) or alcohol use (χ^2 (2) = 3.73, p = 0.28, phi = 0.20, p = 0.16) indicating that drug use was similar across age groups.

4.6.1 Self-report cannabis use at Time 1

Forty-five per cent of 17 year olds, 26% of 18 year olds and 22% of 19 year olds reported using cannabis. From those, 100% of 17 year olds recruited to the current study and 88% of both 18 and 19 year olds reported they had started using cannabis by age 16 or younger. The youngest age of first reported cannabis use was found in the 17-year-old group; one participant began at age 13. Twenty-one per cent of 17 year olds, 13% of 18 year olds and 0% of 19 year olds in the current study reported using cannabis weekly or more often. Three participants in the youngest age group reported using the drug the day before testing, whereas for 18 year olds the most recent (n = 1) was a week prior to testing and 19 year olds was 2 months before (n = 1). Box plots showed that participants with recent cannabis use were not outliers on executive function and social cognition task scores.

4.6.2 Self-report ecstasy use at Time 1

Ecstasy use was similar across all age groups: 17 year olds (10%), 18 year olds (6%) and 19 year olds (6%) reported using ecstasy. Of these, 67% of 17 year old, 50% of 18 year old and 0% of 19-year-old ecstasy users had begun using ecstasy by age 16 or younger. One of the 17 year olds reported starting using this drug at age 14, which was earlier than first use in the other age groups. Last ecstasy use prior to participating in the study was a month or less for 33% of 17-year-old and 50% of 19-year-old ecstasy users and more than a month for 18-year-old users. There was no reported ecstasy use in the previous 24 hours prior to participating in the study.

4.6.3 Self-report alcohol use at Time 1

Seventy-seven per cent of 17 year olds, 94% of 18 year olds and 89% of 19 year olds reported drinking alcohol. Of these, 13% of 17 year olds, 34% of 18 year olds and 44% of 19 year olds reported that they consumed over the weekly limit. A higher percentage of 18 and 19 year olds reported alcohol use than 17 year olds, with the greatest amount of alcohol consumed by 19 year olds. These data indicate a shift from drug use to alcohol use as students commence university.

4.7 Self-report mental illness at Time 1

Reported mental illness was depression (3%) and OCD (6%) for 17 year olds, depression (3%), depression and ADHD (3%) and OCD (6%) for 18 year olds and depression (2%) and OCD (2%) for 19 year olds, indicating similar frequencies of mental health problems across groups.

4.8 IQ and mood data at Time 2

The sample at Time 2 consisted of 58 participants: 18 year olds (n = 15, 12 females: 3 males), 19 year olds (n = 17, 14 females: 3 males) and 20 year olds (n = 26, 21 females: 5 males). Descriptive statistics for age data in 18, 19 and 20 year old age groups are presented in Table 4.3.

Table 4.3. Descriptive statistics for age data in 18, 19 and 20 year olds age groups at Time 2

	18 year olds (n = 15)	19 year olds (n = 17)	20 year olds (n = 26)
Mean	18 years 5 months	19 years 4 months	20 years 4 months
Standard deviation	2.74	2.46	2.40
Range	18 years 1 month – 18 years 10 months	19 years 0 months – 19 years 8 months	20 years 0 months – 20 years 9 months

Data for IQ, positive and negative affect, anxiety, depression and pubertal development at Time 2 are reported in Table 4.4.

Table 4.4. Means and Standard Deviations for Wechsler Abbreviated Scale of Intelligence, Positive and Negative Affect Scale, Hospital Anxiety and Depression Scale and Pubertal Development Scale for age groups at Time Two

	18 year olds (*n* = 15)	19 year olds (*n* = 17)	20 year olds (*n* = 26)
Verbal IQ	108.47 (10.99)	110.94 (8.58)	105.27 (8.83)
Performance IQ	111.40 (12.11)	109.00 (7.54)	112.31 (10.82)
Full IQ	111.07 (11.44)	111.53 (8.22)	109.65 (6.99)
Positive affect	30.13 (7.75)	32.06 (6.87)	32.54 (5.29)
Negative affect	15.07 (5.18)	12.47 (2.81)	12.54 (2.85)
HADS Depression*	4.47 (2.67)	1.76 (1.68)	2.62 (2.56)
HADS Anxiety	8.73 (3.54)	6.12 (2.71)	7.00 (3.05)
Pubertal Development Scale	3.73 (0.22)	3.81 (0.21)	3.90 (0.15)

* $p < 0.05$

There were no group differences on Verbal IQ (F (2, 55) = 1.95, p = 0.153 η^2 = 0.07), Performance IQ (F (2, 55) = 0.53, p = 0.590, η^2 = 0.02) or Full Scale IQ (F (2, 55) = 0.27, p = 0.761, η^2 = 0.01) across groups at Time 2. Groups did not differ on Positive Affect (F (2, 55) = 0.68, p = 0.510, η^2 = 0.02) or Negative Affect (F (2, 55) = 2.84, p = 0.067, η^2 = 0.09). There were group differences on the HADS Depression score (F (2, 55) = 5.40, p = 0.007, η^2 = 0.16) with 18 year olds scoring significantly higher, indicating greater depression, than 19 year olds (t (30) = 3.47, p = 0.002) and 20 year olds (t (39) = 2.20, p = 0.034). No difference on the HADS Depression score was evident between 19 and 20 year olds (t (41) = 1.21, p = 0.234). There were no group differences on HADS Anxiety score (F (2, 55) = 2.95, p = 0.061, η^2 = 0.10). Anxiety and Depression scores between 8 and 10 are classed as mild (Zigmond & Snaith, 1983) indicating participants were lower than mild.

Data about employment, education and living and friendship changes are reported in Table 4.5.

Table 4.5. Data on employment, education and living and friendship changes at Time 2

	18 year olds (n=15)	19 year olds (n=17)	20 year olds (n=26)
Job	60%	59%	62%
Student	93%	94%	100%
Education	A2 levels 64%	A2 levels 6%	Degree 100%
	Degree 36%	Degree 94%	
Living changed	20%	71%	54%
Live with	Parents 87%	Parents 35%	Parents 23%
	Grandparents 13%	Friends 59%	Friends 61%
		On own 6%	Partner 12%
			Parents & partner 4%
New friends	40%	53%	15%
Changed groups	0%	6%	15%
Closer	0%	0%	8%
Further apart	20%	6%	0%
Back in contact	0%	0%	0%
No change	40%	35%	62%

Note. Education refers to participants' current course of study. Participants stated whether their living arrangements and friendship groups had changed in the previous 12 months. Friendship changes were categorised into one of five categories: making new friends, changing friendship groups, growing further apart from friends, coming back into contact with friends or no change.

A similar proportion of 18, 19 and 20 year olds reported having a job (approximately 60%). A higher percentage of participants in the 19-year-old group (71%) reported their living arrangements had changed in the previous 12 months compared to 20% of 18 year olds and 54% of 20 year olds. Eighteen year olds predominantly lived with their parents (87%) and the remainder lived with grandparents (13%). Nineteen year olds reported living with parents (35%), friends (59%) and on their own (6%). A higher percentage of 20 year olds lived with friends (61%) compared to 18 and 19 year olds. Twenty three per cent of 20 year olds lived with their parents, 12% with their partner and 4% with their parents and partner. A higher percentage of 19 year olds (53%) reported making new friends in the previous 12 months, compared to 40% of 18 year olds and 15% of 20 year olds. Twenty per cent of 18 year olds reported becoming further apart from friends compared to 6% of 19 year olds and 0% of 20 year olds.

4.9 Self-report drug use at Time 2

There was no association between age and self-report cannabis use (χ^2 (2) = 3.86, p = 0.15, phi = 0.26, p = 0.15), ecstasy use (χ^2 (2) = 1.51, p = 0.47, phi = 0.16, p = 0.47) or alcohol use (χ^2 (2) = 0.55, p = 0.76, phi = 0.10, p = 0.76), indicating that drug use was similar across age groups at Time 2.

4.9.1 Self-report cannabis use at Time 2

The highest percentage of cannabis use was in 18 year olds (53%) compared to 35% of 19 year olds and 23% of 20 year olds. Age at first use in the 18-year-old group ranged from 14 years old to 17 years old, 13 to 16 years for the 19-year-old group and 15 to 19 years for the 20-year-old group. Self-reported cannabis use was most frequent in the 20-year-old group with one participant reporting they used cannabis once a week and another two or three times a month. In the 18-year-old group, previous cannabis use ranged from 4 days for one participant and one week for another to over a year before testing. In the 19-year-old group, one participant reported 3 days before testing, another 2 weeks and the remainder last used cannabis over a year prior to testing. In the 20-year-old group, two participants reported using the drug a week before testing, one two weeks before and the remainder over a year before testing.

4.9.2 Self-report ecstasy use at Time 2

Twenty per cent of 18 year olds, 6% of 19 year olds and 12% of 20 year olds reported using ecstasy. In the 18-year-old group, age at first use was reported at age 15, 17 and 18 with last use of the drug reported two weeks, 5 months and 3 years ago. The only participant in the 19-year-old group who reported using ecstasy started at age 18 and had used the drug once two weeks prior to testing. Of the three 20 year old participants who reported ecstasy use, two first used it at age 17 and one at age 18. Previous ecstasy use was reported as 3 months, 6 months and 3 years ago.

4.9.3 Self-report alcohol use at Time 2

A slightly higher percentage of 19 year olds reported consuming alcohol (94%) compared to 87% of 18 year olds and 89% of 20 year olds. Of these participants who consumed alcohol, 23% of 18 year olds, 29% of 19 year olds and 30% of 20 year olds reported consuming over the weekly alcohol limit.

4.10 Self-report mental illness at Time 2

Frequency of mental illness was similar across 18, 19 and 20 year old groups with no participants reporting mental illness in 18 and 19 year olds, whilst one 20 year old reported depression.

To summarise, the age groups at Time 1 and Time 2 were broadly comparable on mood state, anxiety and depression scores, which were not at clinically significant levels according to guidelines by Zigmond and Snaith (1983). Whilst there were some group differences, they did not reflect severe mental illness and fluctuated between moderate/mild to normal. At both time points cannabis, ecstasy and alcohol use were similar across age groups. Chi squared tests found no association between whether participants took part at Time 1 or both time points and self-report alcohol, cannabis and ecstasy use and changes in living arrangements. Data was further explored by comparing Time 1 IQ and mood data for participants who took part at Time 1 or both time points. No group differences were found on the HADS Depression and Anxiety scores, Positive Affect and Negative Affect, Performance or Full Scale IQ. Participants who took part at Time 2 had a significantly higher Time 1 Verbal IQ relative to participants who did not participate at Time 2, although IQ scores are within the normal range. Overall, the Time 2 sample was representative of the Time 1 sample.

Chapter 5

Time 1 cross section analyses

5.1 Chapter overview

This chapter presents Time 1 cross sectional data from 17, 18 and 19 year olds on a battery of executive function and social cognition tasks. The present late adolescent and early adulthood executive function and social cognition data is compared to existing adulthood data from published studies in section 5.6. Gender comparisons are reported in section 5.7. Following this, the effects of IQ, drug and alcohol use, living arrangement and pubertal development on task performance are reported. Findings are discussed in relation to previous research.

5.2 Distribution of data

To assess the distribution of the data, histograms, skewness statistics and box plots per age group were examined (see appendix section 3 for examples of box plots). Clark-Carter (2004) recommended that skewness statistics ranging between ±2.85 are parametric. Using these guidelines, the data are parametric with the exception of combined repeated sorts on the D-KEFS Sorting Test for 18 and 19 year olds (skewness = 3.73 and 6.00 respectively). Chi square, a non-parametric test, was used to analyse the repeated sorts data.

The following box plots had no outliers: IRI Fantasy, IRI Perspective Taking, IRI Personal Distress, D-KEFS Letter Fluency, D-KEFS number of correct free sorts, description score for sort recognition and description score for verbal sorts, D-KEFS Tower achievement score and Tower time per move. The histograms for the Eyes Test were slightly negatively skewed and a low outlier was present on the 17 and 18 year old group box plots, whereas no outliers were evident in the 19 year old group. The histograms for the Voices Test were generally normally distributed. The MASC Total score box plots showed one low outlier for 17 year olds, a low and high outlier for 18 year olds and no outliers for 19 year olds. For IRI Empathic Concern there was a high outlying score in the 19 year old group with no outliers for the 17 and 18 year old groups. The Hayling Scaled boxplots had outliers for the 17 and 18 year old groups whereas the 19 year old group had no outliers. The Brixton scaled box plots had a low outlier for the 17 year old group, no outliers for the 18 year old group with a high outlier and two low outliers present in the 19 year old group. For free sort description score the 17 and 19 year old groups had no outliers whereas there were two low outlying scores in the 18 year old group. There was a low outlying score in the 17 year old group, three low and high outliers in the 18 year old group and no outlying scores in the 19 year old group for D-KEFS perceptual scores descriptive score The box plots for towers completed showed a low outlying score for 17 year olds, two for 18 year olds and one for the 19 year old group. Outliers were retained for the analyses because these are true neuropsychological task scores (Finch, 2012).

5.3 Task scores reported

Inferential statistics are reported in raw scores, with the exception of Hayling and Brixton Tests, for ease of comparison across tests because some measures do not have standardised score equivalents. Standardised scores indicate participants' performance relative to peers the same age. Scaled scores, instead of raw scores, are reported for the Hayling and Brixton Tests because these are reported extensively in the literature (e.g. Barker et al., 2010; Frangou, Donaldson, Hadjulis, Landau & Goldstein, 2005; Joshua, Gogos & Rossell, 2009; Wood & Liossi, 2005). Higher scaled scores on the Hayling Test indicate more accurate response inhibition and higher scaled scores on the Brixton Test relate to greater rule detection compared to lower scores.

Waber et al. (2007) noted that standardised scores capture individual differences, but are not sensitive to developmental differences and recommended the analysis of raw scores. Raw scores are reported for the D-KEFS Letter Fluency, Sorting and Tower Tests with higher Letter Fluency Task scores indicating greater strategy generation. Several indices are reported on the Sorting Test: number of free sorts correct, description score for free sorts, description score for sort recognition and description score for verbal and perceptual sorts with a higher score indicating better concept formation. Number of Towers completed, Achievement score, mean first move time, move accuracy and time per move are reported for the D-KEFS Tower Test. Primary measures for the D-KEFS tests are provided in this chapter; Delis, Kaplan and Kramer (2001) described these as a global achievement score or process scores for key task components. As there is only one primary measure for the Tower Test, optional measures are reported in addition, consistent with previous research (e.g. Larochette, Benn & Harrison, 2009), to provide a more comprehensive assessment.

5.4 Executive function group differences

One way between group ANOVAs were conducted with task scores to identify group differences in 17, 18 and 19 year olds on executive function and social cognition task scores. Considerations when reporting inferential statistics are discussed first. ANOVAs are reported in preference to MANOVA because in MANOVA moderately correlated dependent variables decrease power (Tabachnik & Fidell, 2007). As correlations between dependent variables increase, power of MANOVA decreases (Ramsey, 1982, cited in Field, 2005). Executive function correlations at Time 1 range from $r = 0.20$ to $r = 0.85$ for executive function tasks and $r = 0.20$ to $r = 0.83$ for social cognition tasks. The high r values are for variables from the same task rather than variables across tasks. Post-hoc Tukey HSD tests are reported, because these are conservative when conducting a large number of comparisons (Dancey & Reidy, 2004).

While some statisticians recommend a more stringent p value is needed with multiple tests (e.g. Shaffer, 1995), the p value is not adjusted for multiple testing because this increases Type II errors, the probability of accepting the null hypothesis when it is false (Perneger, 1998) and there is the possibility of loss of power (Field, 2005). Rothman (1990) argued that not adjusting p values is more preferable to adjusting them because this results in fewer errors of interpretation and adjusting for multiple comparisons could lead to important findings being missed. Perneger (1998) argued that adjustments are applicable to Statistical Test Theory (Neyman & Pearson, 1928) and are useful in repetitive decision making, but are not suitable when analysing data. Furthermore, Perneger (1998) commented that multiple adjustments are interpreted differently depending on the number of other tests conducted. The approach of not adjusting the p value applies to all subsequent analyses in this thesis.

Descriptive statistics for executive function tasks are presented in Table 5.1. All p values are reported as two tailed unless otherwise stated.

Table 5.1. Means and standard deviations for age groups at Time 1 on executive function tasks (Hayling & Brixton Tests, D-KEFS Letter Fluency, Card Sorting and Tower Task)

	17 year olds ($n = 31$)	18 year olds ($n = 31$)	19 year olds ($n = 36$)
Measures of response inhibition (Hayling Test) and rule detection (Brixton Test)			
Hayling scaled	5.97 (1.25)	5.74 (1.37)	5.22 (1.76)
Brixton scaled	7.39 (2.00)	7.23 (1.77)	7.17 (1.60)
Measure of strategy generation (D-KEFS Letter Fluency)			
Letter fluency *	39.35 (7.56)	34.00 (8.60)	36.06 (7.36)
Measures of concept formation (D-KEFS Sorting Test)			
Free sorts correct *	12.00 (1.97)	10.74 (1.53)	10.83 (1.98)
Free sort description score *	45.23 (7.66)	39.97 (7.78)	41.75 (7.34)
Sort recognition description score *	48.97 (6.44)	44.42 (7.89)	45.08 (6.81)
Verbal sorts description score	31.84 (7.96)	28.71 (7.10)	30.17 (8.11)
Perceptual sorts description score *	62.35 (8.92)	56.94 (9.99)	56.31 (8.17)
Measures of planning (D-KEFS Tower Test)			
Number of Tower items completed	8.42 (0.85)	8.13 (0.96)	8.33 (0.72)
Tower achievement score	18.26 (2.85)	18.32 (2.70)	17.64 (2.95)
Mean first move time	3.08 (1.10)	3.89 (1.83)	3.96 (1.84)
Time per move	2.60 (0.62)	2.80 (0.78)	2.74 (0.52)
Move accuracy	1.66 (0.44)	1.57 (0.46)	1.65 (0.37)

* p<0.05

5.4.1 Response inhibition and rule detection (Hayling & Brixton Tests)

No significant age group differences were found on the Hayling Test, a measure of response inhibition (F (2, 95) = 2.23, p = 0.113, η^2_p = 0.05) or Brixton Test, a measure of rule detection (F (2, 95) = 0.13, p = 0.875, η^2 < 0.01).

5.4.2 Strategy generation (D-KEFS Letter Fluency Test)

There were significant age group differences for scores on the Letter Fluency Test, a measure of strategy generation (F (2, 95) = 3.70, p = 0.028, η^2_p = 0.07). Results of post hoc Tukey tests showed that 17 year olds scored higher, indicating better performance, than 18 year olds on the Letter Fluency Test (t (95) = 2.69, p = 0.023). There were no significant differences between 17 year olds and 19 year olds (t (95) = 1.72, p = 0.203) or 18 and 19 year olds (t (95) = 1.07, p = 0.534).

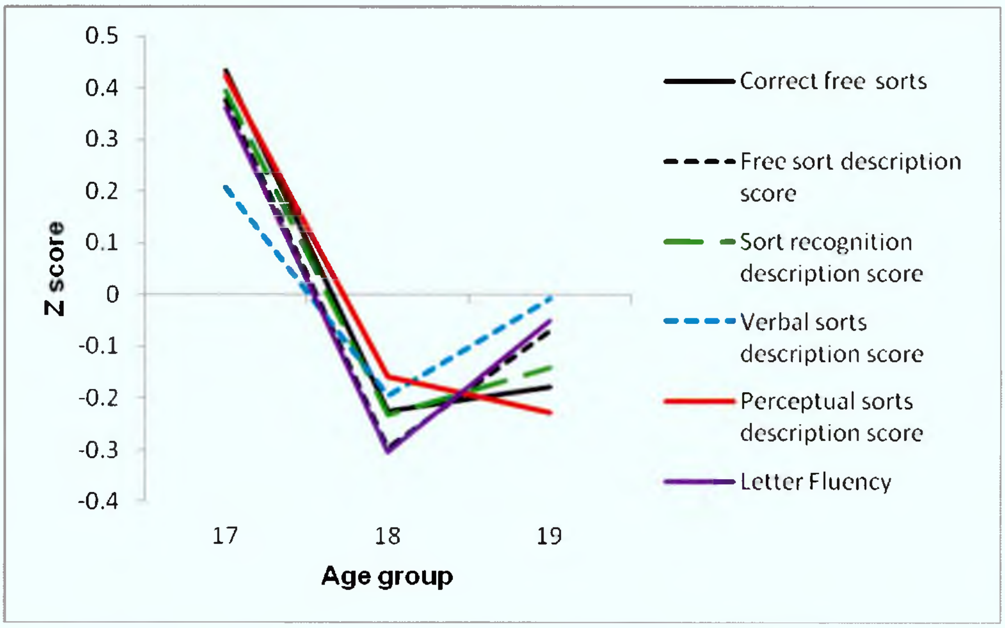
5.4.3 Concept formation (D-KEFS Sorting Test)

There were a number of significant age group differences on the D-KEFS Sorting Test, a measure of concept formation. For number of correct free sorts (F (2, 95) = 4.58, p = 0.013, η^2_p = 0.09), 17 year olds scored significantly higher than 18 year olds (t (95) = 2.69, p = 0.023) and 19 year olds (t (95) = 2.59, p = 0.030). Number of correct free sorts were not significantly different for 18 year olds and 19 year olds (t (95) = 0.20, p = 0.978). On free sort description score (F (2, 95) = 3.87, p = 0.024, η^2_p = 0.08), 17 year olds scored significantly higher than 18 year olds (t (95) = 2.73, p = 0.020). There were no significant differences between 17 year olds and 19 year olds (t (95) = 1.87, p = 0.153) or 18 and 19 year olds (t (95) = 0.96, p = 0.604). On sort recognition description score (F (2, 95) = 3.81, p = 0.026, η^2_p = 0.07), 17 year olds scored significantly higher than 18 year olds (t (95) = 2.54, p = 0.034). There were no significant age group differences for description score for verbal sorts (F (2, 95) = 1.26, p = 0.278, η^2_p = 0.03). On description score for perceptual sorts (F (2, 95) = 4.37, p = 0.02, η^2 = 0.08), 17 year olds scored higher than 18 (t (95) = 2.37, p = 0.050) and 19 year olds (t (95) = 2.74, p = 0.020).

To summarise, 17 year olds scored significantly higher, indicating more accurate concept formation, than 18 year olds on four components of concept formation (number of correct free sorts, free sort description score, sort recognition description score and description score for perceptual sorts). Seventeen year olds also scored significantly higher, indicating more accurate concept formation, than 19 year olds on number of correct free sorts and description score for perceptual sorts.

Raw data were transformed into standardised *z* scores to graphically illustrate peaks and troughs in task performance where group differences were evident for concept formation and strategy generation (D-KEFS Sorting and Letter Fluency Tests).

Figure 5.1. Z score graph for 17, 18 and 19 year old age groups on the D-KEFS Sorting Test, a measure of concept formation, and D-KEFS Letter Fluency Test, a measure of strategy generation



Graphed data in Figure 5.1 follow a U shape suggesting non-linear development of concept formation and strategy generation with a peak at age 17, dip in performance at age 18 and slight upturn in ability on these measures in the 19 year old group, although the difference between 18 and 19 year olds is not significant.

5.4.3.1 Perseveration on the D-KEFS Sorting Test

A Chi square test was conducted to explore age group and number of repeated sorts on the Sorting Test because these variables are categorical. A significant association was found between age and repeated sorts on the D-KEFS Sorting Test (χ^2 (2, N = 98) = 14.75, p < 0.001, Cramer's V = 0.41) with repeated sorts decreasing with age. The highest per cent of repeated sorts was evident in the 17 year old group (35.5%), followed by 6.5% of 18 year olds and 2.8% of 19 year olds repeated sorts. Fisher's Exact Test is reported because more than 25% of cells have an expected frequency of less than 5 (Dancey & Reidy, 2004). Seventeen percent of variation in frequency counts of repeated sorts can be accounted for by age. Table 5.2 demonstrates that 17 year olds made more repeated sorts, with repeated sorts (perseveration) decreasing with age indicating better performance.

Table 5.2. Number of repeated sorts by age group on the D-KEFS Sorting Test

	Zero	One	Two	Three	Four
17 year olds	20	9	1	0	1
18 year olds	29	2	0	0	0
19 year olds	35	0	1	0	0

5.4.4 Measures of planning (D-KEFS Tower Test)

Several indices were calculated for the Tower Test according to the D-KEFS examiner's manual: number of items completed, achievement score (takes into account if items are passed and also the number of moves), mean first move time (total first move time / items administered), time per move (total completion time / total number of moves) and move accuracy (total number of moves / total minimum number of moves required). There were no age group differences for number of Tower items completed (F (2,95) = 0.98, p = 0.378, η^2 = 0.02), Tower achievement score (F (2,95) = 0.60, p = 0.549, η^2_p = 0.01), Tower mean first move time (F (2,95) = 2.87, p = 0.062, η^2_p = 0.06), Tower time per move (F (2, 95) = 0.81, p = 0.447, η^2_p = 0.02) and Tower move accuracy (F (2,95) = 0.44, p = 0.643, η^2_p < 0.01). These results indicate that ability on these measures did not differ significantly as an effect of age in late adolescence in the present cohort.

5.5 Social Cognition group differences

Raw scores on social cognition tasks were analysed with one way between group ANOVAs across age groups. Descriptive statistics are presented in Table 5.3.

Table 5.3. Means and standard deviations for age groups at Time 1 on social cognition tasks with range of possible scores (Reading the Mind in the Eyes, Reading the Mind in the Voices, Movie for the Assessment of Social Cognition and Interpersonal Reactivity Index)

	17 year olds *(n = 31)*	18 year olds (*n* = 31)	19 year olds (*n* = 36)
Static visual stimuli (Reading the Mind in the Eyes Test)			
Eyes Range 0 - 36	27.26 (4.83)	27.61 (3.55)	28.23 (3.26)
Auditory stimuli (Reading the Mind in Voices Test)			
Voices Range 0 - 25	17.06 (2.25)	16.97 (2.66)	16.86 (2.26)
Dynamic visual and auditory stimuli with social interaction (MASC)			
MASC correct	35.48 (3.79)	35.19 (3.25)	35.83 (3.32)
MASC excessive mental state inference errors	5.48 (2.78)	6.16 (2.25)	5.19 (2.73)
MASC insufficient mental state inference errors	2.48 (1.81)	2.39 (1.26)	2.69 (1.51)
MASC no ToM errors Range 0 - 45	1.55 (0.93)	1.26 (1.00)	1.28 (1.06)
Self report (Interpersonal Reactivity Index)			
IRI Fantasy	18.35 (5.35)	16.65 (6.06)	17.18 (4.37)
IRI perspective	17.03 (3.85)	16.90 (4.00)	17.03 (4.04)
IRI empathic	21.29 (3.45)	20.26 (3.66)	20.60 (3.08)
IRI personal distress Range 0 - 28	12.61 (4.67)	14.52 (5.28)	14.06 (4.21)

All p > 0.05

5.5.1 Reading the Mind in the Eyes and Voices Tests

One way between group ANOVAs showed no significant age group differences in total scores on the Reading the Mind in the Eyes (F (2, 94) = 0.52, p = 0.594, η^2_p = 0.01) or Reading the Mind in the Voice tasks F (2, 95) = 0.06, p = 0.941, η^2_p < 0.01).

5.5.2 Movie for the Assessment of Social Cognition

Groups were not different on the total score of the Movie for the Assessment of Social Cognition (F (2, 95) = 0.29, p = 0.750, η^2_p < 0.01), MASC excessive mental state inference errors (i.e. over-attribution of mental state content) (F (2, 95) = 1.19, p = 0.310, η^2_p = 0.02), MASC insufficient mental state errors (i.e. under-attribution of mental state content) (F (2, 95) = 0.35, p = 0.703, η^2_p < 0.01) and MASC no Theory of Mind errors (i.e. physical causation, no mental state attribution) (F (2, 95) = 0.83, p = 0.438, η^2_p = 0.02).

5.5.3 Interpersonal Reactivity Index

For self-report empathy, there were no group differences on the four factors of the Interpersonal Reactivity Index: Fantasy (F (2, 94) = 0.87, p = 0.424, η^2_p = 0.02), Perspective Taking (F (2, 94) = 0.01, p = 0.989, η^2_p < 0.01), Empathic Concern (F (2, 94) = 0.75, p = 0.476, η^2_p = 0.02) and Personal Distress (F (2, 94) = 1.38, p = 0.256, η^2_p = 0.03).

5.6 Comparison with existing adult data

The present late adolescence / early adulthood data is compared to existing adulthood data to contextualise the present data and provide a broader comparison. A summary of how executive function and social cognition change between late adolescence and adulthood based on published data is presented in Tables 5.4 and 5.5. The ▲ symbol in the table indicates whether the highest task performance is at age 17, 18, 19 years or adulthood. The existing adulthood papers were chosen because they specified the age of the adult group and gave descriptive statistics for task performance on identical tasks to the present study. Some studies (e.g. Greve, Farrell, Besson & Crouch, 1995) had typically developing participants. Where the study involved atypically developing participants the control data was used for comparison (e.g. Kirchner, Hatri, Heekeren & Dziobek, 2011).

Table 5.4. Comparison between late adolescent data (17, 18, 19 year olds) and existing adult data on executive function tasks

	17 year olds (*n = 31)*	18 year olds (*n* = 31)	19 year olds (*n* = 36)	Existing adult data
Measures of response inhibition and rule detection				
Hayling scaled	5.97 (1.25)	5.74 (1.37)	5.22 (1.76)	5.60 (0.76) ▲ *M* =28.2 years Henry, Mazur & Rendell (2009)
Brixton raw errors	12.10 (6.76)	11.94 (4.56)	12.47 (5.50)	10.7 (35.00) ▲ *M* = 22.8 years Andrés & Van der Linden (2000)
Measure of Strategy generation				
Letter fluency	39.35 (7.56)	34.00 (8.60)	36.06 (7.36)	48.3 (17.57) ▲ *M* =28.2 years Henry, Mazur & Rendell (2009)
Measures of concept formation				
Free sorts correct	75.00%	67.13%	67.69%	80.22% ▲ *M* = 22 years
Free sort description score	70.67% ▲	62.45%	65.23%	71.89% ▲
Sort recognition description score	76.52% ▲	69.41%	70.44%	76.72% ▲ Greve, Farrell, Besson & Crouch (1995)
Measures of planning				
Number of Tower items completed	8.42 (0.85)	8.13 (0.96)	8.33 (0.72)	
Tower achievement score	18.26 (2.85)	18.32 ▲ (2.70)	17.64 (2.95)	17.88 (3.83) *M* = 23.03 years
Mean first move time	3.08 (1.10)▲	3.89 (1.83)	3.96 (1.84)	34.21 (27.81)
Time per move	2.60 (0.62)▲	2.80 (0.78)	2.74 (0.52)	3.30 (1.08)
Move accuracy	1.66 (0.44)	1.57 (0.46)▲	1.65 (0.37)	1.68 (0.37) Larochette, Benn & Harrison (2009)

Table 5.5. Comparison between late adolescent data (17, 18 and 19 year olds) and existing normative adult data on social cognition tasks

	17 year olds *(n = 31)*	18 year olds *(n* = 31)	19 year olds *(n* = 36)	Existing adult data
Static visual stimuli				
Eyes	27.26 (4.83)	27.61 (3.55)	28.23 (3.26)▲	25.1 (3.8) *M* = 31.8 years Kirchner, Hatri, Heekeren & Dziobek (2011)
Auditory stimuli				
Voices	17.06 (2.25)	16.97 (2.66)	16.86 (2.26)	18.77 (2.41) ▲ *M* = 24.3 years Golan, Baron-Cohen, Hill & Rutherford (2007)
Dynamic visual and auditory stimuli with social interaction				
MASC correct	35.48 (3.79)	35.19 (3.25)	35.83(3.32) ▲	33.34 (5.26) *M* = 33.2 years
MASC excessive mental state inference errors	5.48 (2.78)	6.16 (2.25)	5.19 (2.73)	Ritter et al. (2011)
MASC insufficient mental state inference errors	2.48 (1.81)	2.39 (1.26)	2.69 (1.51)	
MASC no ToM errors	1.55 (0.93)	1.26 (1.00)	1.28 (1.06)	
Self-report empathy				
IRI Fantasy	18.35 (5.35)▲	16.65 (6.06)	17.86 (4.37)	16.30 (5.40)
IRI Perspective	17.03 (3.85)	16.90 (4.00)	17.03 (4.04)	20.40 (4.20)▲
IRI Empathic	21.29 (3.45)	20.26 (3.66)	20.60 (3.08)	21.60 (4.30)
IRI Personal distress	12.61 (4.67)	14.52 (5.28)	14.06 (4.21)	10.10 (3.90) ▲ Hassenstab et al. (2007)

▲ best performance on tasks

Tables 5.4 and 5.5 show a combination of changes, with some studies demonstrating functions peaking in late adolescence (achievement score, mean first move time, time per move and move accuracy on the D-KEFS Tower Test) while other functions peak in adulthood (Brixton Test: rule detection, D-KEFS Letter Fluency: response generation and D-KEFS free sorts correct: concept formation). Seventeen year olds scored similarly to adults on concept formation (free sorts description score and sort recognition description score), with poorer performance in 18 and 19 year old groups, consistent with the notion of non-linear development.

Table 5.5 shows that the 19 year old group showed better performance on the Reading the Mind in the Eyes Test (emotion recognition with static stimuli) and the total score of the Movie for the Assessment of Social Cognition (a dynamic measure) relative to adults, 17 and 18 year olds. Adults attained the highest score on the Reading the Mind in the Voice Test, indicating that emotion recognition from auditory stimuli continues to develop between late adolescence and adulthood. Seventeen year olds rated themselves highest relative to 18 year olds, 19 year olds and adults on the Fantasy scale of the IRI suggesting that 17 year olds have a higher tendency to associate with characters in books and films. The data show that Perspective Taking, the tendency of a person to consider other peoples' viewpoints, continues to develop following late adolescence, whereas Empathic Concern, sympathetic feelings towards other people's misfortune, is relatively stable across late adolescence and adulthood. Changing living arrangements and friendship groups in late adolescence may lead to higher Personal Distress ratings, feelings of apprehension in stressful situations, in late adolescence relative to adults. Evidence for changing living arrangements and friendship groups in the present sample is reported in Chapter 4. Sixteen per cent of 17 year olds, 68% of 18 year olds and 75% of 19 year olds reported a change in living arrangements in the previous 12 months. Forty two % of 17 year olds, 45% of 18 year olds and 67% of 19 year olds reported making new friendships.

5.7 Correlations between social cognition and executive function task scores

Appendix Section 4 presents correlations between executive function and social cognition task scores to explore the relationship between these variables. However, it must be noted that correlation does not imply causation (Dancey & Reidy, 2004).

Scores on the Eyes Test ($r = 0.39, p < 0.001$), Voices Test ($r = 0.33, p = 0.001$), MASC correct ($r = 0.23, p = 0.023$) and IRI Perspective Taking ($r = 0.21, p = 0.037$) positively correlated with the Brixton Test, a measure of rule detection. MASC insufficient mental state errors negatively correlated with scores on the Brixton Test ($r = -0.22, p = 0.034$). It is possible that scores on the Eyes, MASC and Brixton Tests correlated due to the visual nature of tasks. For example, the Eyes Test requires participants to identify mental states shown in photographs of eye regions, the MASC requires attribution of mental states to characters in dynamic film clips and the Brixton Test requires participants to identify a rule in visual stimuli. Scores on the Brixton Test and Voices Test could correlate due to good pattern identification resulting in successful rule detection on the Brixton Test and informing emotion recognition in auditory stimuli on the Voices Test.

Letter fluency scores, a measure of strategy generation, positively correlated with MASC correct scores ($r = 0.28, p = 0.005$) assessing emotion recognition in dynamic, visual and auditory stimuli and negatively correlated with MASC insufficient errors ($r = -0.24, p = 0.020$). Strategy generation may require flexible behaviour allowing participants to generate words beginning with a particular letter in a methodical way. Flexible behaviour is utilised in social situations when generalising concepts to different situations (Ahmed & Miller, 2011).

Scores on the Voices Test, an assessment of emotion recognition in the auditory domain, significantly correlated with several indices of the Sorting Test, a measure of concept formation: free sorts correct ($r = 0.22, p = 0.031$), free sort description score ($r = 0.20, p < 0.050$), sort recognition description score ($r = 0.25, p = 0.014$), description score for verbal sorts ($r = 0.23, p = 0.025$) and description score for verbal perceptual sorts ($r = 0.21, p = 0.041$). It is possible that Voices Test scores correlated with indices on the Sorting Test due to a verbal component of the tasks. Voices Test scores also correlated with number of towers completed, a measure of planning ($r = 0.27, p = 0.008$). Planning may be utilised in social situations to decide how to act in response to another person's behaviour.

5.8 Gender differences

Gender differences in executive function and social cognition were examined as previous research has indicated gender may affect task performance with females scoring significantly higher than males on social cognition tasks (e.g. Kalkut et al., 2009; Derntl et al., 2010; Baron-Cohen, Jolliffe, Mortimore & Robertson, 1997). Group data were collapsed to provide two subgroups: females ($n = 77$) and males ($n = 21$). Due to uneven sample sizes, Mann Whitney U tests were conducted to compare task performance across males and females. Descriptive statistics (median and range) are presented in Table 5.6.

Table 5.6. Medians and ranges of executive function task scores for females and males

	Females (n = 77)	Males (n = 21)
Measures of response inhibition (Hayling Test) and rule detection (Brixton Test)		
Hayling scaled	6.00 (1.00 - 9.00)	6.00 (4.00 - 7.00)
Brixton scaled	7.00 (1.00 - 10.00)	7.00 (4.00 - 10.00)
Measure of strategy generation (D-KEFS Letter Fluency)		
Letter fluency	37.00 (17.00 - 56.00)	36.00 (19.00 - 57.00)
Measures of concept formation (D-KEFS Sorting Test)		
Free sorts correct	11.00 (7.00 - 15.00)	11.00 (9.00 - 15.00)
Free sort description score	41.00 (13.00 - 59.00)	44.00 (36.00 - 54.00)
Sort recognition description score	45.00 (23.00 - 60.00)	48.00 (35.00 - 57.00)
Verbal sorts description score	31.00 (12.00 - 47.00)	32.00 (19.00 - 48.00)
Perceptual sorts description score *	58.00 (34.00 - 80.00)	61.00 (47.00 - 72.00)
Measures of planning (D-KEFS Tower Test)		
Number of Tower items completed	8.00 (6.00 - 9.00)	9.00 (6.00 - 9.00)
Tower achievement score	18.00 (13.00 – 24.00)	17.00 (14.00 - 24.00)
Mean first move time	3.40 (1.40 - 9.70)	3.10 (1.40 - 7.70)
Time per move	2.70 (1.80 - 4.40)	2.40 (1.60 - 4.00)
Move accuracy	1.50 (1.00 - 3.40)	1.70 (1.10 - 3.30)

* $p < 0.05$

There was a significant difference for description score of perceptual sorts, a measure of concept formation (U = 576.50, Z = 2.01, p = 0.04, r = 0.20) with males scoring higher than females. This is in line with Greve, Farrell, Besson and Crouch (1995) who reported that males scored significantly higher than females on number of correct free sorts and free sort description score on the California Card Sorting Test, a measure of concept formation (Delis, Squire, Bihrle & Massman, 1992). There were no other significant gender differences on executive function task scores. Other research supports this finding showing no gender differences in behavioural results on letter fluency (Harrison, Buxton, Husain & Wise, 2000), planning assessed with the Tower of London (Boghi et al., 2006; Luciana, Collins, Olson & Schissel, 2009) and inhibition (Magar, Phillips & Hosie, 2010).

More male participants were recruited in a second testing phase between January 2011 to December 2011 to account for the gender imbalance resulting in a sample size of 119 participants, with 77 females (*M* age = 220.26, *SD* = 9.07) and 42 males (*M* age = 222.43, *SD* = 8.39). Additional males completed the following measures: Positive Affect and Negative Affect Scale (Watson, Clark & Tellegen, 1988), Hospital Anxiety and Depression Scale (Zigmond & Snaith, 1983), Self-Administered Rating Scale for Pubertal Development (Carskadon & Acebo, 1993) and the Wechsler Abbreviated Scale of Intelligence (Wechsler, 1999). Participants completed the Reading the Mind in the Eyes Test (Baron-Cohen et al., 2001), Reading the Mind in the Voice Test (Golan et al., 2007), Movie for the Assessment of Social Cognition (Dziobek et al., 2006) and the Interpersonal Reactivity Scale (Davis, 1983). Participants only completed social cognition tasks because present and existing findings indicate no or few gender differences on executive function tasks (Boghi et al., 2006; De Luca et al., 2003; Harrison, Buxton, Husain & Wise, 2000; Luciana, Collins, Olson & Schissel, 2009; Magar, Phillips & Hosie, 2010). Descriptive statistics (median and range) are presented in Table 5.7.

Table 5.7. Medians and ranges of mood, IQ and social cognition task scores for males and females

	Females (n = 77)	Males (n = 42)
Demographics		
Positive Affect	32.00 (17.00 - 42.00)	30.00 (21.00 - 47.00)
Negative Affect	12.00 (10.00 - 34.00)	12.50 (10.00 - 21.00)
Anxiety *	8.00 (0 - 16.00)	7.00 (2.00 - 14.00)
Depression	3.00 (0 - 16.00)	2.00 (0 - 8.00)
WASI Verbal IQ	103.00 (85.00 - 138.00)	106.00 (85.00 - 122.00)
WASI Performance IQ	104.00 (77.00 - 119.00)	105.00 (89.00 - 127.00)
WASI Full IQ	105.00 (85.00 - 133.00)	107.00 (87.00 - 117.00)
Static visual stimuli		
Eyes	28.50 (11.00 - 34.00)	28.00 (16.00 - 32.00)
Auditory stimuli		
Voices	17.00 (10.00 - 22.00)	17.00 (13.00 - 20.00)
Dynamic visual and auditory stimuli with social interaction		
MASC correct	36.00 (24.00 - 43.00)	36.00 (28.00 - 39.00)
MASC excessive mental state inference errors *	5.00 (0 - 12.00)	6.00 (3.00 - 12.00)
MASC insufficient mental state inference	3.00 (0 - 9.00)	2.00 (0 - 5.00)
MASC no ToM errors	1.00 (0 - 5.00)	1.00 (0 - 3.00)
Self-report empathy		
IRI Fantasy	17.00 (4.00 – 28.00)	17.00 (8.00 - 27.00)
IRI perspective	17.50 (8.00 – 25.00)	16.00 (8.00 - 24.00)
IRI empathic *	21.00 (15.00 – 28.00)	19.00 (13.00 - 24.00)
IRI personal distress *	14.50 (2.00 – 26.00)	11.00 (4.00 - 20.00)

* $p < 0.05$

There was a significant group difference on HADS Anxiety (U = 1076.50, Z = 2.10, p = 0.04, r = 0.19) with females scoring significantly higher than males. For social cognition measures, there were significant gender differences on the MASC, a social cognition task using dynamic stimuli. Males made significantly more excessive mental state inference errors (i.e. over-attribution of mental state content) compared to females ($U = 1264.50$, $Z = 1.98$, $p < 0.05$, $r = 0.18$). Results of Mann Whitney tests also showed gender differences on two indices of the Interpersonal Reactivity Index, a self-report measure of empathy: Empathic Concern ($U = 1013.00$, $Z = 3.13$, $p < 0.01$, $r = 0.29$) and Personal Distress ($U = 930.50$, $Z = 3.60$, $p < 0.01$, $r = 0.33$). Empathic Concern, assessing sympathetic feelings to others, was significantly higher in females than males. Females also rated themselves significantly higher in Personal Distress than males, indicating that females experienced more anxiety than males in tense social situations.

To summarise, findings indicate that males outperformed females on description score for perceptual sorts, a measure of executive function indexing concept formation, and females outperformed males on excessive mental state inference errors of the Movie for the Assessment of Social Cognition, a measure of social cognition with dynamic stimuli. Females were higher than males on self-report empathy measures of Empathic Concern, an assessment of sympathetic feelings towards others, and Personal Distress, anxiety in tense social situations. Results indicate that gender differences were evident on only one subscale of executive function, one measure of social cognition and two self-report empathy subscales.

5.9 Contribution of IQ

To explore a possible contribution of IQ to executive function performance, Full Scale IQ scores were entered as a covariate for tasks showing significant group differences. With Full Scale IQ partialled out, number of correct free sorts (F (2, 94) = 3.49, p = 0.03) and description score for perceptual sorts (F (2, 94) = 3.56, p = 0.03) from the D-KEFS Sorting Test remained significant. Letter fluency (F (2, 94) = 2.52, p = 0.09), description score for free sorts (F (2, 94) = 2.76, p = 0.07) and sort recognition description score (F (2, 94) = 2.68, p = 0.07) were not significant. Results indicate a contribution of IQ to strategy generation performance on the Letter Fluency Task but not to correct free sorts and description score for perceptual sorts on the Sorting Test. It is important to note that Full Scale IQ was not different across groups (see Chapter 4).

To explore a possible contribution of Performance IQ to executive function task performance, Performance IQ was entered as a covariate for Letter Fluency and Sorting Tasks because these showed age group differences. With Performance IQ partialled out, number of correct free sorts (F (2, 94) = 3.78, p = 0.026) and description score for perceptual sorts (F (2, 94) = 3.91, p = 0.023) remained significant. Letter fluency (F (2, 94) = 2.89, p = 0.062), description score for free sorts (F (2, 94) = 2.98, p = 0.056) and sort recognition description score (F (2, 94) = 3.00, p = 0.055) were not significant. Similar to the analysis with Full Scale IQ as a covariate, these results indicate that Performance IQ contributes to strategy generation assessed with the Letter Fluency Task but not to free sorts correct and description score for perceptual sorts on the Sorting Test, a measure of concept formation.

5.10 Demographic effects on executive function and social cognition

5.10.1 Drug use

Research reported in Chapter 2 indicated that cannabis use (McHale & Hunt, 2008), ecstasy use (Yip & Lee, 2006), alcohol use (Parada et al., 2012) and pubertal development (Burnett et al., 2011) affect executive function and social cognition task performance. The effects of these variables on task performance were analysed and are reported below.

Independent samples t-tests were conducted on executive function and social cognition task scores with whether participants had used cannabis (n = 30) or not (n = 68) as the independent variable. There were no significant group differences, indicating that in the present sample cannabis use had no effect on social cognition (all p's > 0.23) and executive function (all p's > 0.14). Descriptive statistics for participants who reported using cannabis previously and participants who did not are presented in appendix sections 4 and 5.

5.10.2 Alcohol use

Independent samples t-tests were conducted for social cognition and executive function scores with whether participants drink alcohol or not as the independent variable. Whilst this is a brief assessment of alcohol use, it was useful to have an indication of alcohol use as previous research has often neglected this variable and research in Chapter 2 show that alcohol use can affect executive function and social cognition. Descriptive statistics for executive function and social cognition task scores of participants who reported alcohol use and participants who reported no alcohol use are presented in appendix section 6 and 7. Four indices of the D-KEFS Sorting Test showed significant group differences. For number of free sorts correct, the group who reported drinking alcohol ($M = 10.99$, $SD = 1.83$) scored lower than the group who reported not drinking alcohol ($M = 12.38$, $SD = 2.06$, t (96) = 2.52, $p = 0.013$). Similarly, for free sort description score participants who reported drinking alcohol ($M = 41.49$, SD = 7.55) scored lower than those who did not ($M = 47.46$, $SD = 7.76$, t (96) = 2.65, $p = 0.01$). Drinkers also scored lower ($M = 45.41$, $SD = 7.15$) on sort recognition description score than non-drinkers ($M = 50.62$, $SD = 6.58$, t (96) = 2.47, $p = 0.015$). The same pattern was found for description score for verbal sorts: participants who consumed alcohol ($M = 29.53$, $SD = 7.47$) scored lower than participants who did not drink alcohol ($M = 34.85$, $SD = 8.44$, t (96) = 2.35, $p = 0.021$). There were no group differences for social cognition task scores.

Participants also reported whether they consumed below or above the recommended weekly limit of alcohol consumption (see appendix sections 7 and 8 for descriptive statistics). Independent samples t-tests were conducted between weekly alcohol consumption and social cognition and executive function scores. Participants who consumed above the weekly limit ($M = 43.59$, $SD = 7.52$) scored lower than the group who drank less ($M = 46.82$, $SD = 6.85$) on the sort recognition description score (t (95) = 2.06, $p < 0.01$). Similarly, participants who consumed over the weekly limit group ($M = 54.37$, $SD = 9.5$) scored lower on the description score for perceptual sorts compared to the under the weekly limit group ($M = 59.8$, $SD = 8.79$, t (95) = 2.67, $p < 0.01$). There were no group differences for social cognition task scores. These results suggest that alcohol use over the weekly limit is associated with a lower ability to describe concept formation.

5.10.3 Changes in living arrangements

Two separate hierarchical multiple regressions were conducted to explore the contribution of age, living changes and anxiety to strategy generation and concept formation using scores on the Letter Fluency and Card Sorting Tests (number of free sorts correct) as criterion variables, with age entered in block one, changes in living arrangements in block two and anxiety in block three (see Tables 5.8 and 5.9). Strategy generation and concept formation were selected as criterion variables because group differences were found for these variables.

Table 5.8. Hierarchical regression analyses with age, living changes and HADS Anxiety as predictor variables and D-KEFS Letter Fluency score as the dependent variable.

	ΔR^2	ΔF	df	β
Step 1: Age	0.04*	3.31	1,87	- 0.19*
Step 2: Age	0.01	0.52	1,86	- 0.15
Living change				- 0.09
Step 3: Age	0.01	0.47	1,85	- 0.16
Living				- 0.10
Anxiety				- 0.08

* $p<0.05$ one tailed

Results in Table 5.8 show that in block one, age was a significant predictor (β = -0.19, t = 1.82, p = 0.036) and accounted for 19% of variance in response generation with greater age associated with better strategy generation. The addition of changes to living arrangements in block two showed age accounted for 15% of variance, whilst living arrangements accounted for 9% of variance on the Letter Fluency Task. In block three, age accounted for 16% of variance, with changes in living arrangements and anxiety accounting for 8% and 6% of variance on the Letter Fluency Task.

The hierarchical regression for the D-KEFS Sorting test is presented in Table 5.9.

Table 5.9. Hierarchical regression analyses with age, living changes and HADS Anxiety as predictor variables and number of correct free sorts on the D-KEFS Sorting Test as the dependent variable.

	ΔR^2	ΔF	df	β
Step 1: Age	0.06	5.68**	1,87	- 0.25**
Step 2: Age	<0.01	0.67	1,86	- 0.20*
Living change				- 0.10
Step 3: Age	<0.01	0.53	1,85	- 0.19
Living				- 0.08
Anxiety				0.08

* $p<0.05$ one tailed ** $p<0.01$ one tailed

Age was a significant predictor of number of free sorts correct and accounted for 25% of variance (β = -0.25, t = 2.38, p <0.01). The addition of changes to living arrangements in block two showed that age accounted for 20% of variance and living arrangements accounted for 10% of variance in number of free sorts correct. In block three, age accounted for 19% of variance and changes to living arrangements and anxiety accounted for 8% of variance to concept formation. These findings indicate that age contributes more to strategy generation (D-KEFS Letter Fluency Task) and concept formation (D-KEFS Sorting Test) than changes in living arrangements and anxiety. Increasing age was associated with poorer performance on the D-KEFS Sorting Test number of correct free sorts.

5.10.4 Pubertal Development

Participants' pubertal development was scored according to the criteria for the Pubertal Development Scale by Carskadon and Acebo (1993), with each item scored either 1 = not yet begun, 2 = barely started, 3 = definitely underway or 4 = seems complete. An average was calculated, with 4 indicating that puberty had been completed. Table 5.10 shows the number of participants who reported completing puberty or not completing puberty in each age group.

Table 5.10. Frequency of pubertal development for each age group

	Puberty not complete	Puberty complete
17 year olds (n = 31)	28	3
18 year olds (n = 31)	17	14
19 year olds (n = 36)	18	18

Table 5.10 shows that as age increases more participants had completed puberty according to the self-report measure. A new variable was created that coded participants who had finished puberty (average of 4 on the PDS) and those who had not finished puberty (less than an average of 4 on the PDS). T-tests were conducted to compare participants who reported completing puberty and those who reported they had not completed puberty on social cognition and executive function task scores for the whole

sample and each age group. There were no significant group differences between participants who had completed puberty (n = 35) and participants who had not (n = 63) for the whole sample on social cognition (all p's > 0.168) or executive function tasks (all p's > 0.273). The equal variances assumed values are reported when Levene's test is significant (Dancey & Reidy, 2004). Descriptive statistics are in appendix sections 9 and 10.

Mann Whitney U tests were conducted to compare participants who reported completing puberty with those who did not in 17, 18 and 19 year old groups separately. There were no differences on social cognition task scores between participants who reported they had completed puberty compared to those still progressing in the 17 year old group (all p's > 0.122) and 18 year old groups (all p's > 0.128). In the 19 year old group, participants who had finished puberty scored lower on the MASC Total score, indicating poorer performance, (median = 24.50, range = 13.00, n = 18) than those who were still progressing (median = 37.50, range = 9.00, U = 93.50, Z = 2.18, T = 254.50, p = 0.029, n = 18). There were no differences in 17, 18 and 19 year old groups based on pubertal development for executive function task performance (all p's > 0.084).

5.11 Discussion

The present findings show evidence of developmental change suggesting a non-linear trajectory for strategy generation and concept formation specifically when comparing 17 and 18 year olds and no developmental change for other variables (inhibition, rule detection, planning, self-report empathy and emotion recognition from visual static, auditory and dynamic stimuli). Full Scale IQ scores were similar across age groups indicating that differences in intelligence did not account for observed group differences on executive function measures, although IQ mediated some aspects of Letter Fluency Task performance, a measure of strategy generation. Different levels of pubertal development between age groups did not account for performance on executive function and social cognition tasks. Self-report alcohol use, particularly above the weekly limit, was associated with poorer concept formation, assessed with the Sorting Test. Data reported in Chapter 4 showed that drug and alcohol use was similar across groups, whilst Negative Affect and Anxiety were higher in the two younger age groups.

The executive functions of strategy generation and concept formation measured by the D-KEFS Letter Fluency and Sorting Test respectively followed a non-linear developmental trajectory in the three age groups with functional peaks shown in the 17 year old group compared to 18 and 19 year olds on Letter Fluency and better performance in 17 year olds compared to 18 year olds on most indices of concept formation. The D-KEFS Letter Fluency Task requires participants to generate as many words as possible beginning with a specific letter in a given time. Successful performance requires participants to generate an effective strategy to retrieve words beginning with the specified letter. The result of IQ contributing to response generation performance on the Letter Fluency Task in Section 5.8 is consistent with previous research (Diaz-Asper, Schretlen & Pearlson, 2004; Harrison, Buxton, Husain & Wise, 2000; Porter, Collins, Muetzel, Lim & Luciana, 2011), but IQ differences are unlikely to be responsible for age group differences on executive tasks because analysis in Chapter 4 shows that groups did not differ in Full IQ.

There were significant group differences on several indices of the Sorting Test, including number of correct free sorts (functional peak in 17 year olds), free sort description score (17 year old group scores were higher than 18 year olds), sort recognition description score (17 year old group scores were higher than 18 year olds) and description score for perceptual sorts (functional peak at 17 years). Eighteen year olds showed a significant dip in performance across all indices of the Sorting Test compared to their younger counterparts but were not significantly different from 19 year olds. The 17 year old group showed a significant peak in functional ability in matching to criterion (free sorts) and description of category identified (description score for perceptual sorts) compared to 18 and 19 year olds. There were no group differences on description score for verbal sorts index of the Sorting Test suggesting that the separate indices of the task are functionally dissociable. Groups may have performed similarly on this index because performance is associated with verbal aptitude and groups were not different on Verbal IQ scores.

Comparing the present late adolescent data with existing adult data reveals different developmental trajectories. Performance peaks in late adolescence for emotion recognition with static visual stimuli (19 year olds), emotion recognition with dynamic stimuli (19 year olds), response inhibition (17 year olds) and several indices of planning (Tower achievement score and Tower move accuracy; 18 year olds, mean first move time and time per move; 17 year olds). Faster mean first move times and time per move at age 17 on the Tower Test possibly indicate some degree of impulsivity in this age group relative to adults. Emotion recognition from auditory stimuli, self-report perspective taking, rule detection, strategy generation and one index of concept formation (number of correct free sorts) continue to develop into adulthood. Non-linear development is evident for two indices of concept formation (description score for free sorts and sort recognition) with functions peaking at age 17, followed by a dip at age 18 and then peaking again in adulthood.

It is possible that the dip in performance at age 18 reflects dynamic brain changes to regions underpinning specific executive functions and corresponds to synaptic pruning occurring in prefrontal networks following age 17 as shown in imaging data (Gogtay et al., 2004). Non-linear development may reflect several dynamic maturational processes including synaptic pruning, increased white matter connectivity (Lebel et al., 2008; Paus, 2005; Sowell et al., 2003) and functional synchronisation (Uhlhaas et al., 2009).

Recent longitudinal data showed evidence of non-linear IQ development in late adolescence possibly reflecting underlying neuronal re-organisation, supporting the present non-linear findings. Ramsden et al. (2011) reported a longitudinal study assessing IQ in adolescents aged 12-16 at Time 1 and 15-20 at Time 2. Participants showed variation in IQ scores between time points, with increases or decreases evident across adolescence (Verbal IQ -20 to +23, Performance IQ -18 to +17 and Full Scale IQ -18 to +21). Following a Hebbian model of neural plasticity, it is possible that focal maturation to regions supporting foundational functions is essential for the emergence of more complex cognitive functions (Hebbs, 1949).

Environmental changes may also play a role in executive function development in late adolescence possibly because independent living develops autonomy. Eighteen and 19 year olds had undergone greater changes in living arrangements relative to 17 year olds. Regression analyses indicated that changes to living arrangements accounted for approximately 10% of variance in strategy generation and concept formation although the contribution of this variable to executive function was not significant and age was the greatest predictor. Whilst the contribution of environmental factors to executive function is speculative in the present study, previous research supports this. For example, Tuvblad et al. (2013) assessed environmental and genetic factors of decision making in a longitudinal twin study. Participants completed the Iowa Gambling Task (Bechara, Damasio, Damasio & Anderson, 1994) at age 11-13, 14-15 and 16-18 years. Non shared environmental factors, not shared by all children in the same family (Plomin et al., 2001), contributed to 65% of variance in task performance at age 11-13, 80% at age 14-15 and 54% at age 16-18. Tuvblad et al. (2013) concluded that environmental factors influence individual differences in decision making.

Age groups were not different on the Tower Test, a measure of planning. Other data similarly show little behavioural differences on this measure across broad age ranges, although EEG data indicated age effects in neural networks underpinning task performance. Guevera, Martínez, Aguirre and González (2011) reported no significant differences for first move time and number of moves on the Tower of Hanoi in 11-13 year olds, 18-20 year olds and 26-30 year olds. The older groups completed significantly more towers in the time limit relative to 11-13 year olds. EEG of prefrontal and parietal areas during task performance showed differences in functional synchronisation between age groups. The 18-20 year olds required increased interhemispheric and intrahemispheric coupling in nearly all frequency bands relative to baseline, whereas 26-30 year olds showed an increase only in selected bands in the right hemisphere. Therefore, it is possible that group differences on the Tower Test in late adolescence are only evident with EEG. Other findings show that performance on a computerised version of the Tower of London Task is associated with activation in frontal, parietal and premotor networks suggesting diverse neural substrates mediate performance on this measure (Wagner, Koch, Reichenbach, Sauer & Schlosser, 2006). Burgess, Veitch, de Lacy Costello and Shallice (2000) proposed that planning comprises multiple stages mediated by different brain networks. These stages include initial planning, remembering the task rules, following a plan and recounting how performance matches the original plan. Thus, it is likely that performance on the Tower Test recruits functions mediated by diverse neural substrates and that might account for the absence of significant group differences on the task.

No effect of age was found for social cognition measures, although gender mediated three aspects of social cognition. Other research has reported non-linear development of emotional processing for faces or words in early adolescence with a significantly longer reaction time evident in 11-12 year old females and 12-13 year old males relative to participants one year younger (McGivern et al., 2002). Although speculative it is possible that the social cognitive functions measured in the current study are well established by late adolescence. Another plausible explanation for no developmental change in social cognition and non-linear executive function development is that these functions are likely to recruit some shared and some disparate neural substrates. Findings indicate diverse neural substrates, including occipito parietotemporal, temporal and prefrontal networks, contribute to performance on the MASC (Wolf et al., 2010). There is also extensive evidence from imaging data that myelination follows a specific template across development occurring in a posterior to anterior direction (Kinney, Karthigasan, Borenshteyn, Flax, & Kirschner, 1994; Lebel et al., 2008; Sowell et al., 2003; Yakovlev & Lecours, 1967) so that occipital networks and posterior frontal networks mature earlier than anterior networks. Consequently current data indicate that socio-cognitive functions measured here show no developmental change and are relatively stable across late adolescence.

Imaging data suggest that social cognition tasks may be less process pure than executive function measures with more functionally diverse abilities recruited during completion of social cognition compared to executive function tasks. For instance, the MASC (Dziobek et al., 2006) requires attribution of mental state content in addition to remembering the scene previously viewed and episodic content from previous scenarios. The task also includes a significant verbal component and groups were not different in this capacity based on Verbal IQ scores, which may have mediated similar scores on this measure. However, another possibility is that different neural substrates mediate similar functional abilities at different age ranges due to dynamic neuronal morphology (Moor, Op de Macks, Güroğlu, Van der Molen & Crone, 2011) and future studies might map behavioural data to imaging data to further establish how maturational change impacts cognitive functions.

Gender accounted for differences on one executive function scale, description score for perceptual sorts, where males performed better than females, and one index of the MASC (Dziobek et al., 2006). Females made fewer errors involving over-attribution of mental state content compared to males, which may be explained as gender differences in interpreting expression intensity. Previous research has shown that females were more accurate than males on an emotion recognition task; however the gender difference was only apparent with subtle expressions at 50% intensity compared to 100% intensity (Hoffmann, Kessler, Eppel, Rukavina & Traue, 2010). Thus, gender differences may be evident on the MASC because this task approximates real life social situations where emotions are portrayed at low to mid intensity (Motley & Camden, 1988). Females also rated themselves significantly higher than males on two sub-scales of the Interpersonal Reactivity Index: Empathic Concern assessing sympathetic feelings towards others, and the Personal Distress scale measure of anxiety levels in tense social situations. Females rated themselves significantly higher on the Empathic Concern scale of the IRI in line with other research (Davis, 1983; Derntl et al., 2010; Krämer, Mohammadi, Doñamayor, Samii & Münte, 2010) possibly due to participants conforming to gender stereotypes (Derntl et al., 2010). Females may assume they are more empathic compared to males because empathy is a larger part of the traditional female stereotype. Social desirability may also affect self-report empathic measures; Laurent and Hodges (2009) assessed social desirability with the Marlowe-Crowne Social Desirability Scale (Crowne & Marlowe, 1960) and empathy with the Interpersonal Reactivity Index (Davis, 1983) in 194 university students (mean age = 19.8 years). Laurent and Hodges (2009) reported a positive correlation between social desirability and IRI Empathic Concern whereas IRI Personal Distress and social desirability were negatively correlated.

Similar to the present findings, Banissy, Kanai, Walsh and Rees (2012) found females scored significantly higher than males on IRI Empathic Concern and Personal Distress scales in a study with 118 participants (mean age = 22.9 years). Banissy et al. (2012) reported that IRI Empathic Concern scores were negatively related to grey matter volume in the inferior frontal gyrus, precuneus and anterior cingulate. Thus smaller grey matter volume in the inferior frontal gyrus was associated with higher Empathic Concern scores. This relates to the notion of synaptic pruning occurring into early adulthood resulting in a more efficient neural network that is evidenced behaviourally in better empathic concern. A possible explanation for females scoring higher than males on Empathic Concern is due to gender differences in grey matter volume. In an MRI study with young adults (mean age = 26 years) females were found to have significantly smaller grey matter volume in the left inferior frontal gyrus relative to males (Witte, Savli, Holik, Kasper & Lanzenberger, 2010).

To summarise, Time 1 cross sectional analyses showed that 17 year olds scored significantly higher than 18 year olds on the Letter Fluency and Sorting Tests, measures of strategy generation and concept formation. No age group differences were evident on social cognition task scores. Converging evidence suggests that adolescence represents an important phase of neural reorganisation with associated behavioural changes (Blakemore & Choudhury, 2006; Giedd, 2004; Giedd et al, 1999; Paus, Keshevan, Giedd, 2008; Sowell et al; 2003; Steinberg, 2008). Importantly late adolescence and early adulthood is also often associated with changes to friendship groups and living arrangements. The 18 and 19-year-old groups in the present study had undergone greater change to their social and living environment than 17 year olds over the preceding twelve months. Therefore, present findings likely reflect the complex interplay between maturational, social and environmental changes that take place in late adolescence and early adulthood and provide evidence of linear social cognitive and non-linear executive function development.

Chapter 6

Time 2 cross sectional and longitudinal data analyses

6.1 Chapter overview

Chapter 6 includes Time 2 cross sectional data analyses of executive function and social cognition task scores. Section 6.2 discusses the time interval between Time 1 and Time 2 testing. As the time interval was not similar for age groups, Time 2 data was analysed by (1) comparing groups at Time 2 in their original groups from Time 1 not taking account of time interval variability between participants, as outlined in section 6.3 below, and (2) taking into account time interval variability by re-categorising participants on the basis of actual chronological age at Time 2 (18, 19 and 20 years) in section 6.5. Section 6.4 compares Time 1 and Time 2 cross sectional findings. Justification and discussion for conducting Time 2 analyses this way is given below. Gender comparisons are reported in section 6.6. Following this, section 6.7 presents longitudinal data analyses. Various longitudinal analyses are considered with justification for the selected analyses. Correlations between time interval and task change score are reported and show that time interval does not correlate with the majority of executive function and social cognition task change scores. Therefore, in subsequent analyses time interval is not used as a covariate. Mixed ANOVAs with age group at Time 1 as the between group factor, Time 1 and Time 2 task score as the within subjects factor and interactions are reported. Section 6.8 discusses the findings in relation to previous research.

In this section, groups are categorised as Younger, Middle and Older referring to participants who were originally in 17, 18 and 19 year old groups at Time 1 (i.e. 17 year olds are re-named the Younger age group, 18 year olds are re-named the Middle age group and 19 year olds are re-named the Older age group). Age groups are renamed because of some participants changing age groups due to different time intervals between testing (see section 6.2) at Time 2. Figure 6.1 shows the Younger, Middle and Older age groups at Time 1 and Time 2.

Figure 6.1. Ages of Younger, Middle and Older groups at Time 1 and Time 2

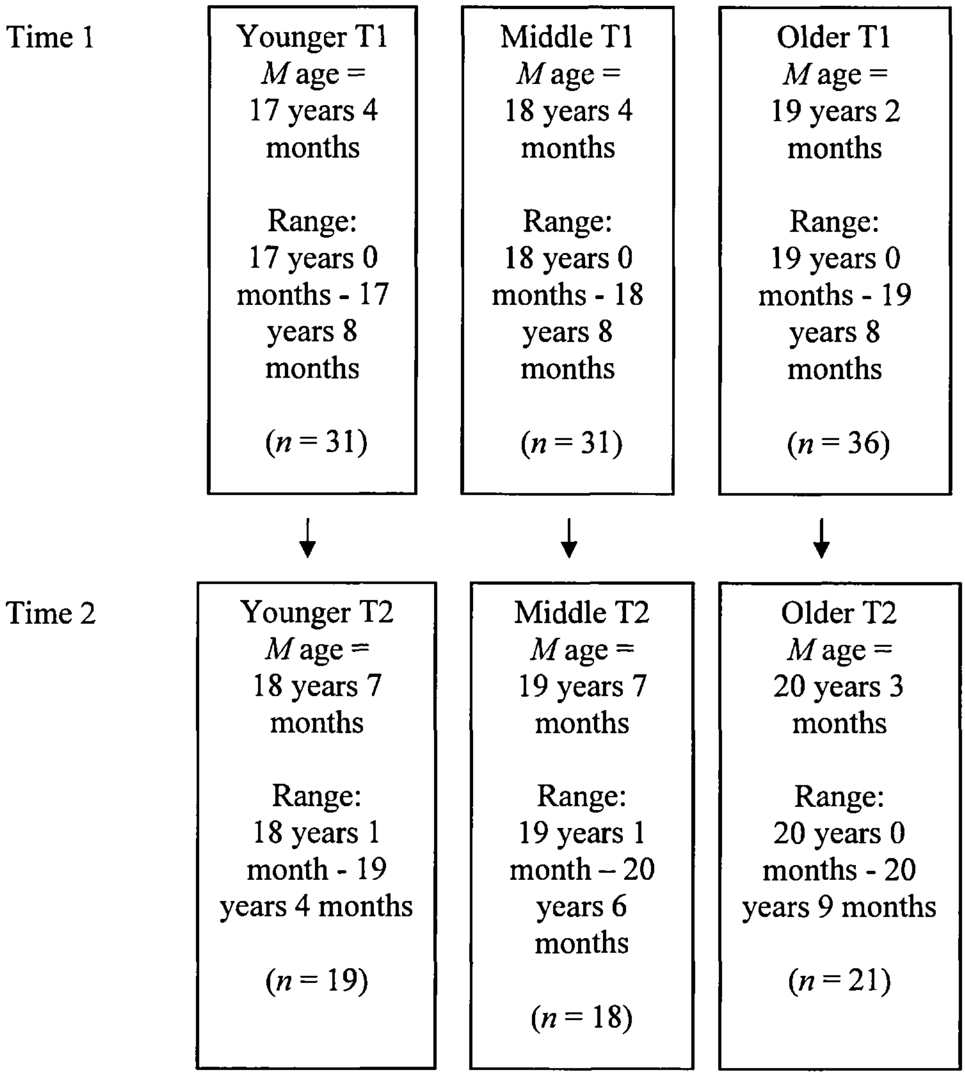


Figure 6.1 shows retention of 61% for the Younger group (n = 19), 58% for the Middle group (n = 18) and 58% for the Older group (n = 21) indicating that retention was similar across age groups at Time 2. Chapter 4 included other studies with similar retention rates (Novack et al., 1991; Zipparo et al., 2008) and explored whether the Time 1 demographic data of participants who only took part at Time 1 differed to participants who took part at both time points. Analyses in Chapter 4 showed that participants who took part at both time points had a higher Time 1 Verbal IQ compared to participants who only took part at Time 1. There were no differences for Performance IQ, Full IQ, affect or HADS comparing Time 1 data for participants who took part at

both time points relative to participants who took part only at Time 1 indicating that the Time 2 sample is representative of the Time 1 sample.

The age ranges in Figure 6.1 show there is overlap in age groups at Time 2 e.g. the Younger group ranges from 18 years 1 month to 19 years 4 months overlapping with the Middle age group that spans from 19 years 1 month to 20 years 6 months. The Middle group overlaps with the Older group that ranges from 20 years 0 months to 20 years 9 months. The overlap in age groups is the rationale for conducting alternative cross sectional analyses in section 6.5 based on actual chronological age.

6.2 Time interval

Table 6.1 shows data about time interval between Time 1 and Time 2 testing for Younger, Middle and Older groups.

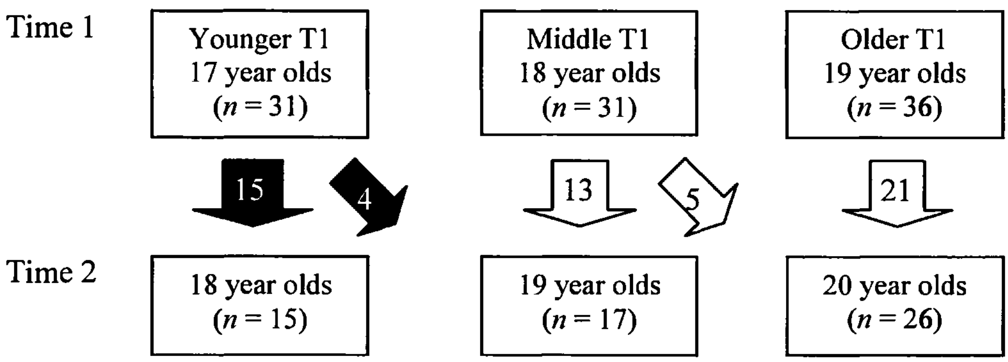
Table 6.1. Descriptive statistics for time interval between Time 1 and Time 2 testing for Younger, Middle and Older age groups

	Younger	Middle	Older
Mean (sd)	15.32 (4.03) months	16.33 (5.37) months	13.14 (1.24) months
Range	12 to 27 months	12 to 26 months	12 to 16 months

Table 6.1 shows that time interval between Time 1 and Time 2 testing was different across age groups in the present study. The Younger age group (t (21) = 2.26, p = 0.035) and Middle age group (t (19) = 2.47, p = 0.024) had a longer time interval between testing than the Older age group, whilst there was no significant difference in time interval between Younger and Middle groups (t (31) = 0.65, p = 0.521). The time interval was different across age groups because Younger participants were away at university at Time 2 so testing was delayed until they returned to Sheffield in the holidays. Some participants in the Middle group were unavailable when first contacted at Time 2. As attrition was high in this age group, Time 2 testing was extended resulting in a longer mean time interval between testing than the other groups. The Older group had a shorter mean time interval compared to the other age groups because they were from Sheffield Hallam University and were available for testing at Time 2 when contacted.

As the time interval between testing varied across age groups, this resulted in some participants moving groups. Four 17 year olds were 19 years old at Time 2 and five 18 year olds were 20 years old at the second time point. Figure 6.2 shows the number of participants in each age group at Time 1 and participant groups at Time 2.

Figure 6.2. Figure showing number of participants in each age group at Time 1, number changing age groups and number in each age group at Time 2



Key: Black = participants who are in the Younger age group at Time 2 (n = 19)
Grey = participants who are in the Middle age group at Time 2 (n = 18)
White = participants who are in the Older age group at Time 2 (n =21)

6.3 Time 2 cross sectional data analyses by Time 1 age group

Cross sectional analyses were conducted to explore group differences between original Time 1 age groups at Time 2 on executive function and social cognition task scores. These analyses were conducted to compare group differences at Time 1 and Time 2 and explore the stability of the group differences. If the pattern of findings was present at Time 1 and Time 2 this may indicate that group differences are due to characteristics specific to the current sample. However, if different cross sectional findings are present at Time 1 and Time 2 this could indicate age related change. If functions show age related change, it would not be expected for cross sectional findings to be the same at Time 1, when participants were 17, 18 and 19 years old, and Time 2 because participants were older at Time 2.

For example, Time 1 cross sectional analyses showed the Younger group (17 year olds) scored significantly higher than the Middle age group (18 year olds) on strategy generation, assessed with the D-KEFS Letter Fluency Task, and some indices of concept formation, measured with the Sorting Test. If the Younger group continued to score significantly higher than the Middle age group at Time 2 this could indicate group differences due to sample characteristics, such as the Younger group finding the study an unusual and novel experience or being more motivated compared to the other groups, possibly resulting in better executive function (Ritter et al., 2012; Pessoa, 2009). If the group differences were not evident at Time 2 this could indicate age related change specific to age 17 and 18 years.

Raw scores are presented for the D-KEFS Letter Fluency, Card Sorting and Tower Tests (Delis et al., 2001) and scaled scores are reported for Hayling and Brixton Tests (Burgess & Shallice, 1997) to be consistent with Time 1 data. While multiple tests are reported on a range of executive function scores, *p* values were not adjusted (see Chapter 5.3).

ANOVAs were conducted because variables had a skewness statistic of ±2.85, with the exception of MASC no ToM errors in the Younger group (skewness statistic = 3.01) indicating generally parametric data (Clark-Carter, 2004). Means, standard deviations and ANOVA inferential statistics comparing Younger, Middle and Older groups on executive function task scores at Time 2 are presented in Table 6.2. Means and standard deviations are reported because the data is considered to be parametric.

Table 6.2. Means, standard deviations and ANOVA F and p values for Younger, Middle and Older participants on executive function tasks at Time 2

	Younger group T2 ($n = 19$)	Middle group T2 ($n = 18$)	Older group T2 ($n = 21$)	$F(2, 55)$	p
Measures of response inhibition and rule detection					
Hayling scaled	6.58 (1.26)	6.50 (0.92)	6.67 (1.49)	0.09	0.919
Brixton scaled	8.47 (1.54)	7.94 (1.55)	8.38 (1.43)	0.65	0.525
Measure of strategy generation					
Letter Fluency	43.16 (9.00)	35.00 (9.40)	39.05 (9.67)	3.51	0.037*
Measures of concept formation					
Free sorts correct	11.00 (1.89)	9.83 (2.09)	11.10 (2.10)	2.24	0.116
Free sort % accuracy	84.32 (11.29)	86.72 (12.09)	93.62 (9.19)	3.99	0.024*
Free sort description score	38.68 (7.34)	36.11 (7.48)	39.05 (8.88)	0.76	0.474
Sort recognition description score	41.79 (6.31)	41.00 (8.34)	40.05 (8.93)	0.24	0.788
Verbal sorts description score	31.79 (8.53)	31.00 (7.61)	31.52 (8.88)	0.24	0.788
Perceptual sorts description score	48.68 (8.89)	46.11 (9.61)	47.57 (11.50)	0.30	0.742
Measures of planning					
Number of Tower items completed	8.63 (0.76)	8.72 (0.58)	8.71 (0.56)	0.12	0.889
Tower achievement score	19.16 (3.39)	19.33 (3.52)	20.24 (3.59)	0.55	0.579
Mean first move time	2.40 (0.45)	3.20 (1.46)	3.25 (1.38)	3.10	0.053
Time per move	1.98 (0.27)	2.31 (0.56)	2.35 (0.41)	4.32	0.018*
Move accuracy	1.62 (0.34)	1.56 (0.28)	1.59 (0.31)	0.17	0.841

* $p < 0.05$

There were significant group differences on the D-KEFS Letter Fluency measure of strategy generation (F (2, 55) = 3.51, p = 0.037, η^2_p = 0.11). The Younger group scored significantly higher on Letter Fluency scores, indicating better strategy generation, than the Middle group (t (35) = 2.70, p = 0.011) but there were no group differences between Younger and Older (t (38) = 1.39, p = 0.173) or Middle and Older groups (t (38) = 1.32, p = 0.195). Free sort % accuracy was calculated by number of correct sorts / attempted sorts x 100. Groups differed significantly on free sort % accuracy on the D-KEFS Sorting Test (F (2, 55) = 3.99, p = 0.024, η^2_p = 0.13) with the Younger group scoring significantly lower, indicating poorer concept formation, than the Older group (t (38) = 2.87, p = 0.007). No other group differences were found for free sort % accuracy between Younger and Middle groups (t (35) = 0.63, p = 0.535) or Middle and Older groups (t (37) = 2.02, p = 0.051) whilst the latter group difference is approaching significance. Groups differed significantly on time per move on the D-KEFS Tower Test (F (2, 55) = 4.32, p = 0.018, η^2_p = 0.14) with the Younger group scoring significantly lower than the Middle group (t (24) = 2.26, p = 0.033) and Older group (t (38) = 3.29, p = 0.002). A lower, faster time per move time in the Younger group relative to the Middle and Older group indicates faster processing speed in the Younger group. No significant differences were evident between the Middle and Older groups on Tower time per move (t (37) = 0.23, p = 0.817).

Inferential statistics reported in Table 6.2 show there were no significant group differences on the Hayling Test, a measure of inhibition, or on the Brixton Test, an assessment of rule detection. Scores on the D-KEFS Sorting Test, a measure of concept formation, showed no significant group differences on the following indices: number of correct free sorts, free sorts description score, sort recognition description score, description score for verbal sorts or perceptual sorts. No group differences were found on the number of towers completed, Tower achievement score, mean first move time or move accuracy.

To summarise, Time 2 cross sectional executive function analyses by original Time 1 age group showed group differences on the D-KEFS Letter Fluency, Sorting and Tower Tests. The Younger group scored significantly higher than the Middle group on the Letter Fluency Task, a measure of strategy generation. The Younger group scored significantly lower on free sort % accuracy, indicating poorer concept formation, compared to the Older group. The Younger group attained a faster time per move on the Tower Test compared to Middle and Older groups.

Means and standard deviations for Younger, Middle and Older age groups on social cognition tasks at Time 2 are reported in Table 6.3.

Table 6.3. Means and standard deviations for social cognition tasks in Younger, Middle and Older groups at Time 2 with ANOVA *F* and *p* values

	Younger T2 (n = 19)	Middle T2 (n = 18)	Older T2 (n = 21)	F (2,55)	p
Static visual stimuli					
Eyes	26.84 (4.65)	27.00 (3.45)	28.71 (2.94)	1.57	0.218
Auditory stimuli					
Voice	16.58 (2.87)	17.33 (2.50)	17.62 (2.54)	0.80	0.449
Dynamic visual and auditory stimuli with social interaction					
MASC correct	35.53 (6.29)	36.56 (3.29)	38.38 (2.31)	2.30	0.110
MASC excessive	5.26 (3.11)	5.00 (2.54)	3.86 (1.68)	1.82	0.172
MASC insufficient	2.63 (2.41)	2.50 (1.62)	1.76 (1.09)	1.41	0.253
MASC no ToM errors	1.58 (2.57)	0.94 (1.11)	1.00 (0.84)	0.84	0.437
Self-report empathy					
IRI Fantasy	19.42 (3.92)	14.56 (5.72)	19.48 (4.42)	6.68	0.003*
IRI Perspective Taking	17.21 (3.79)	16.06 (4.71)	17.81 (3.50)	0.95	0.394
IRI Empathic Concern	21.37 (2.61)	19.39 (4.98)	21.52 (2.71)	2.11	0.131
IRI Personal Distress	10.84 (4.40)	12.89 (5.93)	14.52 (5.25)	2.49	0.093

*p < 0.05

Groups differed significantly on IRI Fantasy score (F (2, 55) = 6.68, p = 0.003, η^2_p = 0.20) with the Younger (t (35) = 3.03, p = 0.005) and Older age groups (t (37) = 3.03, p = 0.004) scoring significantly higher than the Middle age group. This indicated that Younger and Older groups were more likely to report relating to characters in books and films compared to the Middle age group. The Younger and Older groups did not differ significantly on Fantasy score (t (38) = 0.04, p = 0.967).

There were no significant group differences the Reading the Mind in the Eyes Test, a visual static emotion recognition measure and Reading the Mind in the Voice Test, an assessment with auditory stimuli. No group differences were evident on the MASC, a dynamic social cognition measure. There were no significant differences on the Perspective Taking, Empathic Concern or Personal Distress scales of the Interpersonal Reactivity Index, a self-report measure of empathy.

To summarise, Time 2 cross sectional social cognition analyses by original Time 1 age groups showed group differences on the IRI Fantasy scale with Younger and Older groups scoring significantly higher than the Middle age group. No group differences were evident on the Reading the Mind in the Eyes Test, a visual static emotion recognition measure, or the Reading the Mind in the Voices Test, an auditory assessment of emotion recognition. Descriptive statistics presented in Table 6.3 indicate the Older group attained a total score of 3 higher than the Younger group on the MASC, a dynamic measure. However, the ANOVA was not significant and power was 0.45, below the recommended level of 0.7 (Dancey & Reidy, 2004). IRI Personal Distress scores showed a significant trend with the Older group reporting higher personal distress relative to the Younger group. Overall the Time 2 social cognition data suggest that social cognition measured by the tasks in the present study is relatively well developed by early adulthood because there are relatively few age group differences on these tasks at Time 1 and Time 2.

6.4 Comparison with Time 1 cross sectional data

Time 1 cross sectional analyses reported in Chapter 5 showed significant differences on the D-KEFS Letter Fluency and Card Sorting Tests. The Younger age group (17 year olds) scored significantly higher than the Middle age group (18 year olds) on the Letter Fluency Test and the following indices on the Sorting Test: number of correct free sorts, free sort description score, sort recognition description score and description score for perceptual sorts. The Younger age group (17 year olds) scored significantly higher than the Older group (19 year olds) on number of correct free sorts and description score for perceptual sorts. No group differences were evident on the Hayling and Brixton Tests, D-KEFS Tower Test or social cognition task scores at Time 1.

Table 6.7 summarises Time 1 and Time 2 findings. The Time 1 findings of the Younger age group scoring significantly higher compared to the Middle age group on the Letter Fluency Test is evident at Time 2 by the Younger group scoring significantly higher than the Middle age group. This indicates that the group differences on Letter Fluency scores may be due to the sample with the Younger group having better strategy generation than the Middle group, regardless of age.

The Younger group scored significantly lower than the Older age group on free sort % accuracy in the Sorting Test only at Time 2. Whilst no other significant group differences were found on the Sorting Test at Time 2, the means show a similar pattern to Time 1, with a higher mean in the Younger and Older groups relative to the Middle age group for number of free sorts correct, free sorts description score and description score for perceptual sorts. It is possible that significant group differences were not found due to participant attrition resulting in lower power at Time 2 e.g. power for free sorts correct is 0.44. Time 1 findings of group differences on sort recognition description score (Younger group higher than Middle age group) were not evident at Time 2, possibly indicating age related change specific to age 18. Figure 6.3 shows a z score graph of sort recognition description score for Younger, Middle and Older groups at Time 1 and Time 2.

Figure 6.3. Z score graph for sort recognition description score on Younger, Middle and Older groups at Time 1 and Time 2

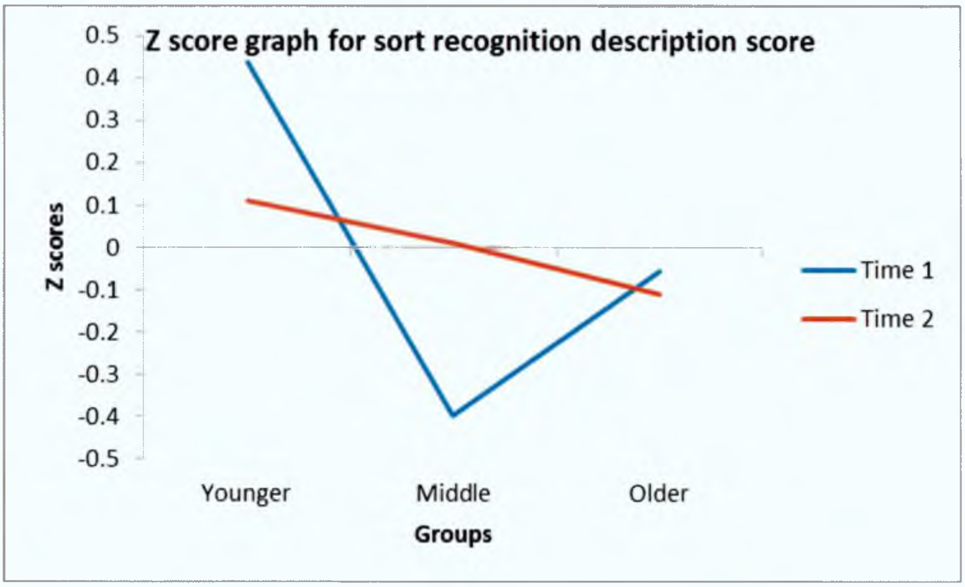


Figure 6.3 supports the notion that non-linear development on sort recognition description score, an index of concept formation, is specific to Time 1 and not evident at Time 2.

6.5 Time 2 cross sectional data analyses of re-categorised groups by chronological age at Time 2

These analyses take into account time interval variability by re-categorising participants into groups based on chronological age at Time 2. The original age groups no longer applied because of some participants changing age groups. Therefore another set of group comparisons were conducted to take account of participants who had changed groups. New groups were defined according to chronological age at Time 2 (18, 19 and 20 year olds) regardless of group membership at Time 1. See Table 4.3 for descriptive age data.

Cross sectional analyses were conducted comparing executive function and social cognition task scores by age at Time 2 with 18, 19 and 20 year old age groups. The data were considered non-parametric due to uneven age group sizes and histograms indicated data did not follow a normal distribution curve (see histograms in appendix section 11). Median and range scores for 18, 19 and 20 year olds on executive function tasks are presented in Table 6.4. Due to non-parametric data, Kruskal Wallis Tests were conducted to examine cross sectional Time 2 group differences on executive function and social cognition task scores in 18, 19 and 20 year olds.

Table 6.4. Median, range scores and Kruskal Wallis Inferential statistics for 18, 19 and 20 year olds at Time 2 on executive function tasks (Hayling & Brixton Tests, D-KEFS Letter Fluency, Card Sorting and Tower Task)

	18 year olds ($n = 15$)	19 year olds ($n = 17$)	20 year olds ($n = 26$)	H	p
Measures of response inhibition and rule detection					
Hayling scaled	6.00 (4.00 – 10.00)	7.00 (6.00 – 8.00)	6.00 (4.00 – 10.00)	0.38	0.825
Brixton scaled	8.00 (6.00 – 10.00)	8.00 (6.00 – 10.00)	8.00 (5.00 – 10.00)	< 0.01	0.999
Measure of strategy generation					
Letter Fluency	44.00 (26.00 – 52.00)	36.00 (17.00 – 65.00)	38.50 (22.00 – 64.00)	3.00	0.223
Measures of concept formation					
Free sorts correct	11.00 (8.00 – 13.00)	10.00 (6.00 – 16.00)	11.00 (6.00 – 15.00)	1.56	0.458
Free sort % accuracy	86.00 (60.00 – 100.00)	86.00 (59.00 – 100.00)	93.50 (63.00 – 100.00)	6.92	0.031*
Free sort description score	38.00 (24.00 – 47.00)	38.00 (21.00 – 55.00)	49.00 (20.00 – 59.00)	0.35	0.838
Sort recognition description score	42.00 (29.00 – 48.00)	44.00 (23.00 – 59.00)	43.00 (22.00 – 54.00)	0.80	0.670
Verbal sorts description score	31.00 (16.00 – 44.00)	32.00 (19.00 – 44.00)	31.00 (17.00 – 47.00)	0.76	0.686
Perceptual sorts description score	48.00 (34.00 – 60.00)	47.00 (31.00 – 68.00)	46.00 (24.00 – 69.00)	0.10	0.953
Measures of planning					
Number of Tower items completed	9.00 (6.00 – 9.00)	9.00 (8.00 – 9.00)	9.00 (7.00 – 9.00)	2.22	0.330
Tower achievement score	19.00 (15.00 – 27.00)	19.00 (17.00 – 26.00)	19.50 (12.00 – 27.00)	0.36	0.833
Mean first move time	2.40 (1.60 – 3.70)	3.00 (1.70 – 7.50)	3.10 (1.00 - 6.80)	3.76	0.153
Time per move	2.00 (1.50 – 2.40)	2.10 (1.60 – 3.10)	2.30 (1.50 – 3.70)	5.11	0.078
Move accuracy	1.70 (1.00 - 2.50)	1.50 (1.20 – 2.20)	1.50 (1.20 – 2.40)	1.23	0.540

* $p < 0.05$

Free sort % accuracy on the D-KEFS Sorting Test, a measure of concept formation, was calculated by number of correct sorts / attempted sorts x 100. Groups differed significantly on this variable (H (2) = 6.92, p = 0.031). Twenty year olds scored significantly higher on free sort % accuracy compared to 18 year olds (U = 103.50, z = 2.53, p = 0.01) with no other significant group differences. Twenty year olds achieved a higher free sort % accuracy by making more free sorts that matched target sorts with fewer errors suggesting that 20 year olds used a better concept formation strategy compared to 18 year olds.

There were no significant group differences on executive function tasks assessing inhibition on the Hayling Test, rule detection on the Brixton Test and on the D-KEFS Letter Fluency measure of strategy generation. On the D-KEFS Sorting Test there were no significant differences for number of correct free sorts, free sorts description score, sort recognition description score, description score for verbal sorts or perceptual sorts. No age group differences were evident on any D-KEFS Tower Test indices, although time per move showed a significant trend with a faster time per move in 18 year olds compared to 19 and 20 year olds.

Table 6.5 shows a summary of Time 1 cross sectional findings comparing 17, 18 and 19 year olds, Time 2 findings by original Time 1 age group (Younger, Middle and Older) and Time 2 findings with groups re-categorised by chronological age (18, 19 and 20 year olds) on executive function tasks.

Table 6.5. Executive function group comparisons at Time 1, Time 2 by original age group and Time 2 re-categorised by chronological age

Executive function Tests	Time 1 comparisons Younger, Middle and Older T1	Time 2 comparisons Original groupings: Younger (17 year olds), Middle (18 year olds) and Older (19 year olds)	Time 2 comparisons New groupings according to chronological age: 18, 19 and 20 year olds
Hayling Test (inhibition)	No group differences	No group differences	No group differences
Brixton Test (rule detection)	No group differences	No group differences	No group differences
Letter Fluency (strategy generation)	Younger group > Middle group	Younger group > Middle group	No group differences
Sorting Test (concept formation)	Younger group > Middle group on number of correct free sorts, free sort description score, sort recognition description score and description score for pereeptual sorts Younger group > Older group on number of correct free sorts and description score for perceptual sorts	Free sort % accuracy Younger group < Older group	Free sort % accuracy 18 year olds < 20 year olds
Tower Test (planning)	No group differences	Time per move Younger group < Middle group Younger group < Older group	No group differences

Table 6.5 shows that no group differences were evident on the Hayling and Brixton Tests, assessing inhibition and rule detection, at Time 1, in Younger, Middle and Older groups at Time 2 or by chronological age at Time 2 (18, 19 and 20 year olds). Seventeen year olds scored significantly higher than the 18 year olds on the Letter Fluency Test, a measure of strategy generation, at Time 1. This group difference was evident at Time 2 with the Younger age group showing better strategy generation than the Middle age group indicating the results are possibly due to participant characteristics of this specific sample. It is possible that the Younger group found the study an unusual and novel experience or were more motivated, resulting in better executive function task performance relative to the other age groups (Ritter et al., 2012; Pessoa, 2009).

Time 1 findings of the 17 year olds scoring significantly higher than 18 year olds on number of correct free sorts, free sort description score, sort recognition description score and description score for perceptual sorts were not evident in Time 2 cross sectional data analyses. This suggests that Time 1 findings may be due to age related change in concept formation specific to age 17 and 18 years. At Time 1 groups did not differ on free sort % accuracy, whilst at Time 2 the Older group scored significantly higher than the Younger group and 20 year olds scored significantly higher than 18 year olds on this index. It is possible that the Older group at Time 2 developed a more efficient strategy than the Younger group and made more free sorts that matched target sorts with fewer errors.

Median, range scores and Kruskal Wallis inferential statistics for 18, 19 and 20 year olds on social cognition tasks are presented in Table 6.6.

Table 6.6. Median, range and Kruskal Wallis inferential statistics comparing 18, 19 and 20 year olds at Time 2 on social cognition tasks (Reading the Mind in the Eyes, Reading the Mind in the Voices, Movie for the Assessment of Social Cognition and Interpersonal Reactivity Index)

	18 year olds (n = 15)	19 year olds (n = 17)	20 year olds (n = 26)	H	p
Static visual stimuli					
Eyes	28.00 (13.00 – 33.00)	28.00 (21.00 – 31.00)	29.00 (17.00 – 33.00)	1.22	0.543
Auditory stimuli					
Voice	17.00 (7.00 – 20.00)	17.00 (13.00 – 23.00)	17.50 (12.00 – 22.00)	0.06	0.969
Dynamic visual and auditory stimuli with social interaction					
MASC correct	38.00 (16.00 – 42.00)	38.00 (31.00 – 40.00)	38.00 (28.00 – 42.00)	0.51	0.774
MASC excessive errors	5.00 (0 - 10.00)	5.00 (1.00 – 10.00)	4.00 (2.00 - 10.00)	1.82	0.402
MASC insufficient errors	2.00 (0 - 9.00)	2.00 (0 - 4.00)	2.00 (0 - 7.00)	0.49	0.781
MASC no ToM errors	1.00 (0 - 11.00)	1.00 (0 - 2.00)	1.00 (0 - 4.00)	1.85	0.397
Self report empathy					
IRI Fantasy	20.00 (14.00 – 24.00)	16.00 (8.00 - 28.00)	19.50 (8.00 – 26.00)	2.38	0.304
IRI Perspective Taking	19.00 (9.00 – 23.00)	16.00 (8.00 – 26.00)	17.50 (8.00 – 23.00)	2.56	0.278
IRI Empathic Concern	22.00 (15.00 – 25.00)	20.00 (11.00 – 24.00)	22.00 (15.00 – 28.00)	5.53	0.063
IRI Personal Distress	12.00 (1.00 - 16.00)	13.00 (0 - 21.00)	14.00 (5.00 – 24.00)	1.00	0.605

All $p > 0.05$

There were no significant group differences on social cognition tasks assessing emotion recognition on the Reading the Mind in the Eyes Test, a visual static emotion recognition measure and Reading the Mind in the Voice Test, an assessment with auditory stimuli. No group differences were evident on the MASC, a dynamic social cognition measure. There were no significant differences on any sub-scale of the Interpersonal Reactivity Index, a self-report measure of empathy, although there was a significant trend for IRI Empathic Concern with 18 and 20 year olds scoring higher than 19 year olds.

To summarise, Time 2 cross sectional analyses comparing 18, 19 and 20 year olds on executive function tasks showed age group differences on free sort % accuracy, a measure of concept formation from the D-KEFS Sorting Test. Twenty year olds attained a significantly higher free sort % accuracy compared to 18 year olds. Higher free sort % accuracy in 20 year olds relative to 18 year olds indicates that the older group made fewer incorrect free sorts suggesting a more accurate concept formation strategy. No age group differences were evident on social cognition tasks.

Table 6.7 shows a summary of Time 1 cross sectional findings comparing 17, 18 and 19 year olds, Time 2 findings by original Time 1 age group (Younger, Middle and Older) and Time 2 findings of groups re-categorised by chronological age (18, 19 and 20 year olds) for social cognition task scores.

Table 6.7. Social cognition group comparisons at Time 1, Time 2 by original age group and Time 2 re-categorised by chronological age

Social cognition tests	Time 1 comparisons Younger, Middle and Older T1	Time 2 comparisons Original groupings: Younger (17 year olds), Middle (18 year olds) and Older (19 year olds)	Time 2 comparisons New groupings according to chronological age: 18, 19 and 20 year olds
Eyes Test Emotion recognition with visual stimuli	No group differences	No group differences	No group differences
Voices Test Emotion recognition with auditory stimuli	No group differences	No group differences	No group differences
Movie for the Assessment of Social Cognition Dynamic stimuli showing social interaction	No group differences	No group differences	No group differences
Interpersonal Reactivity Index Self-report empathy	No group differences	IRI Fantasy Younger group > Middle group Middle group < Older group	No group differences

Table 6.7 shows that the only cross sectional group difference evident for social cognition task scores was for IRI Fantasy scores, with Younger and Older groups at Time 2 scoring significantly higher than the Middle group. Group differences on IRI Fantasy were not evident in Time 1 cross sectional analyses or Time 2 analyses when groups were re-categorised into 18, 19 and 20 year olds. Comparing the present social cognition data with existing adult data in Table 5.5 indicates that social cognitive functions assessed in the present study have reached adult levels apart from scores on Reading the Mind in the Voices Test and IRI Perspective Taking. This suggests that emotion recognition from auditory stimuli continues to develop between early adulthood and the mean age of 24.3 years of participants in the Golan et al. (2007) study. By comparing the present data with Hassenstab et al. (2007), whose sample had a mean age of 40.1 years, the tendency of a person to consider other peoples' viewpoints may also develop beyond early adulthood.

6.6 Executive function and social cognition task score correlations at Time 2

The table in Appendix Section 14 presents executive function and social cognition task scores at Time 2. Scores on the Eyes Test significantly correlated with Tower Achievement scores ($r = 0.35, p = 0.007$) and Tower mean first move time ($r = 0.27, p = 0.043$). Tower mean first move time is a prospective temporal measure of planning and this could facilitate rapid emotion recognition. Tower achievement scores were positively correlated with Voices Test scores ($r = 0.32, p = 0.015$) and MASC Correct ($r = 0.30, p = 0.022$). The Tower Test requires planning and monitoring to ensure adherence to task instructions (Wagner et al., 2006). Planning and monitoring may be relevant in social cognition allowing people to monitor their behaviour and ensure their intentions are fulfilled (Amodio & Frith, 2006).

Brixton Test scores, a measure of rule detection, significantly correlated with MASC correct ($r = 0.36, p = 0.006$), MASC insufficient errors ($r = -0.36, p = 0.005$) and MASC no ToM errors ($r = -0.26, p = 0.050$) indicating that rule detection is beneficial for mental state attribution in dynamic stimuli.

Letter fluency scores significantly correlated with IRI Fantasy scores ($r = 0.32, p = 0.014$). Participants who score highly on the IRI Fantasy are likely to frequently engage with books and films (Davis, 1983). It is plausible that the consideration of several characters simultaneously improves cognitive flexibility and this would be beneficial on the Letter Fluency Task when participants must flexibly initiate responses to generate words starting with a particular letter (Ahmed & Miller, 2011).

6.7 Stability of correlations between executive function and social cognition tasks scores

At Time 1, Eyes and Voices Test scores correlated with Brixton Test scores, a measure of rule detection, whereas at Time 2 Eyes and Voices scores correlated with planning indices on the Tower Test. The different pattern of correlations at Time 1 and Time 2 may be due to a more automatic strategy for completing social cognition tasks developing during late adolescence / early adulthood (Burnett & Blakemore, 2009) that relies less on pattern identification or rule detection. At both time points Brixton Test scores correlated with MASC correct scores, with a stronger correlation evident at Time 2 relative to the first time point. The finding of different correlations between time points on the Eyes and Voices Test scores and stability between time points on the MASC may be due to the Eyes and Voices assessing social perceptual and the MASC assessing social perceptual and social cognitive components of Theory of Mind (Tager-Flusberg, 2001).

At both time points, the correlations are around 0.2 to 0.3 and classed as weak relationships (Dancey & Reidy, 2004). These *r* values are similar to those Ahmed and Miller (2011) reported for correlations between scores on the Eyes Test, Strange Stories, Faux Pas Test and D-KEFS subtests in a sample of 18 to 27 year olds. Carlson and Moses (2001) reported a correlation of $r = 0.66$ between inhibition and ToM task scores in 3 and 4 year olds. The stronger correlations between executive function and social cognition task scores in childhood compared to early adulthood may arise due to executive functions being necessary for children to learn concepts e.g. beliefs (Apperly, Samson & Humphreys, 2009; Carlson & Moses, 2001). The presence of correlations in adulthood indicates that executive functions continue to be important to social cognition when functions are more mature (Apperly et al., 2009).

6.8 Age effect and sampling effect

Sequential designs allow the comparison of cohorts, participants who are the same age but born in different years, to identify whether results are due to age or cohort effects (Shaffer & Kipp, 2013). To examine whether group differences are age related or due to the sample, Mann Whitney U tests were conducted comparing cohorts of a similar age i.e. 18 year olds at Time 1 with 18 year olds at Time 2. If effects are age related there would be no group differences between 18 year olds at Time 1 compared to Time 2. If findings are due to the sample then group differences would be evident between the two 18 year old cohorts. Mann Whitney U tests were conducted due to uneven group sizes. Exact p values are reported because the groups are unevenly balanced (Dancey & Reidy, 2004). The descriptive statistics for the groups are presented in Table 6.8.

Table 6.8. Median and range scores for 18 year olds at Time 1 and 18 year olds at Time 2 on D-KEFS Letter Fluency and Card Sorting Tasks

	18 year olds at T1 ($n = 31$)	18 year olds at T2 ($n = 15$)
Letter Fluency	40.00 (35.00)	44.00 (26.00)
Free sorts correct	11.00 (5.00)	11.00 (5.00)
Free sort description score	39.00 (26.00)	38.00 (23.00)
Sort recognition description score *	45.00 (35.00)	42.00 (19.00)
Description score for verbal sorts	31.00 (31.00)	31.00 (28.00)
Description score for perceptual sorts **	57.00 (46.00)	48.00 (26.00)

$*p < 0.05$, $**p < 0.01$

Eighteen year olds at Time 1 scored significantly higher than 18 year olds at Time 2 on sort recognition description score (U = 140.50, z = 2.16, p = 0.030) and description score for perceptual sorts (U = 105.00, z = 2.99, p = 0.002). These results indicate that group differences on sort recognition description score and description score for perceptual sorts are not age related and might be due to the sample. Group comparisons for Letter Fluency (U = 155.00, z = 1.82, p = 0.069), free sorts correct (U = 228.00, z = 0.11, p = 0.921), free sort description score (U = 189.00 z = 1.02, p = 0.313) and description score for verbal sorts (U = 224.50, z = 0.19, p = 0.857) were not significant.

Analyses in Chapter 5 showed that 17 year olds scored significantly higher, indicating better performance, than 18 year olds on Letter Fluency and the Sorting Test (free sorts correct, free sort description score, sort recognition description score and description score for perceptual sorts). The present analyses found no group differences comparing cohorts of the same age on Letter Fluency, free sorts correct and free sorts description score, indicating that the group differences reported in Chapter 5 for these indices are an age effect not a cohort effect. Cohort group differences were found on sort recognition description score and description score for perceptual sorts indicating that the group differences of 17 year olds scoring higher than 18 year olds on these indices may be due to the sample.

6.9 Gender comparisons

Time 2 data were collapsed to form two subgroups of females (n = 47) and males (n = 11). Due to uneven sample sizes, Mann Whitney U Tests were conducted to examine potential gender differences on IQ, Affect, Anxiety and Depression scores that may have influenced task performance. Medians and ranges of demographic variables are reported in Table 6.8.

Table 6.9. Median and range scores for females and males on demographic data at Time 2 (Verbal IQ, Performance IQ, Full Scale IQ, Positive Affect, Negative Affect, Anxiety and Depression scores)

	Females (n = 47)	Males (n = 11)
WASI Verbal IQ	108.00 (81.00 - 131.00)	109.00 (97.00 - 126.00)
WASI Performance IQ	111.00 (79.00 - 127.00)	111.00 (102.00 - 126.00)
WASI Full IQ	109.00 (84.00 - 128.00)	113.00 (100.00 - 128.00)
Positive Affect	32.00 (14.00 - 45.00)	30.00 (23.00 - 44.00)
Negative Affect	12.00 (10.00 - 29.00)	13.00 (10.00 - 19.00)
Anxiety	7.00 (1.00 - 16.00)	7.00 (3.00 - 11.00)
Depression	2.00 (0 - 9.00)	2.00 (1.00 - 6.00)

all $p > 0.05$

There were no group differences between females and males on the demographic data (all $p > 0.311$) indicating that groups were similar on IQ, mood and anxiety and depression scores. Descriptive statistics for executive function task scores are presented in Table 6.9.

Table 6.10. Median and range scores for females and males on executive function task scores

	Females ($n = 47$)	Males ($n = 11$)
Measure of response inhibition		
Hayling scaled	6.00 (4.00 - 10.00)	6.00 (4.00 - 10.00)
Measure of rule detection		
Brixton scaled	8.00 (6.00 - 10.00)	9.00 (5.00 - 10.00)
Measure of strategy generation		
Verbal fluency	41.00 (17.00 - 65.00)	37.00 (22.00 - 55.00)
Measures of concept formation		
Free sorts correct	10.00 (6.00 - 16.00)	11.00 (8.00 - 15.00)
Free sort description score	38.00 (20.00 - 55.00)	42.00 (32.00 - 59.00)
Sort recognition description score*	41.00 (22.00 - 59.00)	46.00 (32.00 - 54.00)
Verbal sorts description score	32.00 (16.00 - 45.00)	34.00 (24.00 - 47.00)
Perceptual sorts description score *	46.00 (24.00 - 69.00)	49.00 (39.00 - 66.00)
Measures of planning		
Number of Tower items completed	9.00 (7.00 - 9.00)	9.00 (6.00 - 9.00)
Tower achievement score	19.00 (12.00 - 27.00)	19.00 (15.00 - 26.00)
Mean first move time	2.60 (1.00 - 7.50)	3.10 (1.60 - 5.00)
Time per move	2.10 (1.60 - 3.70)	2.30 (1.50 - 3.00)
Move accuracy	1.50 (1.20 - 2.50)	1.50 (1.00 - 2.40)

* $p < 0.05$

There were group differences on the sort recognition description score (U = 153.00 , z = 2.10 , p = 0.036, r = 0.28) and description score for perceptual sorts (U = 159.50, z = 1.96, p = 0.049, r = 0.26) with males scoring higher, indicating better concept formation, than females. No group differences were evident on other executive function task scores. Median and range scores for males and females on social cognition tasks are presented in Table 6.10.

Table 6.11. Median and range scores for females and males on social cognition tasks

	Females (n = 47)	Males (n = 11)
Static visual stimuli		
Eyes	28.00 (13.00 - 33.00)	28.00 (17.00 - 33.00)
Auditory stimuli		
Voices	17.00 (7.00 - 23.00)	17.00 (14.00 – 19.00)
Dynamic visual and auditory stimuli with social interaction		
MASC correct	38.00 (16.00 - 42.00)	37.00 (28.00 - 42.00)
MASC excessive mental state inference errors	4.00 (0 - 10.00)	6.00 (3.00 - 7.00)
MASC insufficient mental state inference	2.00 (0 - 9.00)	2.00 (0 - 7.00)
MASC no ToM errors	1.00 (0 - 11.00)	1.00 (0 - 4.00)
Self-report empathy		
IRI Fantasy	19.00 (8.00 - 28.00)	16.00 (8.00 - 24.00)
IRI Perspective Taking	17.00 (8.00 - 26.00)	17.00 (11.00 - 23.00)
IRI Empathic Concern	22.00 (11.00 - 28.00)	21.00 (12.00 - 23.00)
IRI Personal Distress*	14.00 (4.00 - 24.00)	10.00 (0 - 15.00)

* $p < 0.05$

There was a significant group difference on IRI Personal Distress (U = 141.50, z = 2.33, p = 0.020, r = 0.31) with females scoring higher, indicating greater feelings of anxiety in tense social situations, than males. There were no other group differences on social cognition task scores.

To summarise, no gender differences were evident on IQ, affect, anxiety and depression scores at Time 2. Males scored significantly higher than females, indicating better concept formation, on sort recognition description score and description score for perceptual sorts. Females scored higher than males on IRI Personal Distress, anxiety in tense social situations. The finding of gender differences on description score for perceptual sorts and IRI Personal Distress supports gender differences at Time 1. Gender differences on MASC excessive mental state inference errors (males higher than females) and IRI Empathic concern (females higher than males) were evident at Time 1 but not at Time 2.

6.10 Longitudinal data analyses

This section considers the various options of longitudinal data analyses and provides a rationale for the reported analyses. Confirmatory Factor Analysis is discussed with reference to a longitudinal study conducted by Hughes, Ensor, Wilson and Graham (2009) that assessed executive function development. Following this, the use of time interval between testing as a covariate was considered. Regressions are then discussed before mixed ANOVAs are reported.

Confirmatory Factor Analysis (CFA) allows the predictors of individual differences in developmental change to be examined. Hughes et al. (2009) conducted CFA in a longitudinal study assessing executive function developmental change between ages 4 and 6 years and reported that inhibition, planning and working memory developed significantly across early childhood. The present study did not use CFA because the longitudinal sample size of 58 participants is far below the sample size Kline (2011) recommended of 200 participants. Whilst CFA allows the investigation of developmental change between time points, it does not allow between group comparisons so developmental change in the Younger, Middle and Older groups could not be identified.

A strength of longitudinal studies is that they identify how abilities improve or decline over time (De Luca et al., 2003). However, there are some limitations to this type of design. Longitudinal studies aim to collect data at specific time points, although practicalities of data collection may result in longitudinal studies being subject to creep, the widening of time between testing (Singer & Willett, 2003). Time interval was a possible issue in the current study with a significantly longer time interval between testing evident in the Younger and Middle age groups compared to the Older group. This resulted in some participants moving groups at Time 2. One solution that accounts for uneven time intervals is to adjust for time intervals between testing by using this variable as a covariate (Locascio & Atri, 2011) when analysing task change scores. In a review of longitudinal data analyses in neuropsychological research, Locascio and Atri (2011) suggested calculating a task change score (Time 2 task score – Time 1 task score) to give one score for use in longitudinal data analyses. However, a covariate should have a linear relationship with the dependent variable (Dancey & Reidy, 2004). To assess the suitability of time interval as a covariate, Pearson's correlations were conducted between time interval and task change score. As participants had a varying time interval between testing, the rationale for conducting these correlations was to collapse age groups and examine whether time interval correlated with task change scores. Together with identifying whether time interval is a suitable covariate, if time interval did not correlate with task change score participants with a longer time interval would be retained for further analyses. If time interval and task change score correlated for many of the variables then time interval would be a suitable covariate. No executive function task change scores significantly correlated with time interval; the correlation between sort recognition description change score and time interval showed a significant trend (r = -0.25, p = 0.054) with other correlations not significant ($p >$ 0.117). For social cognition, IRI Perspective Taking significantly correlated with time interval between testing (r = 0.30, p = 0.02) indicating that a longer time interval between testing sessions is associated with greater improvement in self-report Perspective Taking. No other correlations between time interval and social cognition task change scores were significant ($p >$ 0.201). The correlations show that time interval would not be an appropriate covariate because the variable is not linearly related with the majority of task change scores, the dependent variables.

Results of correlational analyses showed that time interval between testing significantly correlated with IRI Perspective Taking change score. Time interval did not correlate with other executive function and social cognition task change scores, suggesting that, with the exception of IRI Perspective Taking, the varying time interval between testing does not contribute to task change scores. Therefore, all participants were retained for further analyses to preserve power.

Another option of longitudinal data analyses were regressions with time interval as a predictor variable and task change score as the criterion variable. However, this method does not investigate between group comparisons (Locascio & Atri, 2011) and time interval and task change score were not linearly related, so the assumption of linearity is not met (Field, 2005). Dimitrov and Rumrill (2003) suggested comparing actual task scores instead of task change scores because when variances are similar across time points, as in these data, this results in similar task change scores. Therefore the following analyses were conducted with actual task scores at Time 1 and Time 2.

Alternative analyses are ANOVAs. Hughes and Ensor (2007) reported repeated measures ANOVAs in a longitudinal study assessing executive function and Theory of Mind at ages 2, 3 and 4. This allowed developmental change to be assessed across time points in a within participants design. The present study employed a mixed design with a between participant factor of group and within participant factor of Time 1 and Time 2 task score. Mixed ANOVAs were considered more appropriate than repeated measure ANOVAs because they allow between group comparisons, within group comparisons across time points and interactions. A 9-month longitudinal study by Tyson, Laws, Roberts and Mortimer (2004) that assessed executive function in schizophrenics and control participants used the same analyses. Tyson et al. reported separate ANOVAs for indices on the Intra/Extra dimensional and Stockings of Cambridge Tests using group (schizophrenic and controls) as a between participant factors, time as a within factor and interactions.

Mixed ANOVAs were conducted using a between group factor of age group at Time 1 (Younger, Middle and Older groups) and a within subjects factor of Time 1 and Time 2 IQ, executive function and social cognition task scores. The Younger, Middle and Older age groups refer to the age groups described in Figure 6.1. These analyses were conducted to explore whether executive function and social cognition task scores for Younger, Middle and Older groups changed significantly between Time 1 and Time 2, indicating developmental change. The inclusion of within and between comparisons allowed the interaction between groups and time points to be examined. Locascio and Atri (2011) recommended ANOVAs for longitudinal data analyses when there are few time points and participants have taken part in the same number of time points. Therefore, the Time 1 descriptive statistics only include participants who took part at Time 2 to allow comparison across time points with the same participants at each time point. Time interval was not included as a covariate because regression lines for the groups were not parallel, indicating that ANCOVAs would not be appropriate because they use adjusted group means instead of the actual means (Dancey & Reidy, 2004).

6.10.1 IQ

Descriptive statistics for Verbal IQ, Performance IQ and Full Scale IQ are presented in Table 6.11 followed by mixed ANOVAs with age group (Younger, Middle and Older) as the between group factor, Time 1 and Time 2 as the within group factor and an interaction.

Table 6.12. Means and standard deviations for WASI Verbal IQ, Performance IQ and Full Scale IQ in Younger, Middle and Older groups at Time 1 and Time 2

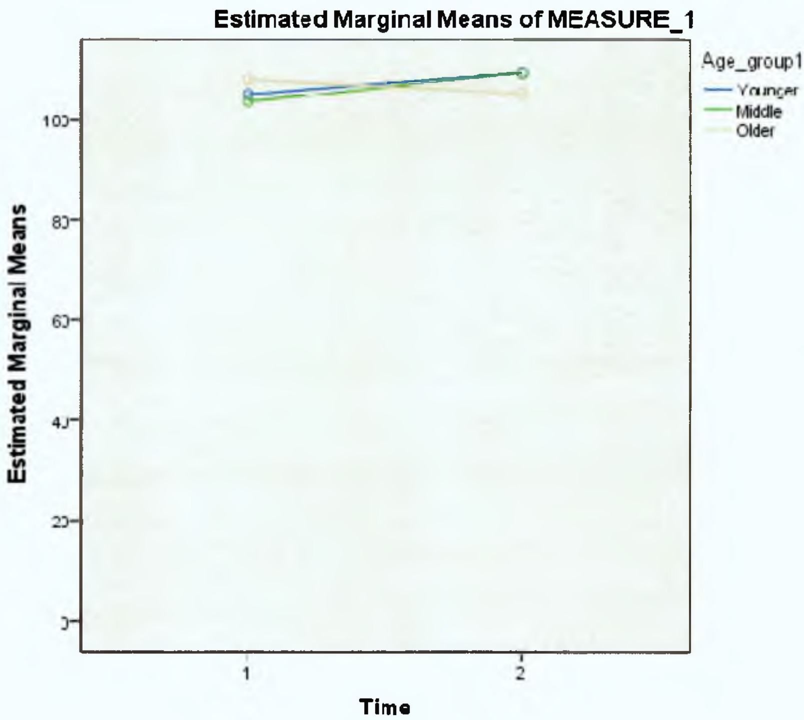
	Verbal IQ	Performance IQ	Full Scale IQ
Younger group Time 1 (*n* = 19)	105.00 (7.74)	103.16 (12.24)	104.63 (8.37)
Younger group Time 2 (*n* = 19)	109.32 (10.69)	111.89 (11.08)	111.89 (10.83)
Middle group Time 1 (*n* = 18)	103.56 (11.16)	99.89 (8.70)	102.00 (10.31)
Middle group Time 2 (*n* = 18)	109.17 (8.35)	106.00 (9.66)	108.72 (7.93)
Older group Time 1 (*n* = 21)	107.90 (6.91)	105.57 (7.06)	107.76 (5.41)
Older group Time 2 (*n* = 21)	105.14 (9.19)	114.76 (8.50)	110.95 (6.70)

Participants varied between Time 1 and Time 2 by -18 to +20 on Verbal IQ, -8 to +25 on Performance IQ and -8 to +18 on Full IQ supporting variation in IQ during adolescence (Ramsden et al., 2011).

There was a significant main effect of time (F (1, 55) = 5.95, p = 0.018, η^2_p = 0.10) for Verbal IQ with the Younger (t (18) = 2.69, p = 0.015) and Middle (t (17) = 2.74, p =

0.014) groups scoring significantly higher on Verbal IQ at Time 2 compared to Time 1. No developmental change was evident in the Older group (t (20) = 1.91, p = 0.071). There was no effect of group (F (2, 55) = 0.05, p = 0.953) on Verbal IQ. There was a significant interaction between time and group (F (2, 55) = 7.33, p = 0.002). The interaction graph in Figure 6.4 shows that the Younger (t (18) = 2.69, p = 0.015) and Middle (t (17) = 2.74, p = 0.014) age groups scored significantly higher on Verbal IQ at Time 2 compared to Time 1. All group means are within the Average range indicating that where there are changes across time groups remain in the same IQ category. The Older group scored lower at Time 2 relative to Time 1, although this was not significant (t (20) = 1.91, p = 0.071).

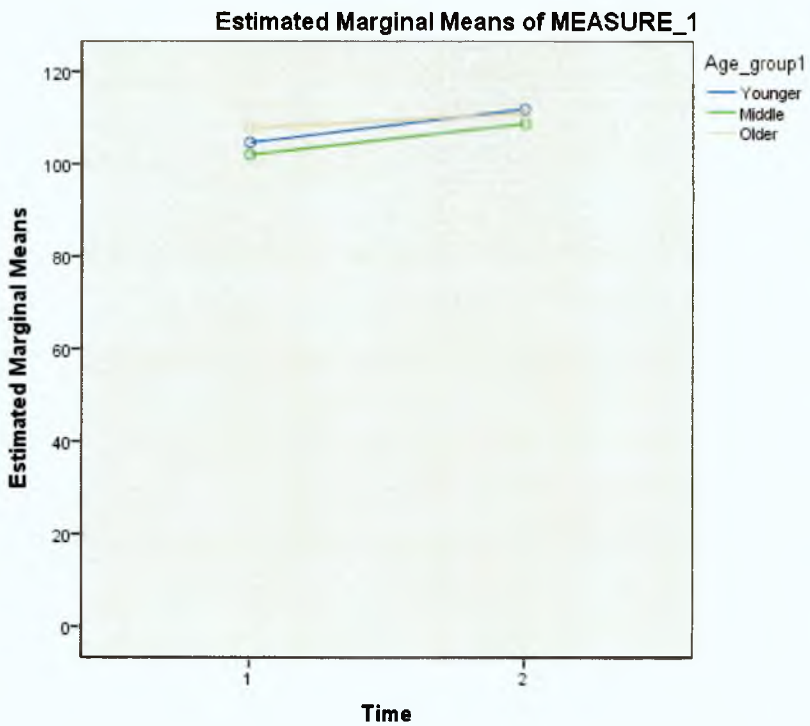
Figure 6.4. Interaction plot showing Verbal IQ scores in Younger, Middle and Older age groups at Time 1 and Time 2.



For Performance IQ there was a significant main effect of time (F (1, 55) = 100.25, p < 0.001, η^2_p = 0.65) although group (F (2, 55) = 3.06, p = 0.055) and interaction (F (2, 55) = 1.40, p = 0.254) were not significant. The Younger group scored significantly higher at Time 2 compared to Time 1 on Performance IQ (t (18) = 5.80, p < 0.001). Similarly, the Middle (t (17) = 3.71, p = 0.002) and Older groups (t (20) = 9.09, p < 0.001) scored significantly higher at Time 2 relative to Time 1. The mean Performance IQ scores for the Younger and Older groups changed from an Average IQ group at Time 1 to High Average at Time 2.

For Full Scale IQ score there was a significant effect of time (F (1, 55) = 61.75, $p <$ 0.001, $\eta^2_p = 0.53$), with no effect of group (F (2, 55) = 1.29, p = 0.283) and a significant interaction (F (2, 55) = 3.21, p = 0.048). The Younger (t (18) = 5.97, $p <$ 0.001), Middle (t (17) = 4.34, $p <$ 0.001) and Older groups (t (20) = 3.09, p = 0.006) attained a significantly higher IQ score at Time 2 relative to Time 1. The interaction plot in Figure 6.5 shows all groups scored higher on Full Scale IQ at Time 2. The mean Full Scale IQ scores for the Younger group changed from an Average IQ group at Time 1 to High Average at Time 2.

Figure 6.5. Interaction plot for Full Scale IQ scores in Younger, Middle and Older groups at Time 1 and Time 2.



Descriptive statistics of executive function task performance for Younger, Middle and Older groups at Time 1 and Time 2 are presented in Tables 6.13 and 6.14.

Table 6.13. Means and standard deviations for Younger, Middle and Older age groups at Time 1 and Time 2 organised in original Time 1 groups on executive function tasks of inhibition, rule detection, strategy generation and concept formation

	Younger group T1 (n = 19)	Younger group T2 (n = 19)	Middle group T1 (n = 18)	Middle group T2 (n = 18)	Older group T1 (n = 21)	Older group T2 (n = 21)
Measures of response inhibition and rule detection						
Hayling scaled	5.84 (1.02) ≈	6.58 (1.26)	5.67 (1.24) ↑	6.50 (0.92)	5.62 (1.36) ↑	6.67 (1.49)
Brixton scaled	7.63 (2.31) ≈	8.47 (1.54)	6.83 (1.98) ↑	7.94 (1.55)	6.86 (1.74) ↑	8.38 (1.43)
Measure of strategy generation						
Letter fluency	40.00 (7.88) ↑	43.16 (9.00)	33.28 (8.46) ≈	35.00 (9.40)	37.05 (7.87) ≈	39.05 (9.67)
Measures of concept formation						
Free sorts correct	11.95 (2.12) ≈	11.00 (1.89)	10.72 (1.78) ≈	9.83 (2.09)	10.90 (2.10) ≈	11.10 (2.10)
Free sort description score	45.42 (7.20) ↓	38.68 (7.34)	38.94 (9.43) ≈	36.11 (7.48)	41.90 (7.83) ≈	39.05 (8.88)
Sort recognition description score	50.11 (5.83) ↓	41.79 (6.31)	43.72 (8.46) ≈	41.00 (8.34)	46.33 (7.45) ↓	40.05 (8.93)
Verbal sorts description score	32.16 (8.52) ≈	31.79 (8.53)	26.44 (7.52) ≈	31.00 (7.61)	30.76 (8.11) ≈	31.52 (8.88)
Perceptual sorts description score	63.37 (7.40) ↓	48.68 (8.89)	58.39 (10.81) ↓	46.11 (9.61)	57.43 (8.52) ↓	47.57 (11.50)

Key: ↑ represents significantly better performance at Time 2 relative to Time 1, ↓ represents significantly poorer performance at Time 2 compared to Time 1 and ≈ represents no significant change in task scores between Time 1 and Time 2

6.10.2 Response inhibition and rule detection (Hayling & Brixton Tests)

The ANOVA showed a significant main effect of time on the Hayling Test (F (1, 55) = 20.65, $p < 0.001$, $\eta^2_p = 0.27$). Paired samples t-tests showed no developmental change in task score for the Younger age group (t (18) = 2.02, p = 0.059). The Middle age group performed significantly better at Time 2 relative to Time 1 (t (17) = 3.22, p = 0.005) and the Older group performed better at Time 2, indicating better inhibition, compared to Time 1 (t (20) = 3.01, p = 0.007). There was no significant main effect of age group (F (2, 55) = 0.08, p = 0.928) or interaction (F (2, 55) = 0.24, p = 0.788) on the Hayling Test.

A significant main effect of time was evident on the Brixton Test (F (1, 55) = 28.54, $p < 0.001$, $\eta^2_p = 0.34$) indicating developmental change. Paired samples t-tests showed scores for the Younger group did not significantly change between Time 1 and Time 2 (t (18) = 1.88, p = 0.076). The Middle age group scored significantly higher at Time 2 compared to Time 1 (t (17) = 3.56, p = 0.002). Similarly, the Older age group attained a higher score, indicating better rule detection, at Time 2 relative to Time 1 (t (20) = 4.36, $p < 0.001$). There was no significant main effect of age group (F (2, 55) = 0.85, p = 0.432) or interaction (F (2, 55) = 0.87, p = 0.424) on the Brixton Test.

6.10.3 Strategy generation (D-KEFS Letter Fluency Test)

A significant main effect of time was found on the Letter Fluency Test indicating developmental change between time points (F (1, 55) = 9.25, p = 0.004, $\eta^2_p = 0.14$). The Younger group scored significantly higher at Time 2, indicating better strategy generation, compared to Time 1 (t (18) = 2.19, p = 0.042). No developmental changes were found in the Middle age group (t (17) = 1.27, p = 0.220) or the Older group (t (20) = 1.77, p = 0.092). There was a significant main effect of age group (F (2, 55) = 3.75, p = 0.030) but the interaction was not significant (F (2, 55) = 0.33, p = 0.718). The significant main effect of age group was explored by conducting t-tests and found the Younger group scored significantly higher than the Middle age group (t (35) = 2.50, p = 0.017), indicating non-linear development and supporting Chapter 5 findings. No other group differences were evident.

6.10.4 Concept formation (D-KEFS Sorting Test)

There was no main effect of time (F (1, 55) = 2.97, p = 0.090, η^2_p = 0.05), group (F (2, 55) = 2.56, p = 0.087) or interaction (F (2, 55) = 1.41, p = 0.253) on number of free sorts correct. There was also no main effect of time (F (1, 55) = 1.73, p = 0.194), group (F (2, 55) = 1.17, p = 0.318) or interaction (F (2, 55) = 1.35, p = 0.267) on description score for verbal sorts. These findings indicate no developmental change between time points, group differences or interaction on number of free sorts correct and description score for verbal sorts.

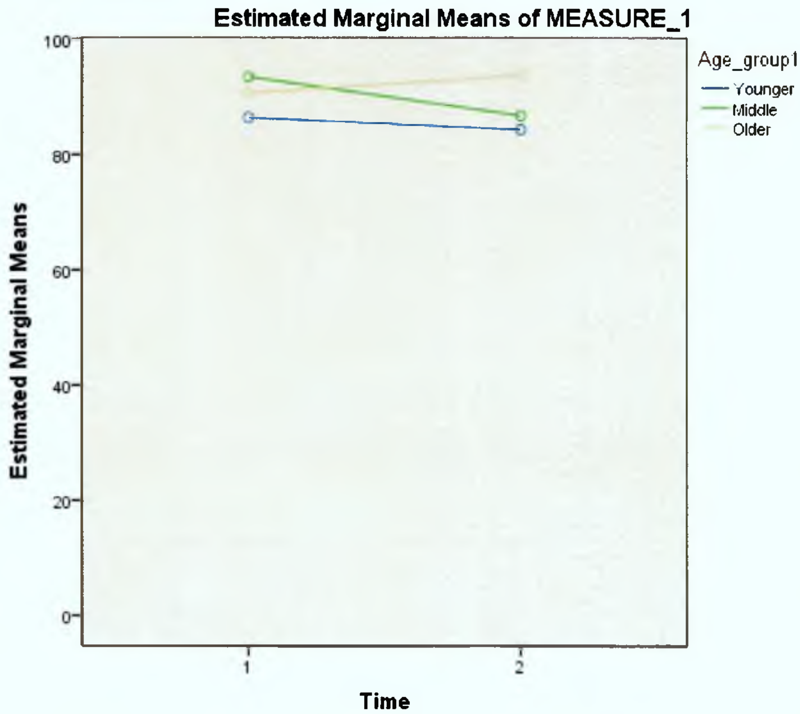
A significant main effect of time was found on free sort description score (F (2, 55) = 9.91, p = 0.003, η^2_p = 0.15) with the Younger group scoring significantly lower at Time 2, indicating poorer concept formation and non-linear development, relative to Time 1 (t (18) = 3.68, p = 0.002). The Middle (t (17) = 1.01, p = 0.326) and Older groups (t (20) = 1.33, p = 0.200) did not show significant changes between time points. There was no effect of age group (F (2, 55) = 2.42, p = 0.098) or interaction (F (2, 55) = 0.97, p = 0.387) on free sort description score.

Developmental change was evident on the sort recognition description score between time points (F (1, 55) = 21.11, $p < 0.001$, η^2_p = 0.28) with the Younger group scoring lower at Time 2, indicating poorer concept formation and non-linear development, compared to Time 1 (t (18) = 4.73, $p < 0.001$). The Middle group showed no change in sort recognition description score over time points (t (17) = 1.00, p = 0.333). The Older group scored significantly lower on sort recognition description score at Time 2 compared to Time 1 (t (20) = 3.15, p = 0.005). There was no effect of age group (F (2, 55) = 1.86, p = 0.165) or interaction (F (2, 55) = 1.62, p = 0.207) for sort recognition description score.

Description score for perceptual sorts showed developmental change (F (1, 55) = 62.96, $p < 0.001$, η^2_p = 0.53). The Younger group (t (15) = 7.51, $p < 0.001$), Middle group (t (13) = 4.49, p = 0.001) and Older group (t (20) = 3.71, p = 0.001) scored significantly lower at Time 2 compared to Time 1. There were no significant main effects of group (F (2, 55) = 1.49, p = 0.234) or interaction (F (2, 55) = 0.84, p = 0.436).

For free sort % accuracy there was no main effect of time (F (1, 55) = 1.64, p = 0.206, η^2_p = 0.03) or age group (F (2, 55) = 3.17, p = 0.05) whilst the interaction was significant (F (2, 55) = 3.53, p = 0.036). Figure 6.6 shows an interaction plot for free sort % accuracy.

Figure 6.6. Interaction plot for free sort % accuracy on the D-KEFS Sorting Test in Younger, Middle and Older age groups at Time 1 and Time 2.



The interaction plot for free sort % accuracy presented in Figure 6.4 shows that the Younger and Middle groups' scores decreased between Time 1 and Time 2 whereas the Older group showed an increase in free sort % accuracy between time points. However, t-tests showed that there was only a significant decrease for the Middle age group suggesting a less efficient concept formation strategy at Time 2 compared to Time 1 (t (17) = 2.72, p = 0.015).

Table 6.13 presents the descriptive statistics for Younger, Middle and Older groups at Time 1 and Time 2 on the D-KEFS Tower Test.

Table 6.14. Means and standard deviations for Younger, Middle and Older age groups at Time 1 and Time 2 organised in original Time 1 groups on an executive function task of planning

	Younger group T1 (n = 19)	Younger group T2 (n = 19)	Middle group T1 (n = 18)	Middle group T2 (n = 18)	Older group T1 (n = 21)	Older group T2 (n = 21)
Measures of planning						
Number of Tower items completed	8.47 (0.91) ≈	8.63 (0.76)	8.11 (1.02) ↑	8.72 (0.58)	8.38 (0.59) ≈	8.71 (0.56)
Tower achievement score	18.16 (3.15) ≈	19.16 (3.39)	18.61 (2.95) ≈	19.33 (3.52)	18.00 (2.85) ↑	20.24 (3.59)
Mean first move time	3.09 (1.14) ↑	2.40 (0.45)	3.94 (2.07) ≈	3.20 (1.46)	4.33 (2.07) ↑	3.25 (1.38)
Time per move	2.51 (0.56) ↑	1.98 (0.27)	2.79 (0.79) ↑	2.31 (0.56)	2.83 (0.52) ↑	2.35 (0.41)
Move accuracy	1.59 (0.37) ≈	1.62 (0.34)	1.60 (0.55) ≈	1.56 (0.28)	1.71 (0.39) ≈	1.59 (0.31)

Key: ↑ represents significantly better performance at Time 2 relative to Time 1, ↓ represents significantly poorer performance at Time 2 compared to Time 1 and ≈ represents no significant change in task scores between Time 1 and Time 2

6.10.5 Planning (D-KEFS Tower Test)

Number of towers completed showed a significant main effect of time indicating significant developmental changes in planning (F (1, 55) = 12.09, p = 0.001, η^2_p = 0.18). The Middle age group completed significantly more towers at Time 2, indicating better planning, relative to Time 1 (t (17) = 3.34, p = 0.004). No significant changes were found between Time 1 and Time 2 in the Younger group (t (18) = 0.90, p = 0.380) or the Older group (t (20) = 1.78, p = 0.090). There was no significant main effect of group (F (2, 55) = 0.28, p = 0.760) or interaction (F (2, 55) = 1.49, p = 0.234) for number of towers completed.

Tower achievement score also changed significantly between time points (F (1, 55) = 6.28, p = 0.015, η^2_p = 0.10). The Older group attained a significantly higher achievement score at Time 2 compared to Time 1 (t (20) = 2.16, p = 0.043). Achievement score takes into account whether towers are completed and the number of moves, indicating that the Older group employed a better planning strategy at Time 2 relative to Time 1. No longitudinal changes were significant between Time 1 and Time 2 in the Younger (t (18) = 1.39 p = 0.183) or the Middle age groups (t (17) = 0.79, p = 0.439). There was no significant main effect of group (F (2, 55) = 0.17, p = 0.847) or interaction (F (2, 55) = 0.81, p = 0.450).

Mean first move time showed a significant main effect of time (F (1, 55) = 18.74, p < 0.001, η^2_p = 0.25) with the Younger group having a significantly shorter mean first move time at Time 2 relative to Time 1 (t (18) = 2.47, p = 0.024). A similar pattern was found in the Older group with a significantly shorter mean first move time at Time 2 compared to Time 1 (t (20) = 3.73, p = 0.001). No developmental change was found in the Middle group (t (17) = 1.73, p = 0.102). There was a significant effect of group for mean first move time (F (2, 55) = 3.25, p = 0.046) which was explored with t-tests. The Younger group scored significantly lower, showing a faster mean first move time than the Older group (t (31.73) = 2.37, p = 0.024) with no other group differences evident. The interaction was not significant (F (2, 55) = 0.41, p = 0.667).

For time per move there was a significant effect of time (F (1, 55) = 78.06, p < 0.001, η^2_p = 0.59). The Younger group (t (18) = 4.74, p < 0.001), Middle group (t (17) = 5.32,

$p < 0.001$) and Older groups (t (20) = 5.45, $p < 0.001$) showed significantly shorter time per move at the second time point, possibly due to participants having completed the task before and already having a strategy to complete the towers. There was no significant effect of group (F (2, 55) = 2.85, $p = 0.066$) or interaction (F (2, 55) = 0.08, $p = 0.925$). For move accuracy there was no significant effect of time (F (1, 55) = 0.48, $p = 0.490$), group (F (2, 55) = 0.28, $p = 0.758$) or interaction (F (2, 55) = 0.42, $p = 0.658$).

Table 6.14 presents the descriptive statistics for Younger, Middle and Older group at Time 1 and Time 2 on social cognition tasks. ↑ represents significantly better performance at Time 2 relative to Time 1, ↓ represents significantly poorer performance at Time 2 compared to Time 1 and ≈ represents no significant change in task scores between Time 1 and Time 2

Table 6.15. Means and standard deviations of social cognition task scores for Younger, Middle and Older age groups at Time 1 and Time 2 organised by original T1 groups

	Younger group T1 (n = 19)	Younger group T2 (n = 19)	Middle group T1 (n = 18)	Middle group T2 (n = 18)	Older group T1 (n = 21)	Older groupT2 (n = 21)
Static visual stimuli						
Eyes	26.63 (5.74) ≈	26.84 (4.65)	27.00 (3.93) ≈	27.00 (3.45)	28.81 (2.44) ≈	28.71 (2.94)
Auditory stimuli						
Voices	16.53 (2.39) ≈	16.58 (2.87)	16.72 (3.05) ≈	17.33 (2.50)	17.57 (2.16) ≈	17.62 (2.54)
Dynamic visual and auditory stimuli with social interaction						
MASC correct	35.05 (4.59) ≈	35.00 (6.57)	35.17 (2.64) ↑	36.56 (3.29)	36.19 (6.43) ↑	38.38 (2.31)
MASC excessive errors	5.95 (3.15) ≈	5.26 (3.11)	6.37 (2.03) ↓	5.00 (2.54)	4.90 (2.66) ↓	3.86 (1.68)
MASC insufficient errors	2.74 (2.10) ≈	2.63 (2.41)	2.22 (1.26) ≈	2.50 (1.62)	2.62 (1.63) ≈	1.76 (1.09)
MASC no ToM errors	1.26 (0.93) ≈	1.58 (2.57)	1.22 (0.73) ≈	0.94 (1.11)	1.29 (0.90) ≈	1.00 (0.84)
Self report						
IRI Fantasy	19.05 (5.04) ≈	19.42 (3.92)	15.67 (5.51) ≈	14.56 (5.72)	17.90 (5.09) ≈	19.48 (4.42)
IRI Perspective Taking	15.89 (3.56) ≈	17.21 (3.79)	16.83 (4.50) ≈	16.06 (4.71)	18.00 (4.04) ≈	17.81 (3.50)
IRI Empathic Concern	21.21 (3.90) ≈	21.37 (2.61)	20.39 (3.66) ≈	19.39 (4.98)	20.57 (2.73) ≈	21.52 (2.71)
IRI Personal Distress	12.53 (5.27) ↓	10.84 (4.40)	14.61 (5.47) ≈	12.89 (5.93)	13.43 (3.79) ≈	14.52 (5.25)

6.10.6 Reading the Mind in the Eyes and Voices Tests

No significant effects of time (F (1, 55) = 0.01, p = 0.915, η^2_p < 0.01), group (F (2, 55) = 1.75, p = 0.183) or interaction (F (2, 55) = 0.07, p = 0.937) were evident on the Reading the Mind in the Eyes Test. Similarly, no effects of time (F (1, 55) = 0.57, p = 0.454, η^2_p = 0.01), group (F (2, 55) = 1.03, p = 0.362) or interaction (F (2, 55) = 0.34, p = 0.712) were found on the Reading the Mind in the Voice Test.

6.10.7 Movie for the Assessment of Social Cognition

Total MASC score showed a significant effect of time indicating developmental change (F (1, 55) = 5.29, p = 0.025, η^2_p = 0.09) with the Middle group scoring significantly higher at Time 2, indicating better social cognition, relative to Time 1 (t (17) = 2.22, p = 0.041) and the Older group scoring significantly higher at Time 2 compared to Time 1 (t (20) = 3.20, p = 0.005). No significant change in MASC total score was found in the Younger group (t (18) = 0.04, p = 0.966) between time points. There were no significant effects of group (F (2, 55) = 2.08, p = 0.135) or interaction (F (2, 55) = 1.69, p = 0.194) on MASC total score.

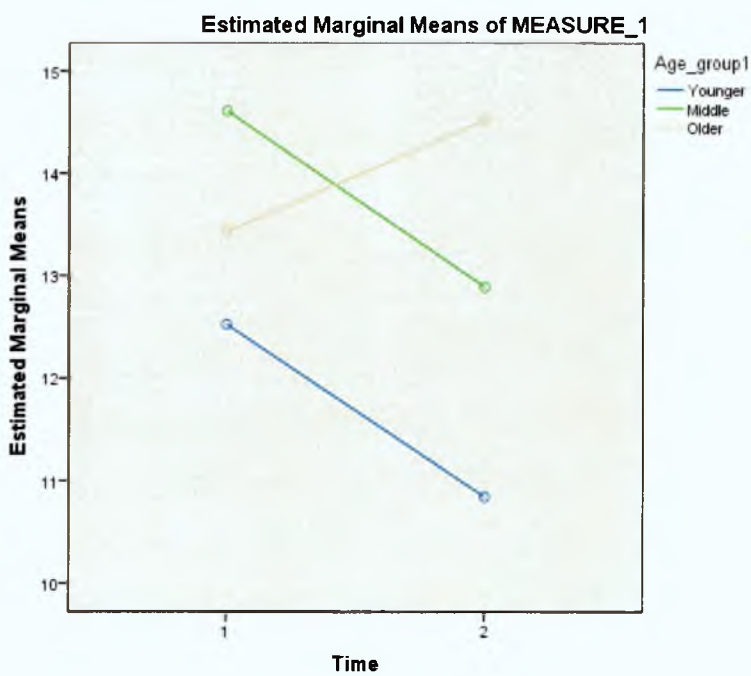
MASC excessive inference mental state errors showed developmental change (F (1, 55) = 9.73, p = 0.003, η^2_p = 0.15) with the Middle group making significantly fewer errors at Time 2 compared to Time 1 (t (17) = 2.38, p = 0.029) and the Older group making significantly fewer errors at Time 2 relative to Time 1 (t (20) = 2.36, p = 0.029). No longitudinal changes were evident in the Younger age group (t (18) = 0.98, p = 0.339). No effect of group (F (2, 55) = 2.14, p = 0.127) or interaction (F (2, 55) = 0.36, p = 0.701) was found for MASC excessive mental state inference errors.

For MASC insufficient inference errors there were no effects of time (F (1, 55) = 1.15, p = 0.288, η^2_p = 0.02), group (F (2, 55) = 0.52, p = 0.595) or interaction (F (2, 55) = 2.51, p = 0.090). There were no effects of time (F (1, 55) = 0.13, p = 0.718), group (F (2, 55) = 0.60, p = 0.553) or interaction (F (2, 55) = 0.77, p = 0.470) on MASC no Theory of Mind errors.

6.10.8 Interpersonal Reactivity Index

No significant effect of time (F (1, 55) = 0.25, p = 0.618, η^2_p< 0.01), group (F (2, 55) = 4.58, p = 0.054) or interaction (F (2, 55) = 1.99, p = 0.147) was evident on the IRI Fantasy scale. There was no significant effect of time (F (1, 55) = 0.06, p = 0.810, η^2_p< 0.01), group (F (2, 55) = 1.03, p = 0.363) or interaction (F (2, 55) = 1.65, p = 0.201) on the Perspective Taking scale. There was no significant effect of time (F (1, 55) <0.01, p = 0.924, η^2_p= 0.01), group (F (2, 55) = 1.03, p = 0.364) or interaction (F (2, 55) = 2.16, p = 0.125) on the Empathic Concern scale. No significant effect of time (F (1, 55) = 2.52, p = 0.118, η^2_p = 0.04) or group (F (2, 55) = 1.40, p = 0.255) was evident on the Personal Distress scale. A significant interaction between age group at Time 1 and time was found for Personal Distress (F (2, 55) = 3.86, p = 0.027). T-tests showed that the Younger group scored significantly lower at Time 2 compared to Time 1 (t (15) = 2.21, p = 0.043). Figure 6.7 shows an interaction plot of IRI Personal Distress scores in Younger, Middle and Older groups at Time 1 and Time 2.

Figure 6.7. Interaction plot showing IRI Personal Distress scores for Younger, Middle and Older age groups at Time 1 and Time 2



The interaction plot in Figure 6.4 indicates that the Middle age group also scored lower at Time 2 compared to Time 1, similar to the Younger group. In contrast, the Older age group scored higher at Time 2 relative to Time 1. However, these differences were not significant.

6.11 Discussion

Time 2 cross sectional analyses by Time 1 age group showed that the Middle group scored significantly lower, indicating poorer strategy generation, than the Younger group on the Letter Fluency Task. The Older group scored significantly higher, indicating a more efficient concept formation strategy, than the Younger group on free sort % accuracy. While the Older group scored higher than the Younger group on free sort % accuracy, the number of correct free sorts was similar, suggesting that the Older group made fewer errors. On the Tower Test, the Middle and Older groups scored significantly higher than the Younger group on time per move. However, the Younger group were faster than the other age groups at Time 1. Younger and Older groups scored higher than the Middle group on IRI Fantasy scale, indicating that Younger and Older groups were more likely to report relating to characters in books and films compared to the Middle age group.

Non-linear development is evident on the Tower Test with the Younger group showing a faster time per move compared to the Middle and Older groups. The group difference may be due to more efficient planning or processing speed.

The Younger and Older groups scored higher than the Middle group on IRI Fantasy. Simulation, thinking how you would feel in a situation (Harris, 1991) may be relevant to IRI Fantasy and relating to characters in books and films. However, the Younger and Older groups scoring higher than the Middle group on the Fantasy scale does not result in group differences on other social cognition tasks. Moreover, it could be questioned whether relating to characters in books and films indicates a maladaptive aspect of empathy because Lynch, Hill, Nagoshi and Nagoshi (2012) found that shame and poor psychological adjustment in university students was mediated by IRI Fantasy scores.

New groupings based on chronological age comparing 18, 19 and 20 year olds showed that 20 year olds scored significantly higher than 18 year olds on free sort % accuracy indicating age related linear development. Twenty year olds achieved higher free sort %

accuracy by making more free sorts that matched target sorts with fewer errors suggesting that the older age group used a better concept formation strategy compared to 18 year olds. This finding supports existing adult data reported in Chapter 5 (Greve et al., 1995) indicating concept formation improves linearly into early adulthood. Data presented in Chapter 4 showed that age groups were similar on IQ, affect and anxiety so these did not account for group differences on concept formation. There were no group differences on social cognition tasks although IRI Empathic Concern was approaching significant with 18 and 20 year olds scoring higher than 19 year olds, indicating non-linear development. In an MRI study assessing brain regions associated with the IRI in early adulthood, Banissy et al. (2012) reported that greater Empathic Concern scores were associated with lower grey matter in the left precuneus, left inferior frontal gyrus and left anterior cingulate. It is possible that non-linear development of Empathic Concern scores may reflect synaptic pruning of frontal regions, one of the latest regions to mature (Gogtay et al., 2004).

Males scoring higher on description score of perceptual sorts than females supports Time 1 gender comparisons and previous research (Greve et al., 1995). This index of concept formation requires participants to describe sorts based on perceptual features of the cards e.g. upper case letters and lower case letters or straight edges and curved edges. A possible explanation for the gender difference is that males have superior visuospatial abilities relative to females (Cazzato, Basso, Cutini & Bisiacchi, 2010). Females scored higher than males on IRI Personal Distress, feelings of anxiety in tense social situations, supporting Time 1 gender comparisons and previous research (e.g. Mestre et al., 2009).

The present study extends previous executive function and social cognition research by employing a sequential design allowing longitudinal developmental changes to be identified. The longitudinal analyses provide evidence of some functions improving (inhibition, rule detection, strategy generation, planning and emotion recognition in dynamic stimuli and feelings of apprehension in stressful situations), whilst concept formation was poorer at Time 2 and other functions showed no developmental change between time points (emotion recognition with visual static and auditory stimuli, sympathetic feelings towards other people's misfortune, tendency to associate with characters in books and films and tendency of a person to consider other peoples' viewpoints). Different developmental trajectories are evident for the age groups on some executive functions. For example, Middle and Older groups performed significantly better on the Hayling and Brixton Tests at Time 2 compared to Time 1 although no developmental change was found in the Younger group. All age groups at Time 2 scored higher than existing adult data on the Hayling Test ($M = 5.60$) reported by Henry, Mazur & Rendell (2009). It is possible that when completing the Hayling Test at Time 2 participants remembered a strategy, e.g. ignoring the content of the sentence and naming objects in the room. In contrast, the Younger group were the only group to score significantly higher at Time 2 compared to Time 1 on the Letter Fluency Test. A possible explanation is maturation of the posterior limb of the internal capsule leading to more efficient strategy generation in late adolescence (Bava et al., 2010). White matter maturation into late adolescence is associated with a decrease in mean diffusivity, a DTI measure indexing average magnitude of water diffusion (Schmithorst & Yuan, 2010). Mean diffusivity in the posterior limb of the internal capsule reaches 90% maturation by age 18 (Lebel et al., 2008) a similar age to the Younger group at Time 2. Therefore improved strategy generation in the Younger group at Time 2 compared to Time 1 may reflect white matter maturation in the posterior limb of the internal capsule specific to this age.

The finding that only the Younger group scored significantly lower at Time 2 compared to Time 1 on free sort description score on the D-KEFS Sorting Test supports the notion of non-linear development in concept formation (Kalkut et al., 2009; Taylor et al., 2013) reported in Chapter 5. However, all age groups scored significantly lower on description score for perceptual sorts at Time 2 relative to Time 1 indicating that the cards at Time 2 may have been more challenging than the cards at Time 1.

Previous longitudinal studies with adults have found no developmental change over time on the Tower Test measure of planning. For example, Tyson et al. (2004) found no main effect of time for number of towers solved or mean first move time in participants with a mean age of 39.4 years and time interval of 9 months between testing sessions. Similarly, Davis and Klebe (2001) reported no developmental change in the number of excess moves in participants with a mean age of 32.4 years and a mean of 7.8 years between testing sessions. In contrast, the current findings show the Middle group completed significantly more towers and the Older group attained a higher achievement score at Time 2 relative to Time 1. The Younger and Older groups showed a faster mean first move time at Time 2 and all age groups achieved a faster time per move at Time 2 compared to Time 1. These data provide evidence for longitudinal developmental change in planning specifically during late adolescence / early adulthood. Brain maturation in late adolescence / early adulthood may explain the longitudinal data suggesting planning develops during this age range and previous behavioural data showing planning ability develops in late adolescence / early adulthood (Delis et al., 2001b; Romine & Reynolds, 2005). The faster time per move could be explained by ongoing myelination into early adulthood increasing transmission speed (Sowell et al., 2001). Myelination leads to an increase in Fractional Anisotropy with about half of brain structures reaching 90% FA by age 19 to 20 (Lebel et al., 2008) including the superior longitudinal fasciculus, a fibre tract that extends from parietal to occipital and dorsal premotor and dorsolateral prefrontal regions (Makris et al., 2005). As performance on the Tower of London planning task requires widespread neural substrates including frontal, parietal and premotor areas (Wagner et al., 2006), it is possible that the protracted maturation of the superior longitudinal fasciculus leads to development of planning ability between Time 1 and Time 2. An alternative explanation is that greater functional connectivity between these areas results in more efficient, accurate and automatic processing (Stevens et al., 2007) evidenced by improved planning indices at Time 2.

Performance on the Eyes and Voices Tests showed no developmental change between time points supporting findings presented in Chapter 5 that emotion recognition with static visual and auditory stimuli is relatively stable across late adolescence and early adulthood. At Time 2, the Middle and Older groups scored significantly higher on the MASC due to fewer excessive inference mental state errors compared to Time 1 indicating that social cognition develops longitudinally in late adolescence / early adulthood as measured with naturalistic, dynamic and auditory stimuli. The Older group at Time 2 attained the highest mean score on the MASC and answered 5 more questions correctly than the adult group in Ritter et al. (2011) who had a mean age of 33.2 years. However, types of MASC errors and IQ scores are not reported by Ritter et al. so these cannot be compared. A higher MASC Total score for the Older group in the present study compared to the adult group in Ritter et al. (2011) may reflect the decline in emotion recognition over adulthood. Mill, Allik, Realo and Valk (2009) assessed 18 to 84 year olds on visual static and auditory tests of emotion recognition and reported a decline in recognition of sadness and anger commencing around age 30, possibly due to age related cognitive decline although this was not assessed.

In the present results, the Younger group scored lower on IRI Personal Distress at Time 2 compared to Time 1. This finding supports Davis and Franzoi (1991) who reported Personal Distress decreased in 15 and 16 year olds when tested over three consecutive years. No other developmental changes were found on the IRI Fantasy, Empathic Concern or Perspective Taking scales indicating these aspects of empathy are relatively stable across late adolescence and early adulthood. This finding is partly supported by Haker, Schimansky, Jann and Rössler (2012) who administered the IRI to a control group with a mean age of 32 years (SD 11) in a longitudinal study with a mean interval of 38 months (SD 6.4) between testing and reported no significant longitudinal changes on any subscale suggesting stability over time. The present data show Younger, Middle and Older groups at both time points attained a lower Perspective Taking and higher Personal Distress means compared to adult data reported by Hassenstab et al. (2007). This indicates that self-report Perspective Taking may continue to develop beyond early adulthood. Personal Distress may be higher in the late adolescent / early adulthood sample than later adulthood in the Hassenstab et al. sample due to specific challenges in late adolescence and early adulthood for example changing living arrangements and friendship groups and commencing employment or higher education.

One issue with longitudinal research is practice effects, better performance on tests due to previous completion and becoming accustomed to the study in general (Jønsson et al., 2006). Practice effects were reduced in the present study by giving participants no feedback about whether answers were correct. Alternate forms of tasks reduce practice effects and an interval of a year between testing minimised memory contributing to practice effects (Hausknecht et al., 2007). Therefore, alternative letters and cards were used in the D-KEFS Letter Fluency and Sorting Tests at Time 2. Scores did not all improve at Time 2 compared to Time 1 indicating that practice effects are not a problem in the present study. Another issue with longitudinal research is a decrease in power due to attrition between time points. Power of 0.8 or above is classed as high (Dancey & Reidy, 2004). Power for the effect of time in the ANOVAs was very high; for example 0.99 on the Hayling and Brixton Tests and 1.00 on Tower time per move with several significant longitudinal task score changes evident in these analyses.

To conclude, results of the Time 2 cross sectional analyses show group differences on strategy generation, concept formation (free sort % accuracy), planning (time per move) and tendency to relate to characters in books and films (IRI Fantasy). Results of longitudinal analyses show that executive functions and social cognition follow divergent trajectories with some functions improving between testing (inhibition, rule detection, strategy generation, planning and emotion recognition in dynamic stimuli and feelings of apprehension in stressful situations) and others declining (concept formation) or stabilising (emotion recognition with visual static and auditory stimuli, sympathetic feelings towards other people's misfortune, tendency to associate with characters in books and films and tendency of a person to consider other peoples' viewpoints). The protracted development of functions may reflect continued brain maturation into late adolescence and early adulthood including myelination (Sowell et al., 2001) and functional connectivity (Stevens et al., 2007).

Chapter 7

IQ, mood, gender and executive function predictors of social cognition

7.1 Introduction

Cognitive processes involved in social cognition are currently of interest (Vetter, Altgassen, Phillips, Mahy & Kliegel, 2013) with particular attention on executive functions because they initiate, co-ordinate, maintain and inhibit other functions (Miyake et al., 2000). Studies examining the relationship between executive function and social cognition have predominantly focused on children (e.g. Henning, Spinath & Ascherslaben, 2011; Hughes & Ensor, 2007; Müller, Liebermann-Finestone, Carpendale, Hammond & Bibok, 2012) or atypical populations (e.g. Head Injury; Eslinger et al., 1992, and Autism; Dziobek et al., 2006). Executive functions and social cognition may be related due to functions sharing some common frontal neural substrates (Hughes & Ensor, 2007), although social cognition, assessed with the MASC (Dziobek et al., 2006), is thought to recruit more posterior regions (Wolf et al., 2010).

Some researchers consider social cognition to be domain specific and independent from other cognitive systems (e.g. Baron-Cohen, 1995; Leslie, 1994), whereas a domain general viewpoint suggests that social cognition depends on other cognitive functions such as executive function and language (Apperly, Samson & Humphreys, 2005). The Socio-cognitive Integration of Abilities Model (SOCIAL; Beauchamp & Anderson, 2010), described in Section 1.16.3, proposed that social cognitive development is influenced by internal factors (e.g. personality), external factors (e.g. family environment) and cognitive functions including an attention-executive component. The SOCIAL model supports a domain general viewpoint of social cognition. The attention-executive component comprises attentional control, cognitive flexibility and goal setting, meeting Anderson's (2008) definition of executive function. However, this definition of executive function omits inhibition and strategy generation and it is likely that these executive functions are utilised in social cognition. In contrast, Nelson et al. (2005) incorporated inhibition in the cognitive-regulatory node of the Social

Information Processing Network (see section 1.16.2). In social interaction it might be necessary to inhibit particular behaviour such as anger in order to execute a plan and achieve a particular goal (Nelson et al., 2005). Previous research in children aged 2 to 4 has found a directional relationship of executive functions (planning, inhibition, set shifting and working memory) predicting social cognition (deception, false belief and pretend play) rather than social cognition predicting executive function (Hughes & Ensor, 2007). Executive functions including self-monitoring and inhibition of behaviour allow the avoidance of inappropriate behaviour, possibly resulting in more successful social interactions and social cognitive development.

Data reported in Chapters 5 and 6 indicate that executive functions and social cognition follow different developmental trajectories with social cognition appearing relatively stable by early adulthood. As social cognition is not greatly influenced by age in the present sample, it is of interest which factors such as IQ, mood state and executive functions predict social cognition task ability. Whilst research on executive function and social cognition has focused on childhood, it is possible that different relationships are evident between executive functions and social cognition between childhood and adulthood. For example, executive functions may be necessary in the development of social cognition during childhood but not in adulthood or executive functions may continue to be crucial in adult social cognition (Apperly, Samson & Humphreys, 2009). It is important to establish the contribution of domain general processes such as executive functions and language to social cognition in late adolescence / early adulthood when social cognition is more mature relative to childhood and adolescence (Apperly, Samson & Humphreys, 2009).

Similarly, Head Injury (HI) studies support the interplay of executive functions and social cognition. For example, Muller et al. (2010) reported that HI participants (mean age 32 years) scored lower than standard scores on strategy generation (Verbal Fluency), inhibition (Stroop Test) and mental flexibility (Trail Making Test) and significantly lower than a control group on second order false belief tasks, the Faux Pas Test and the Eyes Test. Whilst Muller et al. (2010) did not note whether there was a significant difference between participants' executive function and standard scores, overall the results indicate HI is associated with deficits in executive function and social cognition suggesting some interplay between these processes. Furthermore, Eslinger et al. (1992) reported a case study of DT who suffered a haemorrhage at age 7 resulting in damage to the left prefrontal network. In childhood DT reached all normal developmental milestones, but then experienced a delayed onset of deficits in adolescence including executive functions (planning and cognitive flexibility), empathic ability and moral development. Eslinger et al. concluded that executive functions and social cognition are closely related due to deficits in both following HI particularly during adolescence/early adulthood.

Some studies have reported executive function predictors of social cognition. Ahmed and Miller (2011) administered all D-KEFS Tests (Delis et al., 2001), the Eyes Test (Baron-Cohen et al., 2001), Strange Stories (Happé, 1994) and Faux Pas Test (Stone et al., 1998) to a sample of 123 18 to 27 year olds (70 females and 53 males). Ahmed and Miller extended previous research by assessing a wider range of executive functions. The authors also investigated whether age, gender, ethnicity, family income, geographical region raised and Full Scale IQ estimated from the Wechsler Test of Adult Reading (Wechsler, 2001) predicted social cognition task scores. Full Scale IQ significantly predicted the Eyes Test scores and gender significantly predicted performance on the Faux Pas Test with females scoring higher than males. Executive function scores did not predict performance on the Eyes Test. Strategy generation, assessed with the Verbal Fluency Test and deductive reasoning, assessed with the Word Context Test, significantly predicted performance on the Strange Stories Test. Successful strategy generation and deductive reasoning require flexible initiation of responses that are vital in social interactions to flexibly initiate behaviour (Ahmed & Miller, 2011). Strategy generation, assessed with the Verbal Fluency Test, and concept formation, indexed by the number of confirmed correct sorts on the Sorting Test, significantly predicted scores on the Faux Pas Test, requiring simultaneous consideration of two people's mental states. It is possible that working memory may be involved in remembering words produced in the Verbal Fluency Test, sorts made on the Sorting Test and consideration of two people's mental states in the Faux Pas Test. These findings indicate that different sub-components of executive function predict separate parts of social cognition. However, the study did not assess some aspects of social cognition e.g. empathy or social cognition with auditory or dynamic stimuli in this sample.

Vetter et al. (2013) investigated executive function predictors of social cognition in 139 participants aged 12 to 23 years. Participants completed executive function tasks of inhibition (Antisaccade Task; Miyake et al., 2000), updating (Letter Memory Task; Miyake et al., 2000) and shifting (Colour-shape Task; Friedman et al., 2006). The Antisaccade Task required participants to focus on a fixation point on a computer screen and then inhibit attention to a black square, instead focusing on an arrow presented on the other side of the computer screen and pressing a button to identify the arrow direction. Stimuli for the Letter Memory Task, a measure of updating, were lists 5 to 9 letters long with participants required to recall the last 3 letters in each list. For the Colour-shape Task assessing shifting, participants classified objects by colour (green or red) or shape (circle or triangle) by pressing a button. Reaction times were recorded and a difference in mean reaction time between mixed blocks and single task blocks was calculated. Participants also completed the facial scale from the Cambridge Mindreading Face-Voice Battery (CAM; Golan et al., 2006), consisting of dynamic, silent clips 3 to 5 seconds long showing an actor portraying an emotion, to assess social cognition. The authors conducted this study to improve on previous ToM research in late adolescence that had small sample sizes (neuroimaging studies e.g. Burnett & Blakemore, 2009) and often employed static stimuli or assessed a narrow range of executive functions. Age showed a significant positive correlation with inhibition, updating, shifting and CAM task scores indicating that these executive functions and mental state understanding in dynamic clips continue to develop between early adolescence and early adulthood. Vetter et al. found that inhibition was the only significant executive function predictor of scores on the CAM and suggested that inhibition of the first spontaneous guess may be required to allow consideration of the whole clip and a sensible answer to be given. A limitation of this study is that social cognition was only assessed with one task and, whilst the task was dynamic, it omitted vocal information and social interaction.

An alternative method for investigating executive function predictors of social cognition is the dual-task paradigm, when participants complete executive function and social cognition tasks simultaneously. In a study by Bull, Phillips and Conway (2008), participants completed the Reading the Mind in the Eyes Test (Baron-Cohen et al., 2001) and Theory of Mind Stories Task (Happé, 1994; Stone et al., 1998) as single tasks and concurrently with inhibition, switching and updating tasks. Participants performed significantly worse on the Stories dual task with all executive function tasks compared to completing solely the Stories Task, possibly due to sharing attentional skills (Bull et al., 2008; McKinnon & Moscovitch, 2007). Performance on the Eyes Test was significantly lower during inhibition dual task relative to completing the Eyes Test as a single task. Bull et al. (2008) concluded that inhibition was crucial to mentalising and proposed that when completing the Eyes Test it is necessary to inhibit social attributes associated with age and gender that might be automatically activated (Santos & Young, 2005) and instead focus on mental states.

Previous research therefore shows that ability on some executive function tasks predict ability on measures of social cognition across broad age ranges. For example, strategy generation (Letter Fluency Test) and deductive reasoning (Word Context Test) significantly predicted Strange Stories Task scores whilst strategy generation (Letter Fluency Test) and concept formation (Sorting Test) significantly predicted scores on the Faux Pas Test (Ahmed & Miller, 2011). In another study, Vetter et al. (2013) found that inhibition, measured by an Antisaccade Task, significantly predicted scores on the CAM Facial Task across adolescence and early adulthood. However, reviewed studies have assessed social cognition with a limited range of tasks, e.g. lacking dynamic stimuli: Reading the Mind in the Eyes, Strange Stories and Faux Pas Tests (Ahmed & Miller, 2011) or restricted to only one task (Vetter et al., 2012) and across broad age groups.

The effect of IQ, age, mood and gender was also assessed in the present analyses by considering Verbal IQ, Performance IQ, Full scale IQ, age, Positive Affect and Negative Affect from the PANAS (Watson et al., 1988), Depression and Anxiety scores from the HADS (Zigmond & Snaith, 1983) and gender. These were based on previous research reviewed in Chapters 1 and 2 that age, gender, IQ, affect, depression and anxiety may affect social cognition and executive function task performance. For example, Thomas et al. (2007) reported a main effect of age on an emotion recognition task and Choudhury et al. (2006) reported a main effect of age in children, adolescents and adults in an emotion Perspective Taking Task. Gender differences have been reported on self-report empathy (Derntl et al., 2010). With regard to IQ, Golan et al. (2007) reported a significant correlation between WASI Verbal IQ and the Voice Test but not the Eyes Test possibly due to the Voice Test requiring more verbal processing than the Eyes Test. Ibanez et al. (2013) found that Performance IQ, assessed with Raven Progressive Matrices (Raven, 2000) predicted scores on the Eyes Test in early adolescence.

Mood has also been shown to affect executive function; capacity limitation theories (e.g. Seibert & Ellis, 1991) propose that both positive and negative mood impairs executive function by reducing available cognitive resources. In contrast, the "mood as information" model suggests that positive mood may result in a heuristic processing style that impairs executive function, whilst negative mood increases motivation and may lead to improved executive function ability. Phillips, Smith and Gilhooly (2002) found that positive mood compared to neutral mood resulted in poorer planning, indexed by solving fewer trials in the minimum number of moves on the Tower of London Task. Phillips, Bull, Adams and Fraser (2002) reported that participants in a happy mood showed better strategy generation, assessed with a Verbal Fluency Task, relative to participants in a neutral mood. This finding conflicts with the "mood as information" model because a broad search space is needed for successful strategy generation. Some studies have assessed mood and social cognition. For example, sadness related to better performance on the Director Perspective Taking Task compared to happiness (Converse et al., 2008) but lower emotion recognition relative to neutral mood (Chepenik et al., 2007). Mixed findings are evident for the effects of depression on executive function and social cognition. Favre et al. (2009) found no group differences on set shifting (WCST), strategy generation (Letter Fluency) and inhibition (Stroop Test), whereas Uekermann et al. (2008) reported a depressed group scored lower than a control group on strategy generation (Verbal Fluency). The inconsistent findings may be explained by differences in symptom severity and measures used. Mild to moderate depression (dysphoria) is associated with greater visual emotion recognition accuracy, assessed with the Eyes Test, compared to a control group (Harkness et al., 2005). Airaksinen et al. (2005) compared different anxiety sub groups and found no group differences between controls and participants with Generalized Anxiety Disorder on strategy generation (Letter Fluency) whereas individuals with obsessive compulsive disorder and panic disorder showed impairments on motor tracking (Trail Making Test).

The present study adds to the literature by examining executive function predictors of social cognition using a range of executive function tasks with social cognition assessed in different task formats including emotion recognition in static visual stimuli (Eyes Test), auditory stimuli (Voice Test), dynamic stimuli (MASC) and self-report empathy (IRI). The following executive functions were assessed in the present study: inhibition (Hayling Test), rule detection (Brixton Test), strategy generation (D-KEFS Letter Fluency), concept formation (D-KEFS Sorting Test) and planning (D-KEFS Tower Test). Inhibition might allow a person to inhibit their mental states and consider another person's viewpoint, or to inhibit their first guess and consider the whole clip (Vetter et al., 2013) in the MASC. Rule detection could be relevant to social cognition because detecting patterns in stimuli may assist with detecting patterns in social situations e.g. attending to facial expressions, body language and prosody could result in successful mental state understanding. Strategy generation and concept formation may relate to social cognition because social situations require flexible initiation of responses (Ahmed & Miller, 2011). Planning may relate to social cognition by participants being better able to plan how to act in social situations. The age range of participants in the present study is more constrained than previous studies to focus more on late adolescence and early adulthood when brain maturation is dynamic (Sowell et al., 2001; Gogtay et al., 2004).

7.2 Method

7.2.1 Participants

This chapter presents data from the same participants as in Chapters 4, 5 and 6. The sample at Time 1 consisted of 98 participants (77 females and 21 males) with 58 participants (47 females and 11 males) completing the study at Time 2, a mean of 15 months (SD = 3.67 months) after Time 1. Age groups were collapsed to allow whole group analysis resulting in a mean age at Time 1 of 18 years 4 months (SD = 9.15 months) and a mean age at Time 2 of 19 years 6 months (SD = 9.54 months).

7.2.2 Measures

The Wechsler Abbreviated Scale of Intelligence provided Verbal, Performance and Full Scale IQ scores. The Positive and Negative Affect Scale (PANAS) and the Hospital Anxiety and Depression Scale (HADS) measured mood state and anxiety and depression respectively. Participants completed the Hayling and Brixton Tests assessing inhibition and rule detection. Three tests were selected from the D-KEFS: the Letter Fluency Test, a measure of response generation, the Sorting Test, a measure of concept formation and the Tower Test, a measure of planning. Participants completed social cognition tasks assessing emotion recognition in visual static stimuli (Reading the Mind in the Eyes Test), auditory stimuli (Reading the Mind in the Voices Test) and dynamic, visual and auditory stimuli (Movie for the Assessment of Social Cognition; MASC) and self-report empathy (Interpersonal Reactivity Index; IRI). Figure 3.1 in Chapter 3 shows a diagram of the task battery. Alternative versions of the D-KEFS Letter Fluency and Sorting Tests were administered at Time 1 and Time 2 to reduce practice effects.

7.2.3 Plan of analyses

Data analyses explored age, IQ, gender and mood state and executive function predictors of social cognition task scores at Time 1 and Time 2 separately. The variables considered were age, gender, Verbal IQ, Performance IQ, Full scale IQ, Positive Affect and Negative Affect from the PANAS (Watson et al., 1988), and Depression and Anxiety scores from the HADS (Zigmond & Snaith, 1983). Other variables, such as drug use, were not included as predictors because analyses in Chapter 5.9 indicate that drug use does not affect social cognition task scores in the present sample. Correlations were conducted between age, IQ and mood state variables (see Appendix section 13) and executive function variables (see Appendix section 14) to check for multicollinearity, when variables correlate highly (0.8 or above; Dancey & Reidy, 2004; Field, 2005). If variables correlated highly then one variable would be removed because a high level of collinearity indicates that the variables are measuring the same construct (Dancey & Reidy, 2004) and would make it difficult to identify which of the two variables contributes more to criterion variable variance (Miles & Shevlin, 2011). Full Scale IQ was not included as a predictor in the multiple regression due to high multicollinearity with Verbal IQ ($r = 0.82, p < 0.01$) and Performance IQ ($r = 0.80, p < 0.01$) shown in the correlation matrix in Appendix section 13. Verbal and Performance IQ were retained to examine whether different aspects of IQ predict social cognition. It is possible that Performance IQ, assessed with block design and matrix reasoning, may relate to visual social cognition tasks due to the visuospatial nature of the both measures. The correlation matrix in Appendix section 14 shows that the greatest correlation between executive function variables was $r = 0.24$ for Letter Fluency and Brixton Scaled scores showing no indication of multicollinearity and that variables assess different aspects of executive function.

Separate regressions were conducted with Eyes, Voices, MASC Total score, MASC excessive mental state inference errors, IRI Fantasy and IRI Personal Distress as dependent variables. These tasks assess the following aspects of social cognition: emotion recognition in visual stimuli (Eyes Test), auditory stimuli (Voices Test), and dynamic visual and auditory stimuli (MASC Total score). MASC excessive mental state inference errors refer to errors when the participant has over-attributed the mental state content. These MASC variables are of interest because Middle and Older groups scored higher at Time 2 compared to Time 1 on MASC Total score due to fewer MASC excessive inference errors. Other MASC error variables were not included as dependent variables in a multiple regression due to small variance. Personal Distress and Fantasy were selected from the IRI self-report measure of empathy because an interaction was found between age group and time for Personal Distress and Time 2 group differences were evident on the Fantasy scale (Younger and Older groups scored higher than the Middle group).

Multiple regressions were conducted for each dependent variable to explore whether age, IQ, mood and gender predicted social cognition task performance. The following variables were entered into multiple regressions as independent variables: age, gender, Verbal IQ, Performance IQ, Positive Affect, Negative Affect, Depression and Anxiety. Following this, the age, IQ, gender and mood state variables that significantly predicted social cognition were entered into Step 1 to account for any effects and executive function task scores (Hayling Scaled, Brixton Scaled, Letter Fluency, Free Sorts Description and Tower Achievement Scores) were entered into Step 2 of hierarchical regressions. The forced entry method was used to enter all predictors into regressions meaning no decision about the order of variables was required (Field, 2005).

A score from each executive function task was selected to reflect the range of executive functions measured and assess whether inhibition, rule detection, strategy generation, concept formation and planning predict social cognition task scores. Executive function variables included in the analyses were Hayling Scaled scores, Brixton Scaled scores, Letter Fluency scores, Sorting Test free sort description scores and Tower Achievement scores. Hayling and Brixton Scaled scores were selected because these are the most frequently used measure of performance for these tasks reported in the literature (Barker et al., 2010; Frangou, Donaldson, Hadjulis, Landau & Goldstein, 2005; Joshua, Gogos & Rossell, 2009; Wood & Liossi, 2005). Primary measures (Letter Fluency, Free sort description score and Tower Achievement scores) were selected from the D-KEFS Tests because these are often reported in the literature and provide an overall indication of task performance (Strauss et al., 2006).

7.3 Results

Predictors of Time 1 social cognition data are presented in Section 7.3.1 and Time 2 data in Section 7.3.3.

7.3.1 Time 1 data

7.3.1.1 Reading the Mind in the Eyes Test: Static visual stimuli

The model with age, IQ, gender and mood state variables as predictor variables and Eyes Test score as the dependent variable is presented in Table 7.1.

Table 7.1. Results of multiple regression analysis for age, IQ, gender and mood state predictors of the Reading the Mind in the Eyes Test at Time 1

	β	t	p
Age	0.20	1.83	0.072
Gender	-0.05	0.52	0.606
Verbal IQ	0.24	2.15	0.035*
Performance IQ	0.18	1.69	0.095
PANAS Positive Affect	-0.22	2.08	0.041*
PANAS Negative Affect	-0.02	0.17	0.868
HADS Depression	-0.11	0.95	0.348
HADS Anxiety	-0.03	0.24	0.812

$R = 0.44$, $R^2 = 0.19$, Adjusted $R^2 = 0.11$

Results presented in Table 7.1 show that the model containing age, IQ, gender and mood state variables significantly predicted performance on the Eyes Test (F (8, 79) = 2.32, $p = 0.027$) and accounted for 11% of variance (Adjusted $R^2 = 0.11$). Verbal IQ ($\beta = 0.24$, $t = 2.15$, $p = 0.035$) positively predicted Eyes Test scores whilst Positive Affect negatively predicted Eyes Test scores ($\beta = -0.22$, $t = 2.08$, $p = 0.041$). A hierarchical regression was conducted with Verbal IQ and Positive Affect entered into Step 1 and executive function variables entered into Step 2 with the Eyes Test score as the dependent variable (see Table 7.2).

Table 7.2. Results of hierarchical multiple regression analysis for the prediction of the Reading the Mind in the Eyes Test at Time 1

	β	t	p
Model 1 – IQ and Positive Affect			
Verbal IQ	0.24	2.38	0.019*
Positive Affect	-0.16	1.63	0.107
Model 2 – IQ, Positive Affect and executive function predictors			
Verbal IQ	0.14	1.30	0.196
Positive Affect	-0.11	1.16	0.250
Hayling Scaled	0.05	0.52	0.605
Brixton Scaled	0.33	3.22	0.002*
Letter Fluency	0.06	0.54	0.594
Free sort description score	-0.04	0.42	0.675
Tower Achievement score	0.03	0.33	0.743

Model 1: $R = 0.29$, $R^2 = 0.08$, Adjusted $R^2 = 0.06$
Model 2: $R = 0.44$, $R^2 = 0.19$, Adjusted $R^2 = 0.13$

Results presented in Table 7.2 show that Model 1 significantly predicted Eyes Test scores (F (2, 94) = 4.25, $p = 0.017$) with Verbal IQ ($\beta = 0.24$, $t = 2.38$, $p = 0.019$) being a significant predictor. Model 2 also significantly predicted Eyes Test scores (F (7, 89) = 3.03, p = 0.007, F change = 2.41, p = 0.043, R^2 change = 0.11) and accounted for 13% of variance (Adjusted R^2 = 0.13). Rule detection assessed with the Brixton Test (β = 0.33, t = 3.22, p = 0.002) was a significant predictor. The Brixton Test, a measure of rule detection in a visuospatial format, requires participants to identify the pattern followed by a coloured circle on subsequent page turns in an array of blank circles. Successful pattern identification and rule detection could improve emotion recognition in visual stimuli because a particular pattern of facial expressions or body language may be associated with a certain mental state. The Brixton and Eyes Tests are also both visual tasks.

7.3.1.2 Reading the Mind in the Voice Test: Auditory stimuli

Table 7.3 presents the regression analysis with age, IQ, gender and mood state variables as independent variables and scores on the Voice Test as the dependent variable.

Table 7.3 Results of multiple regression analysis for age, IQ, gender and mood state predictors of the Voice Test at Time 1

	β	t	p
Age	0.02	0.22	0.829
Gender	-0.05	0.46	0.648
Verbal IQ	0.38	3.43	0.001*
Performance IQ	0.17	1.56	0.122
PANAS Positive Affect	-0.04	0.38	0.704
PANAS Negative Affect	-0.02	0.19	0.852
HADS Depression	0.11	0.95	0.347
HADS Anxiety	-0.09	0.78	0.437

R = 0.45, R^2 = 0.20, Adjusted R^2 = 0.12

The model with age, IQ, gender and mood state variables significantly predicted Voice Test scores (F (8, 80) = 2.50, p = 0.018) with Verbal IQ being a significant predictor (β = 0.38, t = 3.43, p = 0.001). A hierarchical regression is presented in Table 7.4 with Verbal IQ in Step 1 and executive function task scores in Step 2.

Table 7.4. Results of multiple regression analysis for the prediction of total score on the Reading the Mind in the Voice Test at Time 1

	β	t	p
Model 1 – IQ			
Verbal IQ	0.38	4.04	<0.001*
Model 2 – IQ and executive function predictors			
Verbal IQ	0.32	3.03	0.003*
Hayling Scaled	0.14	1.53	0.130
Brixton Scaled	0.25	2.64	0.010*
Letter Fluency	-0.09	0.85	0.396
Free sorts description score	0.07	0.71	0.482
Towers Achievement score	-0.04	0.38	0.703

Model 1: $R = 0.38$, $R^2 = 0.15$, Adjusted $R^2 = 0.14$
Model 2: $R = 0.48$, $R^2 = 0.23$, Adjusted $R^2 = 0.18$

Results presented in Table 7.4 show that the model with Verbal IQ significantly predicted Voice Test scores (F (1, 96) = 16.32, p <0.001) with Verbal IQ being a significant predictor (β = 0.38, t = 4.04, p <0.001). The model with Verbal IQ and executive function variables also predicted Voice Test scores (F (6, 91) = 4.58, p < 0.001) with Verbal IQ (β = 0.32, t = 3.03, p = 0.003) and rule detection, assessed with the Brixton Test (β = 0.25, t = 2.64, p = 0.010), significantly predicting Voice Test scores. Good pattern identification would result in successful rule detection on the Brixton Test that may be relevant when detecting patterns in auditory stimuli informing emotion recognition.

7.3.1.3 MASC Total score: Dynamic visual and auditory stimuli

Table 7.5 shows the regression analysis with age, IQ, gender and mood state variables entered as predictor variables and MASC Total score as the dependent variable.

Table 7.5. Results of multiple regression analysis for age, IQ, gender and mood state predictors of MASC Total score at Time 1

	β	*t*	*p*
Age	0.16	1.42	0.159
Gender	-0.20	1.89	0.062
Verbal IQ	0.18	1.64	0.104
Performance IQ	0.23	2.16	0.034*
PANAS Positive affect	-0.13	1.28	0.203
PANAS Negative affect	0.07	0.63	0.532
HADS Depression	-0.26	2.33	0.022*
HADS Anxiety	0.02	0.17	0.864

$R = 0.45$, $R^2 = 0.21$, Adjusted $R^2 = 0.13$

Results presented in Table 7.5 show that the model with age, IQ, gender and mood state variables significantly predicted MASC Total score (F (8, 80) = 2.59, p = 0.014) that accounted for 13% of variance (Adjusted R^2 = 0.13). Performance IQ (β = 0.23, t = 2.16, p = 0.034) and HADS Depression scores (β = -0.26, t = 2.33, p = 0.022) were significant predictors of MASC Total score.

A hierarchical regression was conducted with Performance IQ and HADS Depression scores entered in Step 1 and executive function variables in Step 2 with MASC Total score as the dependent variable (refer to Table 7.6).

Table 7.6. Results of hierarchical multiple regression analysis for the prediction of MASC Total score at Time 1

	β	t	*p*
Model 1: IQ and Depression			
Performance IQ	0.24	2.41	0.018*
HADS Depression	-0.26	2.60	0.011*
Model 2 : IQ, Depression and executive function predictors			
Performance IQ	0.15	1.38	0.173
HADS Depression	-0.26	2.66	0.009*
Hayling Scaled	-0.07	0.72	0.477
Brixton Scaled	0.17	1.57	0.120
Letter Fluency	0.22	2.17	0.033*
Free sort description score	-0.02	0.20	0.841
Tower Achievement score	0.14	1.37	0.176

Model 1: $R = 0.35$, $R^2 = 0.12$, Adjusted $R^2 = 0.10$
Model 2: $R = 0.48$, $R^2 = 0.23$, Adjusted $R^2 = 0.17$

Overall, Model 1 was significant (F (2, 86) = 5.93, p = 0.004) with Performance IQ (β = 0.24, t = 2.41, p = 0.018) and HADS Depression scores (β = -0.26, t = 2.60, p = 0.011) significantly predicting MASC Total score. Table 7.6 shows that with the addition of executive function variables in Step 2 the model remained significant (F (7, 81) = 3.49, p = 0.003, F change = 2.33, $p < 0.05$, R^2 change = 0.11) and accounted for 7% more variance than model 1 (Adjusted R^2 = 0.17). HADS Depression score (β = -0.26, t = 2.66, p = 0.009) and strategy generation, assessed with the Letter Fluency Test, were significant predictors (β = 0.22, t = 2.17, p = 0.033) of MASC Total score, an assessment of social cognition with dynamic stimuli that included visual and auditory information. Successful strategy generation may require flexible behaviour that allows participants to work through words beginning with a particular letter in a methodical way. Flexible behaviour is relevant in social situations to allow the generalisation of concepts to different situations (Ahmed & Miller, 2011).

7.3.1.4 MASC excessive mental state inference errors

The model with age, IQ, gender and mood state variables as predictors of MASC excessive mental state errors is presented in Table 7.7.

Table 7.7. Results of multiple regression analysis for age, IQ, gender and mood state predictors of MASC excessive mental state inference errors at Time 1

	β	t	p
Age	-0.14	1.23	0.221
Gender	0.33	3.20	0.002**
Verbal IQ	-0.16	1.49	0.141
Performance IQ	-0.24	2.29	0.025*
PANAS Positive affect	0.05	0.50	0.616
PANAS Negative affect	-0.12	1.06	0.291
HADS Depression	0.16	1.45	0.151
HADS Anxiety	0.09	0.78	0.435

R = 0.47, R^2 = 0.22, Adjusted R^2 = 0.14

Table 7.7 shows that the model with age, IQ, gender and mood state variables significantly predicted MASC excessive mental state inference errors (F (8, 80) = 2.79, p = 0.009, R = 0.47, R^2 = 0.22 Adjusted R^2 = 0.14) and accounted for 14% of variance (Adjusted R^2 = 0.14). Gender (β = 0.33, t = 3.20, p = 0.002) and Performance IQ

(β = -0.24, t = 2.29, p = 0.025) were significant predictors of MASC excessive mental state inference errors, when mental state content is over-interpreted. Males (median = 6.00, range = 9.00) made significantly more MASC excessive mental state errors than females (median = 5.00, range = 12.00, U = 510.50, z = 2.60, p = 0.009, r = 0.26).

A hierarchical regression was conducted with Performance IQ and Gender in Step 1, executive function variables in Step 2 and MASC excessive mental state inference errors as the dependent variable (see Table 7.8).

Table 7.8. Results of hierarchical multiple regression analysis for the prediction of MASC excessive mental state inference errors at Time 1

	β	t	p
Model 1: IQ and Gender			
Performance IQ	-0.26	2.79	0.006*
Gender	0.31	3.28	0.001*
Model 2 : IQ, Gender and executive function predictors			
Performance IQ	-0.19	1.84	0.069
Gender	0.32	3.28	0.001*
Hayling Scaled	-0.01	0.05	0.957
Brixton Scaled	-0.06	0.57	0.571
Letter Fluency	-0.10	0.97	0.332
Free sort description score	-0.15	1.47	0.145
Tower Achievement score	0.12	1.20	0.198

Model 1: R = 0.39, R^2 = 0.16, Adjusted R^2 = 0.14
Model 2: R = 0.46, R^2 = 0.22, Adjusted R^2 = 0.15

Results in Table 7.8 show that Model 1 significantly predicted MASC excessive mental state errors (F (2, 95) = 8.71, p < 0.001) with Performance IQ (β = -0.26, t = 2.79, p = 0.006) and Gender (β = 0.31, t = 3.28, p = 0.001) being significant predictors. With the addition of executive function variables in Step 2 the model remained significant (F (7, 90) = 3.53, p = 0.002, F change = 1.39, p = 0.237, R^2 change = 0.06) although this did not result in a significant F Change indicating that the addition of executive function variables did not explain significantly more variance in MASC excessive mental state inference errors than model 1. Gender was a significant predictor (β = 0.32, t = 3.28, p = 0.001) whilst no executive function variables significantly predicted MASC excessive mental state inference errors.

7.3.1.5 Interpersonal Reactivity Index (IRI) Fantasy

The model with age, gender and mood state variables as predictors and IRI Fantasy as the dependent variable is presented in Table 7.9.

Table 7.9. Results of multiple regression analysis for age, IQ, gender and mood state predictors of IRI Fantasy at Time 1

	β	t	p
Age	0.02	0.15	0.885
Gender	0.05	0.50	0.617
Verbal IQ	0.15	1.37	0.173
Performance IQ	0.04	0.39	0.698
PANAS Positive affect	-0.07	0.65	0.520
PANAS Negative affect	-0.10	0.81	0.418
HADS Depression	-0.18	1.50	0.137
HADS Anxiety	0.37	3.08	0.003*

$R = 0.38$, $R^2 = 0.15$, Adjusted $R^2 = 0.06$

Whilst the model with age, IQ, gender and mood state variables did not significantly predict Fantasy scores (F (8, 79) = 1.70, p = 0.112), HADS Anxiety score was a significant predictor (β = 0.37, t = 3.08, p = 0.003). A hierarchical regression was conducted with HADS Anxiety scores in Step 1 and executive function variables in Step 2.

Table 7.10. Results of hierarchical multiple regression analysis for the prediction of IRI Fantasy at Time 1

	β	t	p
Model 1: Anxiety			
Anxiety	0.26	2.53	0.013*
Model 2 : Anxiety and executive function predictors			
Anxiety	0.23	2.20	0.031*
Hayling Scaled	0.09	0.88	0.384
Brixton Scaled	0.21	1.99	0.050
Letter Fluency	0.12	1.11	0.269
Free sort description score	-0.05	0.49	0.628
Tower Achievement score	-0.10	0.91	0.367

Model 1: $R = 0.26$, $R^2 = 0.07$, Adjusted $R^2 = 0.06$
Model 2: $R = 0.38$, $R^2 = 0.15$, Adjusted $R^2 = 0.08$

The results in Table 7.10 show that Model 1 with Anxiety scores ($\beta = 0.26$, $t = 2.53$, $p = 0.013$) significantly predicted IRI Fantasy scores (F (1, 86) = 6.38, $p = 0.013$). Model 2 also significantly predicted IRI Fantasy scores (F (6, 81) = 2.28, $p = 0.043$, F change = 1.44, $p = 0.220$, R^2 change = 0.08) although Anxiety was the only significant predictor. Rule detection, assessed with the Brixton Test, approached significance ($\beta = 0.21$, $t = 1.99$, $p = 0.050$), with no other executive function variables contributing to IRI Fantasy scores. The Brixton Test assesses rule detection in visual stimuli. It is possible that this relates to IRI Fantasy, the tendency to associate with characters in books and films, by evaluating information e.g. participants evaluate the movement of coloured circles to ascertain the pattern and predict where the coloured circle will move to next. Participants who score highly on IRI Fantasy would evaluate characters in books and relate to them. Anxiety may predict IRI Fantasy because people who score highly on HADS Anxiety may relate to characters in books and films as a coping strategy.

7.3.1.6 IRI Personal Distress

Table 7.11 presents the model with age, IQ, gender and mood state variables as predictors and IRI Personal Distress as the dependent variable.

Table 7.11. Results of multiple regression analysis for age, IQ, gender and mood state predictors of IRI Personal Distress at Time 1

	β	t	p
Age	0.28	2.57	0.012*
Gender	-0.33	3.29	0.001**
Verbal IQ	0.05	0.45	0.656
Performance IQ	-0.07	0.70	0.488
PANAS Positive affect	-0.15	1.52	0.133
PANAS Negative affect	0.16	1.51	0.136
HADS Depression	-0.05	0.43	0.671
HADS Anxiety	0.22	2.00	0.049*

$R = 0.51$, $R^2 = 0.26$, Adjusted $R^2 = 0.19$

The regression analysis of age, IQ, gender and mood state variables resulted in a significant model that accounted for 19% of variance in IRI Personal Distress (F (8, 79) = 3.53, $p = 0.002$, $R = 0.51$, $R^2 = 0.26$, Adjusted $R^2 = 0.19$). Table 7.11 shows that age in months ($\beta = 0.28$, $t = 2.57$, $p = 0.012$), gender ($\beta = -0.33$, $t = 3.29$, $p = 0.001$) and

HADS Anxiety scores (β = 0.22, t = 2.00, p = 0.049) were significant predictors of IRI Personal Distress scores. Data analysis presented in Chapter 5 showed that females (median = 14.50, range = 24.00) scored significantly higher than males (median = 10.00, range = 16.00) on Personal Distress (U = 440.00, z = 3.15, p = 0.002, r = 0.32) indicating females reported greater uneasiness in tense social situations.

A hierarchical regression with age, gender and HADS Anxiety scores entered in Step 1 and executive function variables entered in Step 2 with Personal Distress as the dependent variable is presented in Table 7.12.

Table 7.12. Results of hierarchical multiple regression analysis for the prediction of IRI Personal Distress at Time 1

	β	t	p
Model 1: Age, Gender and Anxiety			
Age	0.19	1.91	0.059
Gender	-0.33	3.34	0.001*
HADS Anxiety	0.25	2.47	0.016*
Model 2: Age, Gender, Anxiety and executive function predictors			
Age	0.17	1.67	0.100
Gender	-0.38	3.77	<0.001**
HADS Anxiety	0.28	2.74	0.008**
Hayling Scaled	-0.20	2.04	0.045*
Brixton Scaled	-0.09	0.92	0.362
Letter Fluency	-0.03	0.33	0.745
Free sort description score	0.14	1.30	0.198
Tower Achievement	-0.13	1.29	0.201

Model 1: R = 0.46, R^2 = 0.21, Adjusted R^2 = 0.18
Model 2: R = 0.54, R^2 = 0.29, Adjusted R^2 = 0.22

Results of the hierarchical regression analysis presented in Table 7.12 showed that Model 1 significantly predicted Personal Distress (F (3, 84) = 7.39, p < 0.001) with gender (β = -0.33, t = 3.34, p = 0.001) and HADS Anxiety scores (β = 0.25, t = 2.47, p = 0.016) being significant predictors. The addition of executive function variables in model 2 again resulted in a significant model (F (8, 79) = 3.99, p = 0.001, F change = 1.74, p = 0.134, R2 change = 0.08) with gender (β = -0.38, t = 3.77, p < 0.001), HADS Anxiety (β = 0.28, t = 2.74, p = 0.008) and inhibition, indexed by Hayling Scaled score, (β = -0.20, t = 2.04, p = 0.045) being significant predictors. Scores on the Hayling Test, an assessment of inhibition, negatively predicted self-report Personal Distress, personal feelings of apprehension in stressful situations. A lower level of Personal Distress suggests better social functioning, possibly as a result of inhibition appeasing the situation e.g. inhibition would reduce the likelihood of a person becoming angry or upset in a stressful situation.

A summary of predictors of social cognition task performance is presented in Table 7.13.

Table 7.13. Summary of predictors of social cognition task performance at Time 1

Social cognition task	Age, IQ, gender and mood state predictors	Executive function predictors
Emotion recognition with static visual stimuli		
Eyes Test	Verbal IQ Positive affect (-ve)	Rule detection (Brixton Test) +ve
Emotion recognition with auditory stimuli		
Voices Test	Verbal IQ	Rule detection (Brixton Test) +ve
Dynamic visual aud auditory stimuli with social interaction		
MASC total score	Performance IQ (+ve), HADS Depression (-ve)	Strategy generation (Letter Fluency) +ve
MASC excessive mental state inference errors	Gender (males higher than females), Performance IQ (-ve)	No executive function predictors
Self-report empathy		
IRI Fantasy	HADS Anxiety (+ve)	No executive function predictors
IRI Personal Distress	Age (+ve), Gender (females higher than males) HADS Anxiety (+ve)	Inhibition (Hayling Test) –ve

+ve and –ve refers to the direction of relationship between predictor and dependent variable

7.3.2 Summary of Time 1 data

7.3.2.1 Age, IQ, gender and mood state predictors

At Time 1, Verbal IQ predicted scores on the Eyes and Voices Tests, measures of emotion recognition in visual static and auditory stimuli, possibly due to the verbal task requirements. Performance IQ, assessed with Block Design and Matrix Reasoning, positively predicted MASC Total score and negatively predicted MASC excessive mental state inference errors. Block design requires the ability to analyse abstract visual stimuli and visual-motor coordination and Matrix Reasoning requires visual information processing and abstract reasoning (Wechsler, 1999). Performance IQ may relate to the MASC by both requiring visual processing. Age predicted self-report Personal Distress, the tendency to feel anxious and uneasy in tense interpersonal situations. Gender predicted MASC excessive mental state inference errors (males higher) and IRI Personal Distress (females higher). Mood state predicted some aspects of social cognition; Positive Affect negatively predicted Eyes Test scores, HADS Depression scores negatively predicted MASC Total score and HADS Anxiety scores predicted IRI Fantasy and Personal Distress scores indicating that mood state can influence social cognition in a non-clinical sample.

7.3.2.2 Executive function predictors

Rule detection, assessed with the Brixton Test, was a significant predictor of scores on the Eyes and Voices Tests, measures of emotion recognition in visual static and auditory stimuli possibly due to shared pattern recognition processes across tasks. Strategy generation, assessed with the Letter Fluency Test, predicted MASC Total score. No executive function variables significantly predicted scores on the IRI Fantasy, indicating that functions assessed in the present study did not contribute to IRI Fantasy. Inhibition, assessed with the Hayling Test, negatively predicted IRI Personal Distress.

7.3.3 IQ, gender, mood state and executive function contributions to social cognition at Time 2 (*M* = 15 months, *SD* = 3.67 months after Time 1)

Correlations between age, IQ and mood state variables at Time 2 are presented in Appendix section 15. Correlations between executive function variables are presented in

Appendix section 16. The correlation matrices were inspected for variables with a correlation of 0.80 or higher indicating multicollinearity. Age, IQ and mood state variables were not correlated above 0.8 indicating no mutlicollinearity. The highest executive function correlation was r = 0.30 for Brixton Scaled scores and Tower Achievement indicating no multicollinearity for executive function predictors.

7.3.3.1 Reading the Mind in the Eyes Test: Static visual stimuli

The model with age, IQ, gender and mood state variables did not predict scores on the Eyes Test (F (9, 48) = 1.45, p = 0.193, R = 0.46, R^2 = 0.21, Adjusted R^2 = 0.07). A multiple regression with executive function scores as predictor variables and the Eyes Test as the dependent variable is presented in Table 7.14.

Table 7.14. Results of multiple regression analysis for the prediction of the Reading the Mind in the Eyes Test at Time 2

	β	t	p
Hayling Scaled	-0.08	0.67	0.513
Brixton Scaled	0.19	1.41	0.166
Letter Fluency	-0.07	0.51	0.613
Free sorts description score	-0.18	1.37	0.176
Tower Achievement score	0.34	2.56	0.014*

R = 0.44, R^2 = 0.19, Adjusted R^2 = 0.11

Results in Table 7.14 show that the regression model was significant (F (5, 52) = 2.43, p = 0.047) and accounted for 11% of variance in scores on the Eyes Test (Adjusted R^2 = 0.11). Planning, indexed by Tower Achievement score, significantly predicted performance on the Eyes Test (β = 0.34, t = 2.56, p = 0.014). Completion of the Tower Test requires planning and monitoring of behaviour ensuring adherence to task instructions (Wagner et al., 2006). Planning and monitoring may relate to social cognition because during social interaction people monitor their actions to ensure they fulfil their intentions and are appropriate in the current situation (Amodio & Frith, 2006).

7.3.3.2 Reading the Mind in the Voice Test: Auditory stimuli

There were no significant age, IQ, gender or mood state predictors of performance on the Reading the Mind in the Voice Test (F (9, 48) = 2.06, p = 0.053). A multiple regression with executive function scores as the predictor variables and Voice Test score as the dependent variable is presented in Table 7.15.

Table 7.15. Results of multiple regression analysis for the prediction of the Reading the Mind in the Voice Test at Time 2

	β	t	p
Hayling Scaled	0.93	0.67	0.355
Brixton Scaled	0.08	0.55	0.585
Letter Fluency	-0.08	0.57	0.572
Free sorts description score	<-0.01	<0.01	0.994
Tower Achievement score	0.29	2.08	0.043*

R = 0.35, R^2 = 0.12, Adjusted R^2 = 0.04

Whilst the overall model was not significant, (F (5, 52) = 1.47, p = 0.215, R = 0.32, R^2 = 0.10, Adjusted R^2 = 0.09), Tower Achievement score significantly predicted scores on the Voices Test (β = 0.29, t = 2.08, p = 0.043) and accounted for 4% of variance, indicating that planning contributes to emotion recognition in auditory stimuli. Following the initial regression model, another regression was conducted excluding any variables that were not significant to examine whether this resulted in a more parsimonious model that accounted for more of the variance (Field, 2005).

Table 7.16. Results of regression with Tower Achievement scores as the predictor variable and Voice Test scores as the dependent variable

	β	t	p
Tower achievement score	0.32	2.50	0.015*

R = 0.32, R^2 = 0.10, Adjusted R^2 = 0.09

The results in Table 7.16 show that Tower Achievement score significantly predicted and accounted for 9% of variance of scores on the Voice Test (F (1, 56) = 6.27, p = 0.015, R = 0.32, R^2 = 0.10, Adjusted R^2 = 0.09, β = 0.32, t = 2.50, p = 0.015).

7.3.3.3 MASC total score: Dynamic stimuli showing social interaction

Table 7.17 presents the multiple regression with demographic predictors of MASC Total score.

Table 7.17. Results of multiple regression analysis for age, IQ, gender and mood state predictors of MASC Total score at Time 2

	β	t	p
Age	0.24	1.90	0.063
Gender	-0.23	1.90	0.063
Verbal IQ	-1.98	1.86	0.070
Performance IQ	-1.68	1.62	0.112
Full Scale IQ	3.26	2.01	0.050
PANAS Positive affect	-0.13	1.01	0.316
PANAS Negative affect	0.09	0.63	0.529
HADS Depression	-0.11	0.64	0.526
HADS Anxiety	-0.06	0.37	0.717

$R = 0.60$, $R^2 = 0.37$, Adjusted $R^2 = 0.25$

Whilst the model with age, IQ, gender and mood state variables significantly predicted MASC Total score overall (F (9, 48) = 3.07, $p = 0.006$, $R = 0.60$, $R^2 = 0.36$, Adjusted $R^2 = 0.25$), the individual variables did not significantly predicted MASC Total score possibly indicating a lack of power. Full Scale IQ was a marginally significant predictor ($\beta = 3.26$, $t = 2.01$, $p = 0.050$) of MASC Total score.

A regression was conducted with executive function task scores as independent variables and MASC Total score as the dependent variable (see Table 7.18).

Table 7.18. Results of multiple regression analysis with executive function predictors of MASC Total score at Time 2

	β	t	p
Hayling Scaled	-0.02	0.13	0.901
Brixton Scaled	0.32	2.40	0.020*
Letter Fluency	-0.12	0.90	0.375
Free sorts description score	-0.02	0.18	0.857
Tower Achievement score	0.22	1.65	0.105

$R = 0.43$, $R^2 = 0.18$, Adjusted $R^2 = 0.11$

The model significantly predicted MASC Total score (F (5, 52) = 2.35, p = 0.054) and accounted for 11% of variance (Adjusted R^2 = 0.11) with rule detection, assessed with Brixton Scaled scores, being a significant predictor (β = 0.32, t = 2.40, p = 0.020) of MASC Total score. This finding suggests that pattern recognition could be beneficial when identifying the rule on the Brixton Test and this aids mental state attribution in dynamic stimuli.

7.3.3.4 MASC excessive mental state inference errors

Age, IQ, gender and mood state variables (F (9, 48) = 1.38, p = 0.225) and executive function task scores (F (5, 52) = 1.00, p = 0.425) did not predict MASC excessive mental state inference errors, when mental state content is over-interpreted.

7.3.3.5 IRI Fantasy

Age, IQ, gender and mood state variables did not significantly predict IRI Fantasy scores (F (9, 48) = 1.86, p = 0.081). Table 7.19 presents the multiple regression with executive function variables as predictors and IRI Fantasy as the dependent variable.

Table 7.19. Results of regression analysis with executive function scores as predictors of IRI Fantasy at Time 2

	β	t	p
Hayling Scaled	0.06	0.45	0.654
Brixton Scaled	0.08	2.55	0.582
Letter Fluency	0.28	2.10	0.040*
Free sorts description score	0.10	0.77	0.444
Tower Achievement score	0.05	0.39	0.699

R = 0.36, R^2 = 0.13, Adjusted R^2 = 0.05

Results presented in Table 7.19 show that whilst the overall model was not significant (F (5, 52) = 1.57, p = 0.185), Letter Fluency was a significant predictor of Fantasy scores (β = 0.28, t = 2.10 p = 0.040) and accounted for 5% of variance in IRI Fantasy scores (Adjusted R^2 = 0.05). Following the initial regression model, another regression was conducted excluding variables that were not significant to examine whether this resulted in a more parsimonious model.

Table 7.20. Results of regression analysis with Letter Fluency as the predictor variable and IRI Fantasy as the dependent variable

	β	t	p
Letter Fluency	0.32	2.53	0.014*

$R = 0.32$, $R^2 = 0.10$, Adjusted $R^2 = 0.09$

Results in Table 7.20 show that Letter Fluency was a significant predictor of Fantasy scores (F (1, 56) = 6.41, $p = 0.014$, $R = 0.32$, $R^2 = 0.10$, Adjusted $R^2 = 0.09$, $\beta = 0.32$, $t = 2.53$ $p = 0.014$) and accounted for 9% of variance in IRI Fantasy scores (Adjusted $R^2 = 0.09$).

7.3.3.6 IRI Personal Distress

Table 7.21 presents a multiple regression with IQ, age, gender and mood state variables as predictors and IRI Personal distress as the dependent variable.

Table 7.21. Results of multiple regression analysis for age, IQ, gender and mood state predictors of IRI Personal distress at Time 2

	β	t	p
Age	0.30	2.21	0.032*
Gender	-0.36	2.79	0.008**
Verbal IQ	-0.84	0.74	0.461
Performance IQ	-1.04	0.95	0.348
Full Scale IQ	1.54	0.89	0.376
PANAS Positive affect	-0.21	1.59	0.119
PANAS Negative affect	0.05	0.31	0.756
HADS Depression	-0.02	0.12	0.907
HADS Anxiety	0.19	1.06	0.292

$R = 0.53$, $R^2 = 0.28$, Adjusted $R^2 = 0.15$

The model with IQ, age, gender and mood state variables significantly predicted Personal Distress (F (9, 48) = 2.09, p = 0.049) and accounted for 15% of variance (Adjusted R2 = 0.15). Results presented in Table 7.21 show that age ($\beta = 0.30$, $t = 2.21$ $p = 0.032$) and gender ($\beta = -0.36$, $t = 2.79$ $p = 0.008$) were significant predictors of IRI Personal Distress scores. Increasing age was associated with more Personal Distress and females (median = 14.00, range = 20.00) scored significantly higher than males (median = 10.00, range = 15.00, U = 141.50, z = 2.33, p = 0.02, r = 0.24).

Table 7.22 presents a multiple regression analysis with executive function scores as predictors and IRI Personal Distress as the dependent variable.

Table 7.22. Results of multiple regression analyses with executive function scores as predictors of IRI Personal Distress at Time 2

	β	t	p
Hayling Scaled	-0.26	1.97	0.054
Brixton Scaled	-0.16	1.16	0.250
Letter Fluency	0.18	1.37	0.178
Free sorts description score	-0.08	0.59	0.555
Tower Achievement score	0.07	0.49	0.624

$R = 0.34$, $R^2 = 0.11$, Adjusted $R^2 = 0.03$

Results presented in Table 7.22 show that the model with executive function task scores did not significantly predict IRI Personal Distress scores (F (5, 52) = 1.33, p = 0.265), although Hayling Scaled was a marginally significant predictor (β = -0.26, t = 1.97 p = 0.054), supporting the findings at Time 1.

Table 7.23 presents a summary of demographic and executive function predictors at Time 2.

Table 7.23. Summary predictors of social cognition task performance at Time 2

Social cognition task	Age, IQ, gender and mood state predictors	Executive function predictors
Emotion recognition with static visual stimuli		
Eyes Test	Not significant	Planning (Tower achievement) +ve
Emotion recognition with auditory stimuli		
Voices Test	Not significant	Planning (Tower achievement) +ve
Dynamic visual and auditory stimuli with social interaction		
MASC Total score	Full Scale IQ (+ve) marginally significant	Rule detection (Brixton) +ve
MASC excessive mental state inference errors	Not significant	No executive function predictors
Self-report empathy		
IRI Fantasy	Not significant	Strategy generation (Letter Fluency) +ve
IRI Personal Distress	Age (+ve) Gender (females higher than males)	No executive function predictors

+ve and –ve refers to the direction of the relationships between predictor and dependent variable

7.3.4 Summary of Time 2 data

7.3.4.1 Age, IQ, gender and mood state predictors

Age, IQ, gender and mood state variables were not significant predictors of scores on the Eyes Test, Voices Test, MASC excessive mental state inference errors and IRI Fantasy at Time 2. Full Scale IQ was a marginally significant predictor of MASC Total score. Similar to Time 1, age and gender were significant predictors of IRI Personal Distress, with increasing age associated with greater personal distress and females reporting greater personal distress than males.

7.3.4.2 Executive function variables

Planning, indexed by Tower achievement score, was a significant executive function predictor of performance on the Eyes and Voices Tests with better planning ability associated with higher scores on emotion recognition tasks with static visual and auditory stimuli, possibly due to monitoring of behaviour. Rule detection, assessed by the Brixton Test, significantly predicted MASC Total score with pattern recognition being a possible explanation. Strategy generation, assessed with the D-KEFS Letter Fluency Test, was a significant predictor of IRI Fantasy.

7.3.5 Comparing Time 1 and Time 2 predictors

Similarities and differences between Time 1 and Time 2 predictors are now discussed. The only similarity is that age and gender significantly predicted IRI Personal Distress at both time points. Several differences are evident with some mood state variables and executive functions predicting social cognition at only one time point. For example, HADS Depression scores predicted MASC Total score and Positive Affect predicted the Eyes Test scores at Time 1, but not at Time 2. At Time 1 rule detection, assessed with the Brixton Test, significantly predicted scores on the Eyes and Voices Tests, whereas at Time 2 rule detection predicted MASC Total score. At Time 2, planning, assessed with the Tower Achievement score, significantly predicted scores on the Eyes and Voices Tests. A possible explanation for different predictors of Eyes and Voices Tests across time points is that at Time 2 participants were less reliant on pattern identification due to a more automatic strategy developing in late adolescence and early adulthood (Burnett & Blakemore, 2009). A further difference is that at Time 1 inhibition, assessed with the Hayling Test, significantly predicted IRI Personal Distress, but not at Time 2. Different variables may predict social cognition task scores at Time 1 and Time 2 because of the smaller sample size at Time 2 that may reduce power.

7.4 Discussion

The present findings suggest that different IQ and mood state variables and executive functions contribute to performance on social cognition tasks. Disparate executive functions predicting scores on social cognition tasks provide evidence for social cognition being a multidimensional construct (Dziobek et al., 2006) with different cognitive processes contributing to task performance. These findings indicate that social cognition is domain general and other cognitive functions, such as executive functions and language, contribute to social cognition (Apperly et al., 2005).

Verbal IQ predicted scores on the Eyes Test and Voices Test at Time 1. The finding of Verbal IQ predicting scores on the Eyes Test supports Ahmed and Miller (2011), who reported that IQ, assessed with the Wechsler Test of Adult Reading, predicted Eyes Test scores. Verbal IQ also predicted scores on the Voices Test replicating the findings of Golan et al. (2007). A likely explanation is that the Eyes and Voices Tests require verbal processing. Performance IQ predicted MASC Total score and negatively predicted MASC excessive mental state inference errors at Time 1. Previous studies have often reported Full Scale IQ (Baron-Cohen et al., 2001; Dziobek et al., 2006) and omitted Performance IQ. The present findings indicate that Performance IQ predicts mental state understanding in naturalistic stimuli and could be explained by visuospatial abilities.

Age and gender were significant predictors of Personal Distress, personal feelings of apprehension in stressful situations, at both time points. Gender being a significant predictor of Personal Distress, with females scoring significantly higher than males, is consistent with gender analysis in Chapter 5 and previous research (Davis, 1983; Derntl et al., 2010; Krämer et al., 2010). The finding of increasing age being associated with greater Personal Distress is inconsistent with Davis and Franzoi (1991) who reported that Personal Distress decreased in 15 and 16 year olds over three consecutive years.

The present findings do not support Hoffman's (1975; 1976) theory of empathy that during childhood Personal Distress and Perspective Taking develop and then Personal Distress decreases with age because self-oriented distress is transformed to other oriented distress, or Empathic Concern. Increasing Personal Distress with age in the present study may be due to the slightly older participants, compared to Davis & Fanzoi's (1991) sample, who experienced changes in education, living arrangements and friendship groups.

At Time 1 Positive Affect negatively predicted Eyes Test scores supporting Converse et al. (2008) who reported participants induced to feel happy scored lower than sad participants on a modified false belief task and the Director Perspective Taking Task, indicating poorer Theory of Mind and more egocentric behaviour. Greater Positive Affect predicting lower Eyes Test scores supports the "mood as information" model whereby positive mood leads to a heuristic processing style (Park & Banaji, 2000) that is not rigorous and results in shortcuts (Mitchell & Phillips, 2007). A heuristic processing style may explain the poorer performance on the Eyes Test associated with Positive Affect.

At Time 1 HADS Depression scores negatively predicted MASC Total scores. The finding of depression being associated with poorer social cognition task performance supports Uekermann et al. (2008) who reported participants with depression were impaired on affective and cognitive aspects of humour processing in a social cognition stories task relative to controls. Furthermore, participants with major depressive disorder scored lower on the MASC than a control group with group differences not thought to be due to deficits in attention, short term memory or Verbal IQ (Wolkenstien, Schonenberg, Schirm & Hautzinger, 2011). MASC Total scores correlated with number of categories completed on the WCST, a measure of concept formation, indicating that poorer mental state understanding could be due to deficits in executive function. The depressed group scored similarly to the control group on the Eyes Test, a measure of emotion recognition, so it is possible that participants experienced difficulties in integrating contextual information in the MASC (Wolkenstien et al., 2011).

The finding that executive functions contribute to social cognition partly supports the SOCIAL model (Beauchamp & Anderson, 2005) that proposed internal factors (e.g. personality), external factors (e.g. family environment) and executive functions (attentional control, cognitive flexibility and goal setting) influence social cognition. Current findings extend the SOCIAL model by informing that rule detection (Brixton Test), strategy generation (Letter Fluency), inhibition (Hayling Test) and planning (Tower Test) contribute to different aspects of social cognition. The findings also support Tager-Flusberg's framework (2001) consisting of social-perceptual and social-cognitive components of Theory of Mind (see Chapter 3.5). The Eyes and Voices Test are considered to assess the social-perceptual component, requiring interpretation of information from faces and voices. The MASC is considered an assessment of social perceptual processes to interpret facial expressions, speech and body language and social cognitive processes to remember what has happened in previous scenes. At Time 1, rule detection (Brixton Test) predicted scores on the Eyes and Voices Tests, assessing the social perceptual component, and strategy generation (Letter Fluency) predicted MASC Total score, assessing social perceptual and social cognitive Theory of Mind. Flexible behaviour would result in good performance on strategy generation and the MASC. Perhaps strategy generation predicts the MASC not the Eyes and Voices Tests because the MASC is a closer approximation to real life social situations by requiring consideration of facial information, vocal information, speech, body language and memory.

A notable finding is that rule detection, assessed with the Brixton Test, was a significant predictor at Time 1 for emotion recognition in visual static stimuli (Eyes Test) and emotion recognition in auditory stimuli (Voices Test) and at Time 2 for mental state attribution in dynamic stimuli (MASC Total score). The Brixton Test assessed rule detection and requires the ability to successfully identify patterns. Rule detection might be utilised to assess patterns in social cognition e.g. a person may notice a certain expression relates to a particular emotion so they can respond in an appropriate way. This may be attributed to configural processing (Maurer, Le Grand & Mondloch, 2002) when relations between features of a stimulus are perceived.

Higher scores on the Hayling Test at Time 1, indicating better inhibition, were associated with lower Personal Distress, personal feelings of apprehension in stressful situations. It is plausible that better inhibition was associated with lower Personal Distress due to another mediating factor such as coping. Matud (2004) reported that emotional inhibition, assessed with the Emotion Control Questionnaire (Roger & Najarian, 1989) positively correlated with emotional coping, assessed with the Coping Styles Questionnaire (Roger, Jarvis & Najarian, 1993). Therefore better inhibition may be associated with more successful emotional coping resulting in lower Personal Distress.

At Time 2 strategy generation, assessed with the Letter Fluency Task, significantly predicted Fantasy scores, the tendency to relate to characters in books, films and plays. To complete the Letter Fluency Task, participants must flexibly initiate responses to provide a series of words starting with the same letter (Ahmed & Miller, 2011). Cognitive flexibility, assessed with the Wisconsin Card Sorting Test (Heaton et al., 1993), alternate uses (Lezak, 1993) and design fluency (Jones-Gotman & Milner, 1977) significantly correlated with cognitive empathy, comprising IRI Fantasy and Perspective Taking scales (Shamay-Tsoory, Tomer, Goldsher, Bergen & Aharan-Peretz, 2004). Davis (1983) proposed that people who scored highly on the Fantasy scale may frequently engage with books and films. Frequent engagement with books and films could improve cognitive flexibility because several characters must be considered simultaneously to understand the plot and this may be beneficial for performance on the Letter Fluency Task.

The finding of some executive functions contributing to performance on social cognition tasks may be explained by executive functions and social cognition sharing some common neural substrates (Hughes & Ensor, 2007). For instance, the Brixton Test was a significant predictor of the Eyes Test at Time 1 and MASC Total score at Time 2, with similar brain regions associated with these tasks. Performance on the Brixton Test often results in a guess about where the blue circle will move to in the first move, followed by a rule search when there may be incorrect responses and then ideally the rule is discovered. The rule search is associated with activation in the mid dorsolateral prefrontal networks and rule following is associated with activation in temporal, motor and medial/anterior prefrontal networks (Crescentini et al., 2011). The Eyes Test is associated with activation in the posterior temporal sulcus (Moor et al., 2011) and the MASC is associated with activation in temporal and prefrontal networks (Wolf et al., 2010). Therefore, the Brixton Test and Eyes Test both utilise temporal networks and the Brixton Test and MASC utilise medial prefrontal and temporal networks.

Another plausible explanation is that executive functions predict social cognition task performance because social cognition tasks are not process pure and require executive function (Dziobek et al., 2006; Heavey et al., 2000; Hughes & Ensor, 2007). Baron-Cohen et al. (1997) suggested that the Eyes Test did not involve executive functions. However, the present results indicate that the Brixton Test predicted scores on the Eyes Test at Time 1 and Tower achievement score predicted scores on the Eyes Test at Time 2. Tasks may share working memory processes and that could be the process contributing to ability across tasks. Working memory might be involved in considering a person's current and previous mental states (Vetter et al., 2013), keeping in mind the pattern of the coloured circle in the Brixton Test and re-designing plans in the Tower Test according to whether the goal is attained.

Whilst inhibition has been found to predict performance on appearance reality and false belief tasks in childhood (Carlson, Moses & Claxton, 2004), Ahmed and Miller (2011) found inhibition did not predict performance on the Eyes, Strange Stories or Faux Pas Tests in adults. Following Apperly et al. (2009) that some executive functions may be required in social cognition development during childhood and not in adulthood, this suggests inhibition is crucial while social cognition is developing but not during adulthood, although Ahmed & Miller (2011) noted that inhibition may be necessary for other social cognition tasks not employed in their study. Present findings indicate that inhibition does predict social cognition in adulthood, specifically IRI Personal Distress at Time 1, supporting Vetter et al. (2013) who found inhibition predicted scores on the CAM Facial Task. Whilst in childhood, planning assessed with the Tower of Hanoi, did not contribute to performance on appearance reality and false belief tasks (Carslon et al., 2004), in the present adult data planning assessed with the D-KEFS Tower Test predicted scores on the Eyes and Voices Tests at Time 2. Therefore these data indicate possible differential contribution of executive functions to social cognition task performance over childhood and late adolescence / early adulthood and suggest that inhibition predicts social cognition in childhood (Carlson et al., 2004) and late adolescence (Time 1) whilst planning predicts social cognition in early adulthood (Time 2).

To conclude, the analyses in this chapter show that different IQ, mood state and executive function variables predict performance on social cognition tasks assessing emotion recognition in visual static (Eyes Test), auditory (Voices Test), dynamic visual and auditory stimuli (MASC) and self-report empathy (IRI). The present study extends Ahmed and Miller's (2011) findings by examining a wider range of social cognition tasks. Executive functions may predict social cognition due to similar neural substrates associated with task performance or due to task impurity (Hughes & Ensor, 2007).

Chapter 8
General discussion

8.1 Chapter overview

This chapter will summarise the main findings of Time 1 cross sectional data, Time 2 cross sectional data, longitudinal analyses and executive function predictors of social cognition. Findings will be discussed in relation to previous studies and theories. Following this, implications of the research including Head Injury rehabilitation, social cognition assessment, education and the concept of adolescence will be discussed and then limitations and future research ideas will be outlined.

Previous research into executive function and social cognition has focused on childhood (Golan et al., 2008: age 8-12; Pennequin et al., 2010: age 4-7), middle adolescence (Prencipe et al., 2011: age 8-15) or wide age ranges in adulthood (Ahmed & Miller, 2011: age 18-27; Barker et al., 2010: age 20-59; Dumontheil, Apperly & Blakemore, 2010: age 19-27; Dziobek et al, 2006: age 22-62). However, the use of wide age ranges may mask non-linear development of functions (peak in ability followed by a trough). Subsequently, fine-grained age groups were selected following the previous recommendation that broad age groups decrease sensitivity (De Luca et al., 2003).

In Chapter 3, executive function and social cognition tasks were reviewed and a rationale given for the selected task battery. The Hayling and Brixton Tests (Burgess & Shallice, 1997) assessed inhibition and rule detection respectively. The D-KEFS Letter Fluency, Sorting and Tower Tests assessed strategy generation, concept formation and planning (Delis et al., 2001). Social cognition tasks included the Reading the Mind in the Eyes Test (Baron-Cohen et al., 2001) and Reading the Mind in the Voice Test (Golan et al., 2007) to assess emotion recognition in static visual and auditory stimuli. The MASC (Dziobek et al., 2006) provided a dynamic measure of social cognition including social interaction and the IRI (Davis, 1983) assessed self-report empathy.

8.2 Summary of overall findings

8.2.1 Time 1 cross sectional results

Chapter 4 described IQ and mood state cross sectional data when participants aged 17 years 0 months – 17 years 8 months, 18 years 0 months – 18 years 8 months and 19 years 0 months – 19 years 8 months completed executive function and social cognition tasks. Age groups did not differ on Full Scale IQ or drug and alcohol use indicating that these did not contribute to observed age group differences on some executive function tasks. Seventeen and 18 year olds scored significantly higher than 19 year olds on Negative Affect, although scores are similar to normative PANAS data by Crawford and Henry (2004). Seventeen and 18 year olds scored significantly higher than 19 year olds on the Anxiety scale of the HADS (Zigmond & Snaith, 1983) although scores fell within the mild range or lower. Seventeen and 18 year olds had experienced more changes to friendship groups and living arrangements in the preceding 12 months.

Tables 8.1 and 8.2 show a summary of Time 1, Time 2 and longitudinal executive function data analyses.

Table 8.1. Summary of executive function group differences (inhibition, rule detection, strategy generation and concept formation) at Time 1, Time 2 and longitudinal data analyses

	Time 1 (17, 18 and 19 year olds)	Time 2 by original Time 1 age group (Younger, Middle and Older)	Time 2 (18, 19 and 20 year olds)	Longitudinal data analyses
Measures of response inhibition (Hayling Test) and rule detection (Brixton Test)				
Hayling	No group differences	No group differences	No group differences	**Middle and Older groups higher at Time 2 than Time 1**
Brixton	No group differences	No group differences	No group differences	**Middle and Older groups higher at Time 2 than Time 1**
Measure of strategy generation (D-KEFS Letter Fluency Test)				
Letter Fluency	**17 year olds > 18 year olds**	**Younger > Middle**	No group differences	**Younger group higher at Time 2 than Time 1**
Measures of concept formation (D-KEFS Sorting Test)				
Free sorts correct	**17 year olds > 18 year olds and 19 year olds**	No group differences	No group differences	No longitudinal change
Free sort % accuracy	No group differences	**Younger < Older**	**18 year olds < 20 year olds**	**Middle group lower at Time 2 than Time 1**
Free sorts description score	**17 year olds > 18 year olds**	No group differences	No group differences	**Younger group lower at Time 2 than Time 1**
Sort recognition description score	**17 year olds > 18 year olds**	No group differences	No group differences	**Younger and Older groups lower at Time 2 than Time 1**
Verbal sorts desc score	No group differences	No group differences	No group differences	No longitudinal change
Perceptual sorts description score	**17 year olds > 18 year olds and 19 year olds**	No group differences	No group differences	**All groups lower at Time 2 than Time 1**

Table 8.2. Summary of executive function group differences (planning) at Time 1, Time 2 and longitudinal data analyses

	Time 1 (17, 18 and 19 year olds)	Time 2 by original Time 1 age group (Younger, Middle and Older)	Time 2 (18, 19 and 20 year olds)	Longitudinal data analyses
Measures of planning (D-KEFS Tower Test)				
Number of towers completed	No group differences	No group differences	No group differences	**Middle higher at Time 2 than Time 1**
Achievement score	No group differences	No group differences	No group differences	**Older higher at Time 2 than Time 1**
Mean first move time	No group differences	No group differences	No group differences	**Younger and Older groups lower at Time 2 than Time 1**
Time per move	No group differences	**Younger < Middle Younger < Older**	No group differences	**All groups lower at Time 2 than Time 1**
Move accuracy	No group differences	No group differences	No group differences	No longitudinal change

8.2.1.1 Executive function

Chapter 5 presented Time 1 cross sectional executive function and social cognition data. The main findings are that executive functions and social cognition follow divergent developmental trajectories in late adolescence and early adulthood. At Time 1, some functions showed no age group differences (inhibition, rule detection, planning, self-report empathy and emotion recognition from visual static, auditory and dynamic stimuli) whereas there was evidence of developmental change indicating a non-linear trajectory for response generation and concept formation, specifically between 17 and 18 years. Response generation and concept formation, assessed with the D-KEFS Letter Fluency and Sorting Tests, showed a peak at age 17, dip in performance at age 18 and slight upturn in ability on these measures in the 19 year old group, although the difference between 18 and 19 year olds was not significant. Seventeen year olds scored significantly higher than 18 year olds on a number of indices of concept formation: number of free sorts correct, free sort description score, sort recognition description score and perceptual sorts description score.

In a meta-analysis of executive function studies, Romine and Reynolds (2005) concluded that strategy generation (Verbal Fluency Test) continues to develop between 17 and 22 years. In the present study, strategy generation (Letter Fluency Test) showed non-linear development with 17 year olds scoring significantly higher than 18 year olds. The difference in findings may be due to the present study employing a design with more fine-grained age ranges that enabled the identification of non-linear development.

Non-linear development of performance on the D-KEFS Sorting Test supports Kalkut et al. (2009) who reported that 18-24 year olds scored worse than 16-17 year olds on D-KEFS Sorting Test description scores. The present results extend previous findings by identifying that the dip in performance occurs specifically at age 18 and indicates that non-linear development is evident on free sorts correct and free sort description score.

Analyses in Chapter 6 compared 18 year olds at Time 1 with 18 year olds at Time 2 to examine whether group differences were due to the sample. Eighteen year olds at Time 1 scored significantly higher than 18 year olds at Time 2 on sort recognition description score and description score for perceptual sorts, indicating that group differences on these indices may be due to the sample. No cohort group differences were found on Letter Fluency, free sorts correct or free sorts description score indicating that group differences between 17 and 18 year olds are age effects and not due to the sample.

Non-linear development may reflect several dynamic maturational processes including synaptic pruning, increased white matter connectivity (Lebel et al., 2008; Paus, 2005; Sowell et al., 2003) and functional synchronisation (Uhlhaas et al., 2009). During adolescence, long range fibres are myelinated, leading to connectivity between distant brain regions (Uhlhaas et al., 2010). In an EEG study with participants aged 6 to 21, Uhlhaas et al. (2009) found performance on a perception task improved until early adolescence accompanied by increases in neural synchrony of theta, beta and gamma frequencies. Groups of 6-8, 9-11, 12-14, 15-17 and 18-21 year olds were compared and a dip in performance was evident in 15 to 17 year olds with a concurrent decrease in beta neuronal synchrony. Following this, synchrony improved and synchronisation patterns changed from widespread to focal activations. In addition, beta phase synchronisation was strengthened between parietal and occipital regions and theta phase synchronisation increased in frontal brain regions and between anterior and posterior regions. Uhlhaas et al. concluded that there is a transitory destabilisation of functions during late adolescence due to functional network re-organisation. The non-linear development of strategy generation and concept formation in the present research may parallel neural re-organisation with a transitory destabilisation of select functions followed by adult levels of task performance due to further maturation of neural networks.

It is possible that non-linear development of strategy generation and concept formation may be due to interplay of maturational, social and environmental factors (Taylor et al., 2013). Seventeen and 18 year olds reported greater changes to living arrangements and friendship groups during the previous 12 months, indicating greater environmental change. Tuvblad et al. (2013) reported that non-shared environmental factors contributed to 54% of variance in Iowa Gambling Test scores at age 16-18, indicating that environmental factors influence individual differences in decision making during adolescence. Non-shared environmental influences are not shared by all members of the same family (Plomin et al., 2001) and include differences between siblings in their relationships with each other, their peers and their parents and also events specific to the individual, e.g. illness and accidents (Hughes et al., 2005).

Another plausible explanation for 17 year olds showing better strategy generation and concept formation compared to 18 year olds is that the younger age group may have found participating in research at university to be an unusual and novel experience, whereas the 18 and 19 year old groups were primarily university Psychology students. Executive function is thought to be associated with creativity (Benedek, Franz, Heene & Neubauer, 2012; Gilhooly, Fioratou, Anthony & Wynn, 2007). Ritter et al. (2012) reported that active engagement in an unusual event facilitated creativity, assessed with the Unusual Uses Task (Guilford, 1967) when participants gave as many responses as possible in one minute to a question e.g. "What makes a sound?" In one study, participants experienced either a virtual reality environment that distorted speed and size of objects, a normal virtual reality environment or watched a film with distortions of speed and size. Participants in the distorted virtual reality environment scored significantly higher in the Unusual Uses Task, indicating better cognitive flexibility, compared to participants who had experienced a normal virtual reality environment and watched a film. A second study employed an alternative paradigm and included a group who actively violated a schema about breakfast making and a group who followed a normal schema. Participants who had actively engaged in a different activity and broke their breakfast making schema showed better cognitive flexibility relative to participants who had followed a normal schema. Ritter et al. (2012) suggested that unusual events lead to a thinking style characterised by cognitive flexibility. Therefore 17 year olds may have found participating in research at a university to be an unusual and novel experience, resulting in a thinking style characterised by cognitive flexibility that enhanced strategy generation and concept formation. Furthermore, 17 year olds could have been more motivated when participating compared to 18 and 19 year olds. Pessoa (2009) suggested that motivation re-allocates attentional resources to focus on the present task, possibly leading to enhanced behavioural performance on executive function tasks.

Group differences in strategy generation and concept formation between 17 and 18 year olds may be explained by academic preference. Doherty and Mair (2012) compared participants aged 16 to 18 years who had a preference for Science subjects with participants who preferred Social Science subjects on three versions of the Ambiguous Figures Test (vase / faces, duck / rabbit and the Necker cube), a measure of creativity. Participants with a preference for Science subjects attained a higher number of reversals, alternative interpretations of the ambiguous figure, relative to participants with a preference for Social Sciences. Doherty and Mair (2012) suggested that the findings would likely be replicated on performance of the Alternative Uses Task. As creativity has been associated with executive function, specifically strategy generation assessed with the Letter Fluency Task (Gilhooly et al., 2007), it is possible that 17 year olds scored significantly higher than 18 year olds because they differed in academic preference. Forty five per cent of 17 year olds were taking AS Levels and 52% were studying for A2 Levels, when a range of subjects are studied. Therefore, it is possible that the 17 year olds were studying more Science based subjects than the 18 and 19 year olds who were mostly Psychology degree students. However, it is not clear whether academic preference leads to more reversals on the Ambiguous Figures Test or reversal influences academic preference (Doherty & Mair, 2012).

Romine and Reynolds (2005) reported no change on set maintenance (categories achieved) and perseverative errors on the Wisconsin Card Sorting Test after age 14. However, in the present Time 1 cross sectional data, Chi square analyses showed that perseverative sorts decreased with age, indicating more accurate concept formation. It is possible the inconsistent findings are due to the different tasks employed because in the WCST participants must only remember the current sorting rule (Strauss et al., 2006) whereas in the D-KEFS Sorting Test participants must remember all previous sorts. Leshem and Glicksohn (2007) found that greater impulsivity was associated with more WCST perseverative errors so the decrease in D-KEFS Sorting Test perseverative errors with age may be related to a decrease in impulsivity.

8.2.1.2 Social cognition

Table 8.3 summarises Time 1, Time 2 and longitudinal social cognition data analyses.

Table 8.3. Summary of social cognition group differences at Time 1, Time 2 and longitudinal analyses

	Time 1	Time 2 by original Time 1 groups (Younger, Middle and Older)	Time 2 comparing 18, 19 and 20 year olds	Longitudinal analyses
Static visual stimuli				
Eyes	No group differences	No group differences	No group differences	No longitudinal change
Auditory stimuli				
Voices	No group differences	No group differences	No group differences	No longitudinal change
Dynamic stimuli with social interaction				
MASC correct	No group differences	No group differences	No group differences	**Middle and Older groups higher at Time 2 than Time 1**
MASC excessive mental state inference errors	No group differences	No group differences	No group differences	**Middle and Older groups lower at Time 2 than Time 1**
MASC insufficient mental state errors	No group differences	No group differences	No group differences	No longitudinal change
MASC no ToM errors	No group differences	No group differences	No group differences	No longitudinal change
Self-report empathy				
IRI Fantasy	No group differences	**Younger > Middle** **Middle < Older**	No group differences	No longitudinal change
IRI Empathic concern	No group differences	No group differences	No group differences	No longitudinal change
IRI Perspective Taking	No group differences	No group differences	No group differences	No longitudinal change
IRI Personal Distress	No group differences	No group differences	No group differences	**Younger group lower at Time 2 than Time 1**

No age group differences were evident on social cognition tasks at Time 1 indicating that the functions assessed in the present study are relatively stable in late adolescence and early adulthood. Imaging studies have found that different neural regions are recruited during social cognition task performance with a shift from frontal to posterior regions between adolescence and adulthood. Moor et al. (2010) found that performance on the Reading the Mind in the Eyes Test recruited different neural substrates in children, adolescents and adults. Performance was associated with activation in medial prefrontal networks only in early adolescence (10 to 12 years), not mid adolescence (14 to 16 years) or adulthood (19 to 23 years), although the posterior superior temporal sulcus was recruited in all age groups. The adult group also recruited the inferior frontal gyrus, indicating that different neural substrates contribute to performance on this task between adolescence and adulthood. Sebastian et al. (2012) proposed that the medial prefrontal cortex may be associated with social cognition during childhood, and recruited less in adulthood when social cognitive functions may be more automatic. There is extensive evidence that myelination occurs in a posterior to anterior direction (Kinney et al., 1994; Lebel et al., 2008; Sowell et al., 2003; Yakovlev & Lecours, 1967) so that occipital networks and posterior frontal networks mature earlier than anterior networks which might explain why no age group differences were evident in late adolescence on social cognition measures in the current study.

There were gender differences on social cognition tasks with females making fewer excessive mental state inference errors on the MASC compared to males possibly due to females being more accurate at recognising emotions portrayed at mid intensity (Hoffman et al., 2010) as they are in the MASC that approximates real life social situations. Females also rated themselves significantly higher than males on the Empathic Concern and Personal Distress scales of the IRI supporting previous research (Banissy et al., 2012; Davis, 1983; Derntl et al., 2010; Krämer et al., 2010). Possible explanations are that participants conformed to gender stereotypes (Derntl et al., 2010) or social desirability (Laurent & Hodges, 2009).

The effect of puberty on executive function and social cognition task performance was examined by comparing participants who had reported completing puberty on the Self-Administered Rating Scale for Pubertal Development with those who had not. For the sample overall there were no group differences on executive function or social cognition tasks indicating that stage of pubertal development did not contribute to age group differences on task performance. Burnett et al. (2011) found a relationship between pubertal development and emotion understanding in participants aged 9 to 16 years. Studies that found no relationship between pubertal development and performance on an emotion recognition task (Thomas et al., 2007; 14 to 18 year olds) and executive function tasks (Magar, Hosie & Phillips, 2010; 11 to 17 year olds) had participants of a closer age to the present study. Participants in the Burnett et al. (2011) study were younger than in the present study, indicating that hormones influence social cognition more around puberty than later in adolescence. In the 19 year old group, participants who had finished puberty scored lower on the MASC than those who were still progressing. During adolescence, there is a drive for peer acceptance and an increase in sensitivity to peer evaluation (Scherf, Behrmann & Dahl, 2011; Sebastian et al., 2010). A plausible explanation for this finding is that participants who had not finished puberty experienced an urge for peer acceptance and as a result were more successful at attributing mental states in the naturalistic clips of the MASC. Following the development of social cognition around puberty (Burnett et al., 2011; McGivern et al., 2002), the present social cognition data suggest that social cognition is relatively stable by late adolescence.

8.2.2 Time 2 cross sectional results

Time 2 age groups were re-named Younger, Middle and Older groups because some participants changed age groups due to different time intervals between testing. Younger, Middle and Older refers respectively to participants who were originally in 17, 18 and 19 year old groups at Time 1.

Analyses comparing Younger, Middle and Older groups at Time 2 showed that the Younger group scored significantly higher, indicating better strategy generation, than the Middle group on the Letter Fluency Test. This group difference was evident at Time 1 indicating that the group differences on Letter Fluency scores may be due to the sample and not age related change, e.g. the Younger group finding the study an unusual and novel experience or being more motivated resulting in better executive function relative to the other groups (Ritter et al., 2012; Pessoa, 2009). The Younger group scored significantly lower on free sort % accuracy, indicating poorer concept formation, relative to the Older group. Non-linear development is evident with the Younger group showing a significantly quicker time per move compared to the Middle and Older groups on the Tower Test. Protracted myelination into late adolescence may result in faster reaction times due to the myelin sheath increasing transmission speed around brain regions (Sowell et al., 2001). The increase in time per move in the Middle group could be explained by disruption due to neural re-organisation (Uhlhaas et al., 2009). The group difference on time per move could be due to an executive function difference or underpinned by faster processing speed due to more effective neural connectivity. Kochunov et al. (2010) reported that processing speed was associated with white matter integrity in frontal regions and this continues to develop into late adolescence and early adulthood (Schmithorst & Yuan, 2010).

The only social cognition group difference was found on IRI Fantasy with the Younger group scoring significantly higher than the Middle group and the Older group on this measure. However, Davis (1983) commented that the Fantasy scale was the least theoretically driven of the IRI subscales, being more related to Verbal IQ than social functioning. Baron-Cohen and Wheelwright (2004) suggested that the Fantasy scale assesses imagination or emotional self-control and whilst these may correlate with empathy, the Fantasy scale may not assess empathy.

Time 2 cross sectional group differences were analysed between 18, 19 and 20 year olds on executive function and social cognition tasks. Twenty year olds attained significantly higher free sort % accuracy on the D-KEFS Sorting Test indicating a more accurate concept formation strategy, compared to 18 year olds. This supports existing adult data (Greve et al., 1995) indicating that concept formation improves into early adulthood.

Executive functions of inhibition, rule detection and planning showed no group differences at Time 1 and Time 2. Other factors may contribute to executive function scores that showed no age group differences including individual differences in attention (Friedman et al., 2007; Magar et al., 2010). Friedman et al. (2008) reported a substantial genetic component to inhibition, updating and shifting, although the authors acknowledged that environmental factors can also influence executive functions e.g. a person with good executive functions may select a suitable environment to further develop executive functions.

8.2.3 Longitudinal results

The Younger and Middle age groups had a significantly longer time interval between testing compared to the Older age group. Uneven time interval can be accounted for in analysis by using this variable as a covariate (Locascio & Atri, 2011). As a covariate should have a linear relationship with the dependent variable (Dancey & Reidy, 2004), correlations were conducted between time interval and task change scores to examine whether time interval would be a suitable covariate. Perspective Taking change score and time interval showed a significant correlation with no other correlations significant. This indicated that time interval was not a suitable covariate because there was not a linear relationship for the majority of variables and varying time interval did not contribute to change score. Repeated measures ANOVAs using a within subjects factor of Time 1 and Time 2 task scores and a between group factor of age group at Time 1 (17, 18 and 19 year olds) were conducted because they allow between group comparisons, comparisons across time points and interactions to be examined.

8.2.3.1 Executive function

Longitudinal changes were evident on the Hayling and Brixton Tests (Middle and Older groups) with higher scores indicating better inhibition and rule detection at Time 2 compared to Time 1. The Younger group scored significantly higher on the Letter Fluency Test of strategy generation at Time 2 compared to Time 1. There were several significant longitudinal changes on the D-KEFS Sorting Test, a measure of concept formation, with lower scores at Time 2 compared to Time 1 evident on free sort description score (Younger group), sort recognition description score (Younger and Older groups) and description score for perceptual sorts (Younger, Middle and Older groups). Longitudinal changes were evident on the D-KEFS Tower Test measure of planning including number of towers completed (Middle group higher, indicating better planning, at Time 2), tower achievement (Older group higher, indicating better planning, at Time 2), mean first move time (Younger and Older groups shorter at Time 2) and time per move (Younger, Older and Middle groups shorter at Time 2).

Given the non-linear findings for concept formation and strategy generation at Time 1 with 18 year olds scoring significantly lower than 17 year olds, it could be expected to find that the Younger age group would score significantly lower on Sorting and Letter Fluency Tests at Time 2 than at Time 1. Indeed, the Younger age group scored significantly lower at Time 2 compared to Time 1 on free sort description score, sort recognition description score and description score for perceptual sorts. However, the Middle and Older groups also scored significantly lower on description score for perceptual sorts and 19 year olds scored lower on sort recognition description score at Time 2 relative to Time 1 indicating the Time 2 cards may have been more challenging than the Time 1 cards. Non-linear findings were not evident between time points on the Letter Fluency Test with the Younger group scoring significantly higher at Time 2 compared to Time 1. Romine and Reynolds (2005) reported that Verbal Fluency and planning continue to develop into early adulthood. The present longitudinal data analyses support Romine and Reynolds (2005) and the notion of Letter Fluency continuing to develop into early adulthood. Whilst there were no age group differences at Time 1 or Time 2, longitudinal analyses showed better performance at Time 2 compared to Time 1 on the D-KEFS Tower Test for number of towers completed (Middle group), achievement score (Older group), mean first move time (Younger and Older groups) and time per move (all age groups), again supporting Romine and Reynolds (2005).

8.2.3.2 Social cognition

For social cognition, no longitudinal change was evident on the Reading the Mind in the Eyes or Voice Tests. Total MASC score showed significant longitudinal change with Middle and Older groups scoring higher at Time 2 due to fewer MASC excessive inference mental state errors. These findings can be considered in relation to Tager-Flusberg's (2001) conceptual framework, consisting of social-perceptual and social-cognitive components of ToM. The Eyes and Voices Tests are considered assessments of social-perceptual ToM, understanding and interpreting information from faces, voices and body posture and attributing mental states. The MASC is considered to assess social-perceptual and social-cognitive components of ToM. Social-cognitive

ToM refers to the use of information over time and events in the attribution of mental states. The present findings indicate that social-cognitive ToM development is more protracted than social-perceptual, supporting the notion of social-perceptual and social-cognitive ToM components having different developmental trajectories (Tager-Flusberg, 2001).

The Social Information Processing Network (Nelson et al., 2005) reviewed in Chapter 1 posits that social information processing involves detection, affective and cognitive regulatory nodes. The cognitive-regulatory node, comprised of the medial and dorsal prefrontal networks and the orbitofrontal network, involved in mental state understanding, inhibition of prepotent responses and generation of goal-directed behaviour, is considered to have the most protracted development into late adolescence. This model is partly supported by the longitudinal data analyses showing that Middle and Older groups scored significantly higher on the MASC at Time 2. Development of inhibition is partly supported by the longitudinal data showing that Middle and Older groups scored significantly higher on the Hayling Test, indicating better inhibition, at Time 2 compared to Time 1.

It is of note that the cross sectional and longitudinal analyses are not consistent. For example, results of Time 1 and Time 2 cross sectional data analyses showed no group differences on the Tower Test measure of planning. Longitudinal analyses showed that the Middle age group completed significantly more towers and the Older group attained a higher Achievement score at Time 2, indicating better planning, compared to Time 1. Longitudinal and cross sectional findings are sometimes not consistent because cross sectional analyses show inter-individual (group) differences, whereas longitudinal analyses show intra-individual change (Schaie, 2005). Furthermore, Schaie (2005) considered cross sectional age comparisons are only appropriate in a stable environment. The stability of the environment could be questioned in the present sample because participants reported considerable changes to living arrangements and friendship groups.

8.2.4 IQ, mood, gender and executive function predictors of social cognition

Previous research has found IQ and executive function task scores significantly predicted social cognition task scores in late adolescence and early adulthood (Ahmed & Miller, 2011; Vetter et al., 2013). The analyses in Chapter 7 extended previous research by examining IQ, mood and executive function predictors on a wide range of social cognition task scores with the task battery consisting of tasks assessing emotion recognition in visual static stimuli (Reading the Mind in the Eyes Test), auditory stimuli (Reading the Mind in the Voice Test), dynamic stimuli (MASC) and self-report empathy (IRI). The main finding was that different IQ, mood state and executive function task scores contribute to social cognition task scores, indicating that domain general processes contribute to social cognition task performance and social cognition is a multidimensional construct (Dziobek et al., 2006).

Apperly, Samson and Humphreys (2009) suggested that executive functions may be necessary in the development of social cognition during childhood but not in adulthood or executive functions may continue to be crucial in adult social cognition. Through consideration of previous research with children and the present analyses, there may be differential contribution of executive functions to social cognition task performance over childhood and late adolescence / early adulthood. Carlson et al. (2004) found that inhibition predicted children's performance on false belief tasks and the present data show inhibition contributes to IRI Personal Distress in late adolescence (Time 1). In contrast, Carlson et al. found that planning did not contribute to appearance reality and false belief tasks in childhood, whereas the present data suggest planning predicts scores on the Eyes and Voices Test at Time 2. This suggests inhibition contributes to the development of social cognition during childhood and in late adolescence, while planning only predicts social cognition in early adulthood. Planning and monitoring may relate to social cognition because during social interaction people monitor their actions to ensure their actions are appropriate in the current situation and that they fulfil their intentions (Amodio & Frith, 2006).

Positive Affect negatively predicted Eyes Test scores at Time 1, indicating Positive Affect impairs performance on tasks requiring emotion recognition in static visual stimuli. This supports the "mood as information" model whereby positive mood leads to a heuristic processing style (Park & Banaji, 2000) resulting in shortcuts and poorer performance (Mitchell & Phillips, 2007). HADS Depression scores negatively predicted MASC Total score, indicating that depression impairs performance on a social cognition task with dynamic, naturalistic stimuli, supporting Wolkenstien et al. (2011).

The finding of the Brixton Test significantly predicting scores on the Eyes Test and Voices Test at Time 1 and MASC Total score at Time 2 may be explained by configural processing when relations between shapes and features of a stimulus are perceived (Maurer, Le Grand & Mondloch, 2002). This indicates that participants who are successful at detecting rules on the Brixton Test are also successful when considering emotion recognition in visual and auditory stimuli. An alternative explanation is that social cognition and executive function may both utilise rule based reasoning (Perner & Lang, 1999).

Previous research has found inhibition, assessed with an Antisaccade Task, significantly predicted scores on the Cambridge Mindreading Face Voice Battery (CAM; Golan et al., 2006) comprised of silent short clips of an actor portraying an emotion (Vetter et al., 2013). In the present study inhibition, assessed with the Hayling Test, did not significantly predict scores on the Eyes Test or MASC, social cognition tasks similar to the CAM. A possible explanation for the inconsistent finding is that different types of inhibition may be related to social cognition. The Antisaccade Task may be associated with visual social cognition tasks because of the task's visual nature that requires effortful suppression of a reflexive saccade (Nigg, 2000) whereas the Hayling Test assesses inhibition in the vocal domain.

Executive functions and social cognition may be related due to functions sharing common frontal neural substrates (Hughes & Ensor, 2007). Alternatively, executive functions may predict social cognition task performance because social cognition tasks are not process pure and require executive function (Dziobek et al., 2006; Heavey et al., 2000; Hughes & Ensor, 2007). Working memory processes may contribute to executive function and social cognition tasks but this was not assessed in the present study. Future research could assess working memory with the Letter Number Sequencing Test from the WAIS (Wechsler, 2008) that requires participants to recall and organise stimuli e.g.

state the numbers first in numerical order and then the letters in alphabetical order for these stimuli 9L2A. Working memory might be involved in considering a person's current and previous mental states (Vetter et al., 2013), keeping in mind the pattern of the coloured circle in the Brixton Test, card sorts generated in the Sorting Test and re-designing plans in the Tower Test according to whether the goal is attained.

8.3 Evaluation of research

This research aimed to fill a gap in knowledge about the developmental trajectory of executive function and social cognition in late adolescence and early adulthood. A strength of the design was the fine grained age groups that allowed comparison of behavioural data during a period of dynamic brain maturation. Previous research in social cognition and executive function during late adolescence has recommended a longitudinal design (Kalkut et al., 2009; Romine & Reynolds, 2005; Tonks et al., 2007; Waber et al., 2007). This allowed the same participants to be assessed at two time points, exploring whether performance remained constant, declined or improved across time points.

This thesis contributes to knowledge by the finding of non-linear development of concept formation and strategy generation with 17 year olds scoring significantly higher, indicating better performance, than 18 year olds. Social cognition data indicate that social cognition remains relatively stable during late adolescence and early adulthood on measures of emotion recognition with visual static and auditory stimuli and self-report empathy. More specifically, Time 1, Time 2 and longitudinal data analyses showed no change in scores on the Reading the Mind in the Eyes and Reading the Mind in the Voice Tests, assessments of emotion recognition in visual static and auditory stimuli. Self-report empathy showed some change, with Younger and Older groups scoring higher than the Middle group on the Fantasy subscale at Time 2. Longitudinal data analyses showed that the Younger group scored lower at Time 2 than Time 1 on Personal Distress. Results of longitudinal analyses showed Middle and Older groups scored higher at Time 2 relative to Time 1 on MASC Total score due to fewer MASC excessive mental state inference errors. Comparing the present data to existing adult data indicates that emotion recognition in auditory stimuli (Voices Test) and the tendency to consider others' viewpoints (IRI Perspective Taking) continue to develop beyond early adulthood. This thesis also contributes to knowledge on executive function predictors of social cognition by employing a wider range of tasks than previous research (e.g. Ahmed & Miller, 2011; Vetter et al., 2013).

A limitation of this research is the attrition rate despite taking measures to limit this such as collecting participants' email addresses, phone numbers and postal addresses. To arrange Time 2 testing, participants were contacted twice by email, twice by phone, leaving an answer phone message and a letter sent to participants who had changed their phone numbers. Despite some participants not taking part at Time 2, the retention rate is similar to other longitudinal studies (Novack et al., 1991; Zipparo et al., 2008).

Chapter 4 examined whether Time 1 demographic data of participants who only took part at Time 1 differed from participants who took part at both time points. Analyses showed that participants who took part at both time points had a higher Time 1 Verbal IQ compared to participants who only took part at Time 1, although Verbal IQ scores were in the average range. The finding of higher Time 1 Verbal IQ in participants who took part at both time points relative to participants who took part only at Time 1 is consistent with some previous longitudinal studies (Beaver, 2013; Jacomb, Jorm, Korten, Christensen & Henderson, 2002). At Time 1, Verbal IQ significantly correlated with scores on the Eyes, Voices and MASC Total score and the following executive function scores: Brixton Test, Letter Fluency, free sort correct, free sort description score, description score for verbal and perceptual sorts and Towers completed. It is possible that because the Time 2 sample had a higher Time 1 Verbal IQ than those who did not take part again, this may have inflated the social cognition and executive function task scores that correlated with Verbal IQ. In the present sample, there were no differences for Performance IQ, Full IQ, affect or HADS comparing Time 1 data for participants who took part at both time points relative to participants who took part only at Time 1 indicating that the Time 2 sample is generally representative of the Time 1 sample.

The sample included more female than male participants, although the gender ratio was broadly balanced across age groups and gender differences were analysed. Other research in late adolescence and early adulthood has included a predominantly female sample (77% female in Vetter, Altgassen, Phillips, Mahy, & Kliegel, 2012; 82% in Vetter et al., 2013). Furthermore, no gender differences have been reported on executive function tasks of phonological fluency (Harrison et al., 2000; Riva et al., 2000; Waber et al., 2007) and inhibition, updating and switching (Magar et al., 2010). Derntl et al. (2010) found gender differences apparent on self-report empathy not behavioural social cognition tasks and Ahmed and Miller (2011) found gender did not predict scores on the Eyes Test.

A small number of participants reported mental illness providing an accurate representation of this age range because late adolescence and early adulthood represents a period of vulnerability to mental illness (Paus et al., 2008). The inclusion of participants who reported a mental illness is in line with other published normative data samples (e.g. Peña-Casanova et al., 2012; Pedraza et al., 2005) that included participants with mental illness and mild Head Injury if a doctor considered their illness to be controlled. Participants in the present sample were all students or in employment and so were functioning appropriately for their age group. Whilst positive affect, negative affect, depression and anxiety were assessed, no data on medication use was collected.

Whilst the D-KEFS has been widely used in executive function research (e.g. Bava et al., 2010; Ahmed & Miller, 2011; Kalkut et al., 2009), this task battery has been criticised because there is no rationale or theory explaining why the nine tests were included in the task battery (Strauss et al., 2006). The Sorting Test has low test-retest reliabilities (Strauss et al., 2006) which may be because the tasks are less novel when completed a second time (Lowe & Rabbitt, 1998). This was considered in the present study by employing alternate versions of Letter Fluency and Sorting Tests. There are low correlations between tasks indicating weak convergent validity (Salthouse et al., 2003), although this could reflect the unity and diversity of executive functions (Miyake et al., 2000). Task specificity, measuring the function of interest, is another issue in executive function assessment (Burgess, 2003). The Letter Fluency Test requires cognitive flexibility, memory, initiation and psychomotor speed (Beilen et al., 2004) so it could be questioned what is the main executive function this task assesses. Miyake et al. (2000) found that performance on the Tower of Hanoi Task, purported to measure planning, was associated with inhibition, possibly due to participants inhibiting their initial disc movement and planning their strategy to achieve the particular tower.

Some researchers have criticised executive function tasks for lacking ecological validity and not reflecting everyday executive function abilities. Odhuba et al. (2006) examined whether the Hayling and Brixton Tests correlated with an assessment of executive functioning in daily life, the Dysexecutive Questionnaire (Wilson et al., 1996) and the Iowa Collateral Head Injury Interview (Martzke, Swan & Varney, 1991) in Head Injured participants. Odhuba et al. concluded that the Hayling and Brixton Tests correlated moderately with measures of everyday executive functioning indicating modest ecological validity and should be used with other executive function measures. Chaytor, Schmitter-Edgecombe and Burr (2006) assessed epileptic or Head Injured participants with the COWAT Letter Fluency Task and two assessments of functioning: the Dysexecutive Questionnaire (Wilson et al., 1996) and Brock Adaptive Functioning Questionnaire (Dywan & Seqalowitz, 1996). Letter Fluency Task scores were not significantly related to everyday functioning (Odhuba et al., 2006). However, these studies recruited Head Injured patients whilst the present study excluded Head Injury so future research could examine whether executive function measures relate to everyday functioning in non-clinical samples.

The social cognition task battery was selected to assess a range of social cognition including visual static stimuli, auditory stimuli, dynamic stimuli and self-report empathy. Whilst some studies have included shortened versions of the Eyes Test (e.g. Hassenstab et al., 2007), the present study included the full version to maximise the possible range of scores. It is of interest that the longitudinal data analyses show the Middle and Older groups scored significantly higher on MASC Total score indicating better social cognition. The MASC is a more naturalistic measure of social cognition than the Eyes and Voices Tests because it includes social interaction and visual and vocal information. This information, together with body language, must be interpreted correctly to complete the task. Whilst a self-report measure of perspective taking was included, future research should include a behavioural measure of perspective taking. The Director Perspective Taking Task was not available for use in the present study, but

Dumontheil et al. (2010) found a significant trend with performance improving on this task between late adolescence and early adulthood.

8.4 Implications

8.4.1 Head injury rehabilitation

Normative data is particularly important in clinical neuropsychology because it allows the comparison of an individual with a representative group to determine whether there are deficits in cognitive functions (Lezak, Howieson & Loring, 2004; Strauss et al., 2006). The present normative data demonstrate the executive function and social cognition capabilities of 17 to 20 year olds. Understanding the development of executive functions in typically developing adolescents is necessary because this has implications for rehabilitation following Head Injury (Reynolds & Horton, 2008). The effectiveness of rehabilitation could be assessed by participants completing executive function and social cognition tasks prior to and after treatment. Executive function deficits specifically in concept formation at age 18 following Head Injury may be typical of that age group and not a result of injury. Non-linear development could reflect functions going offline temporarily during periods of steep maturational change before more efficient neural networks are formed resulting in adult levels of task performance (Uhlhaas et al., 2009).

8.4.2 Social cognition assessment

Brent et al. (2004) suggested that advanced Theory of Mind Tasks could be included as part of a clinical assessment of individuals referred for possible Autistic Spectrum Disorder (ASD). Therefore the social cognition normative data could be relevant in assessing individuals with ASD and assessing the effectiveness of interventions. Golan and Baron-Cohen (2006) found Mind Reading (Baron-Cohen et al., 2004), a taxonomy of 412 emotions, each exemplified in six film clips and six sound clips of a single person portraying the emotion, improved emotion recognition in participants with ASD who used the CD for two hours each week over ten weeks. Golan and Baron-Cohen (2006) suggested that Mind Reading could be the first stage of a training programme, followed by the introduction of context and integration of mental states. Participants with ASD could complete the Eyes Test, Voice Test and MASC before and after an intervention. The MASC could provide an example of a naturalistic context with social interaction. The MASC is computer based and computers appeal to individuals with ASD because of their predictability making it possible to learn about social situations in a stress-free environment (Moore, McGrath & Thorpe, 2000).

8.4.3 Education

Blakemore (2010) proposed that the teenage years are a sensitive period for teaching due to protracted neural reorganisation and that education should focus on cognitive functions that are still developing. The findings of this thesis support the idea of late adolescence / early adulthood being a sensitive period because some functions show developmental change during this age range. For example, longitudinal analyses showed Middle and Older groups improved on inhibition and rule detection and the Younger group showed a decrease in concept formation (free sort description score, sort recognition score and description score for perceptual sorts) at Time 2 compared to Time 1. Sensitive periods can inform education policy by suggesting at what ages particular skills should be included in the curriculum to optimise learning (Thomas & Knowland, 2009). As 18 year olds scored significantly lower than 17 year olds on concept formation (Sorting Test) at Time 1 and the Younger group scored significantly lower at Time 2 compared to Time 1, perhaps this executive function could be incorporated more into university curriculum. Given that longitudinal studies (e.g. Miller & Hinshaw, 2010) indicate that executive function contributes to academic achievement, Best et al. (2011) proposed that executive function training may promote academic achievement. It could be argued that concept formation may relate academically to developing ideas for essays.

8.4.4 Concept of adolescence

It is of interest that the 18 year old group performed significantly poorer on strategy generation and concept formation compared to 17 year olds because in the UK 18 is considered a legislative marker of adulthood. The finding of a trough in executive function performance at age 18 seems inconsistent with the responsibility given at this age and possibly indicates that responsibility should be delayed until executive functions have returned to their previous level. Indeed, the age considered as adolescence has changed over time; in preindustrial societies, adolescence was thought to extend into the 20s and 30s, when males and females reached maximum height (Tanner, 1973). Similarly, Hall (1915) viewed adolescence as spanning between 12 and 22 to 25 years. Arnett (2001) proposed that the late teenage years and early twenties were emerging adulthood, when people considered themselves to be gradually becoming an adult, with participants aged 26 to 35 year olds more likely to consider themselves as adults compared to 18 to 25 year olds. These data suggest that adulthood has not been reached by age 18.

Roenneberg et al. (2004) investigated a biological marker for the end of adolescence and noted that the end of puberty is defined by attaining maximum height, whereas the end of adolescence is more difficult to define. The authors studied chronotypes, preferences in the timing of sleep and wakefulness, by administering the Munich Chronotype Questionnaire (Roenneberg, Wirz-Justice & Merrow, 2003) to 25,000 participants, aged between 15 and 80 years. Roenneberg et al. (2004) suggested that adulthood could be defined around the age of 20, when chronotypes stop delaying and begin advancing (i.e. sleep patterns change so that people go to sleep earlier and wake up earlier, instead of the stay up late/wake up late pattern of sleep in adolescence). The present findings of poorer performance at age 18 on some executive function tasks, indicating that adulthood has not yet been reached, support Roenneberg et al.'s suggestion that adulthood begins around age 20.

8.5 Future research

The results of this thesis have shown that fine-grained age groups are an effective way of investigating executive function development. Future data collection with 16 year olds, particularly on the D-KEFS Letter Fluency and Sorting Tests, would elucidate whether functions increase, decrease or plateau between 16 and 17 years. Furthermore, it would be of interest to test younger participants with the social cognition measures employed in this study to ascertain at what age adult levels of performance are attained.

Future research could consider the implications that non-linear development of letter fluency and concept formation executive functions have on academic achievement. A dip in academic performance has been reported at Key Stage 3 (11 to 13 years). This has been attributed to commencing secondary school (Whitby, Lord, O'Donnell & Grayson, 2006), but might also reflect non-linear functional development. Executive functions and academic achievement correlate from 5 to 17 years (Best, Miller & Naglieri, 2011) so it might be useful to establish how executive function relates to academic achievement beyond age 17.

Another possibility for future research is to investigate the effects of menstrual cycle phase on executive function and social cognition task performance in late adolescence and early adulthood. A study reviewed in Chapter 3 by Maki et al. (2002) found that oestrogen correlated positively with Phonological and Category Fluency Task scores and correlated negatively with mental rotation. Verbal fluency and fine motor performance, assessed with the Grooved Pegboard Test, were better in the luteal phase, associated with high oestrogen levels, compared to the follicular phase. Mental rotation was significantly better in the early follicular phase, associated with low oestrogen levels, compared to the luteal phase. These findings could influence participants' performance on the D-KEFS Letter Fluency and Tower Test so future research should collect data on participants' menstrual cycle phase.

The present work could be extended by collecting EEG and MRI data because it is possible that whilst there were few cross sectional behavioural executive function differences, there may be changes in neural network activation over late adolescence and early adulthood. For example, Guevera et al. (2011) found no group differences between 11-13 year olds, 18-20 year olds and 26-30 year olds on first move time and number of moves on the Tower of Hanoi. More participants aged 18-20 and 26-30 completed the task in the time limit compared to 11-13 year olds. There was greater synchronisation between prefrontal and parietal regions in the older age groups compared to the younger group allowing faster task completion. Burnett and Blakemore (2009) reported a decrease in functional connectivity between the medial prefrontal cortex and left posterior temporal sulclus / temporo-parietal junction between adolescence (11-18 year olds) and adulthood (22-32 year olds) in a social cognition study. These findings indicate changes in functional connectivity associated with executive function and social cognition task performance between adolescence and early adulthood. Furthermore, reaction time data could be collected on social cognition tasks by presenting the stimuli in E Prime with task instructions informing participants to respond as quickly and accurately as possible. Vetter et al. (2012) found speed of processing on the Identical Pictures Test (Ekstrom, French, Harman & Dermen, 1976) increased significantly between early adolescence (12-15 years) and early adulthood (18-22 years). While speed of processing was unrelated to Eyes Test scores and a Story Comprehension Test, it is possible that processing speed could be related to dynamic stimuli that show emotional expressions for a short time (Vetter et al., 2012). Therefore assessing reaction time data on the MASC and processing speed would be an idea for future research.

8.6 Conclusion

Previous research in executive function and social cognition has focused on childhood (Pennequin et al., 2010), adolescence (Prencipe et al., 2011; Tonks et al., 2007) or broad age ranges in adulthood (Dziobek et al., 2006) resulting in scant data in late adolescence and early adulthood. This research employed a sequential design including cross sectional and longitudinal analyses with fine-grained age groups in late adolescence and early adulthood. Fine grained age groups were selected on the recommendation that broad age ranges decrease sensitivity (De Luca et al., 2003) and may mask non-linear development. Time 1 cross sectional data indicated linear social cognitive development and non-linear development of strategy generation and concept formation, assessed with the D-KEFS Letter Fluency and Sorting Tests. Seventeen year olds scored significantly higher, indicating better performance, than 18 year olds on these tasks with a slight improvement at age 19. However, the Younger group continued to score significantly higher than the Middle age group on strategy generation at Time 2, indicating the group differences may be specific to the sample, such as the Younger group finding the study an unusual and novel experience (Ritter et al., 2012) or were more motivated (Pessoa, 2009) resulting in better executive function task performance compared to the other groups. Group differences on concept formation were not evident at Time 2, indicating non-linear development is specific to age 18. Non-linear development may reflect several dynamic maturational processes including synaptic pruning, increased white matter connectivity (Lebel et al., 2008) and functional synchronisation (Uhlhaas et al., 2009).

Results of longitudinal analyses indicate that some functions improved between testing (inhibition, rule detection, strategy generation, planning and emotion recognition in dynamic stimuli), whilst concept formation declined and other functions stabilised (emotion recognition in visual static and auditory stimuli, sympathetic feelings towards others' misfortune, the tendency to associate with characters in books and films, the tendency to consider other peoples' viewpoints and feelings of apprehension in stressful situations). Comparing the present data with existing adulthood data suggests that emotion recognition with auditory stimuli and IRI Perspective Taking continue to develop beyond early adulthood.

Chapter 7 analyses showed that different IQ, mood state and executive functions predicted scores on social cognition tasks assessing emotion recognition in visual static, auditory, dynamic visual and auditory stimuli and self-report empathy. Executive functions may predict social cognition task performance due to similar neural networks associated with task performance or due to task impurity (Hughes & Ensor, 2007).

Future research with 16 year olds would elucidate whether functions improve, decrease or stabilise between 16 and 17 years. Collecting EEG and MRI data would inform which neural networks were associated with executive function and social cognition task performance, possibly showing changes to functional connectivity in this age range.

Overall, these findings provide evidence of concept formation following a non-linear trajectory specific to age 18 whereas, social cognition develops linearly. Some functions, such as inhibition, rule detection, strategy generation, planning and emotion recognition in dynamic stimuli show longitudinal development into early adulthood. The protracted development of functions may reflect continued brain maturation into early adulthood including myelination (Sowell et al., 2001) and function connectivity (Stevens et al., 2007).

81, 694 words

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Appendices

Appendix Section 1. Interpersonal Reactivity Index (Davis, 1983)

The following statements inquire about your thoughts and feelings in a variety of situations. For each item, indicate how well it describes you by choosing the appropriate letter on the scale at the top of the page: A, B, C, D, or E. When you have decided on your answer, fill in the letter next to the item number. Read each item carefully before responding. Answer as honestly as you can. Thank you.

ANSWER SCALE:

0	1	2	3	4
DOES NOT DESCRIBE ME ME WELL				DESCRIBES ME VERY WELL

1. I daydream and fantasize, with some regularity, about things that might happen to me. (FS)

2. I often have tender, concerned feelings for people less fortunate than me. (EC)

3. I sometimes find it difficult to see things from the "other guy's" point of view. (PT) (-)

4. Sometimes I don't feel very sorry for other people when they are having problems. (EC)

(-)

5. I really get involved with the feelings of the characters in a novel. (FS)

6. In emergency situations, I feel apprehensive and ill-at-ease. (PD)

7. I am usually objective when I watch a movie or play, and I don't often get completely caught up in it. (FS) (-)

8. I try to look at everybody's side of a disagreement before I make a decision. (PT)

9. When I see someone being taken advantage of, I feel kind of protective towards them. (EC)

10. I sometimes feel helpless when I am in the middle of a very emotional situation. (PD)

11. I sometimes try to understand my friends better by imagining how things look from their perspective. (PT)

12. Becoming extremely involved in a good book or movie is somewhat rare for me. (FS) (-)

13. When I see someone get hurt, I tend to remain calm. (PD) (-)

14. Other people's misfortunes do not usually disturb me a great deal. (EC) (-)

15. If I'm sure I'm right about something, I don't waste much time listening to other people's arguments. (PT) (-)

16. After seeing a play or movie, I have felt as though I were one of the characters. (FS)

17. Being in a tense emotional situation scares me. (PD)

18. When I see someone being treated unfairly, I sometimes don't feel very much pity for them. (EC) (-)

19. I am usually pretty effective in dealing with emergencies. (PD) (-)

20. I am often quite touched by things that I see happen. (EC)

21. I believe that there are two sides to every question and try to look at them both. (PT)

22. I would describe myself as a pretty soft-hearted person. (EC)

23. When I watch a good movie, I can very easily put myself in the place of a leading character. (FS)

24. I tend to lose control during emergencies. (PD)

25. When I'm upset at someone, I usually try to "put myself in his shoes" for a while. (PT)

26. When I am reading an interesting story or novel, I imagine how I would feel if the events in the story were happening to me. (FS)

27. When I see someone who badly needs help in an emergency, I go to pieces. (PD)

28. Before criticizing somebody, I try to imagine how I would feel if I were in their place. (PT)

NOTE: (-) denotes item to be scored in reverse fashion

PT = perspective-taking scale

FS = fantasy scale

EC = empathic concern scale

PD = personal distress scale

Appendix Section 2. Demography measure

Please answer the following questions. All answers are anonymous and will be kept confidential.

Have you ever sustained a head injury which led to you being unconscious for 30 minutes?

YES / NO

Have you ever used cannabis? YES / NO

If YES: How old were you when you first used cannabis? _____ years

How often do you use cannabis? __________

When was the last time you used cannabis? __________

Have you ever used ecstasy? YES / NO

If YES: How old were you when you first used ecstasy? _____ years

How often do you use ecstasy? _________

When was the last time you used ecstasy? __________

Do you drink alcohol? YES / NO

The recommended weekly limit of alcohol consumption is 14 units for women and 21 units for men. One unit of alcohol is equal to half a pint of beer, lager or cider, a small shot of spirits or 125 ml glass of wine.

Do you drink over the recommended weekly limits of alcohol consumption? YES / NO

Do you have any of the following:	Depression	YES / NO
	Obsessive compulsive disorder	YES / NO
	Autism / Asperger's Syndrome	YES / NO
	ADHD	YES / NO

Are you a student? YES / NO

If YES:
What are you studying for? GCSE / BTEC / apprenticeship / AS levels / A2 Levels / degree

Do you have a job? YES / NO

If YES:
What is your job title? ________________

How many hours a week do you work? _____ hours

Who do you live with? parent(s) / friends / partner / on own

Please state whether the following have changed over the last year, and if so how they have changed:

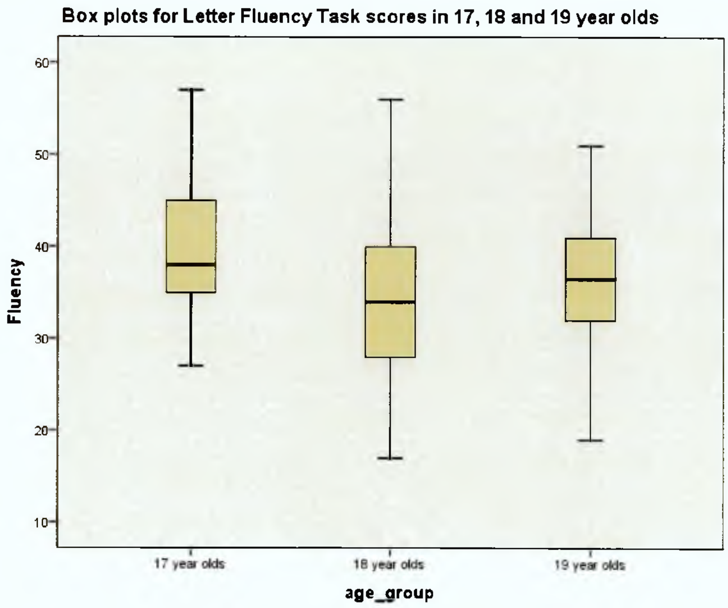
Living arrangements (e.g. have you moved away from home to live in university accommodation?)

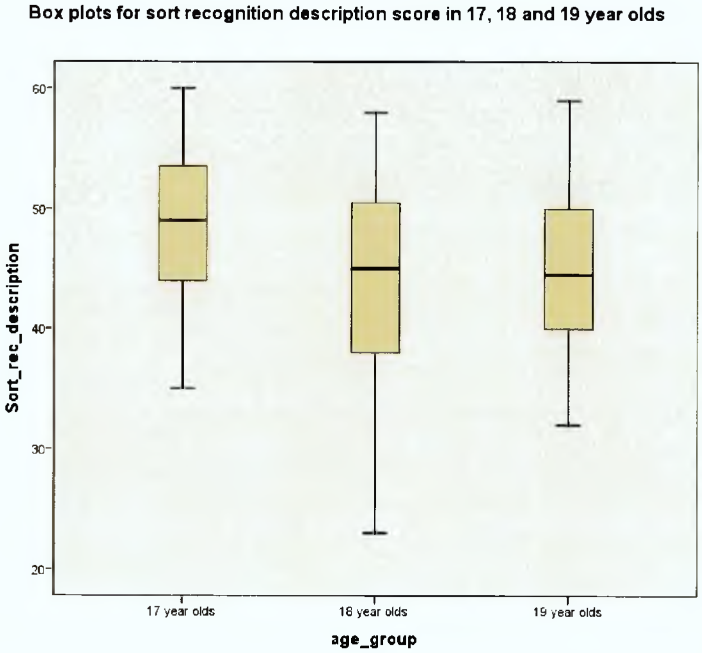
____
____
____
____

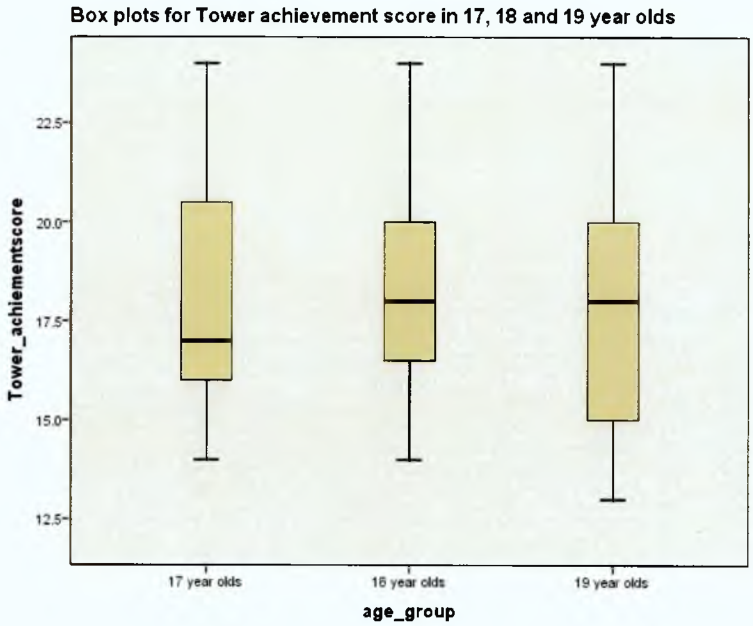
Friendship groups

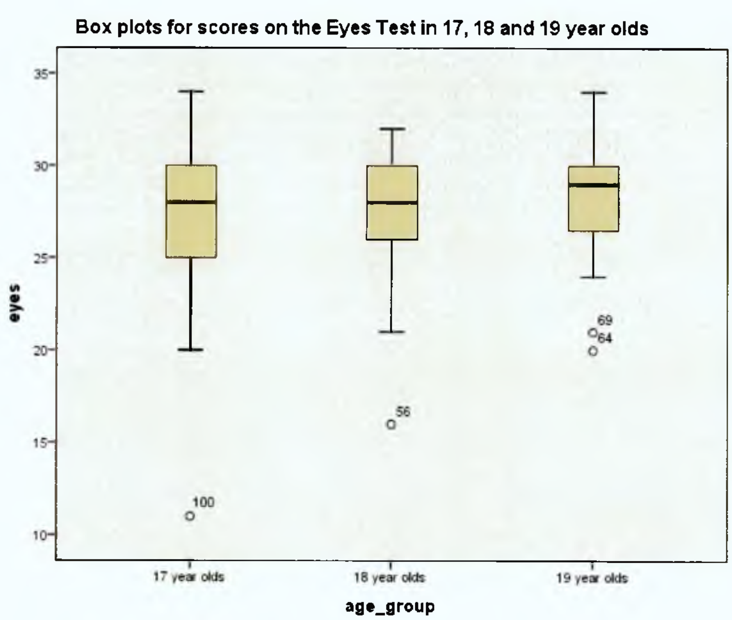
____
____
____
____

Appendix Section 3. Examples of box plots for executive function and social cognition tasks at Time 1 in 17, 18 and 19 year olds.

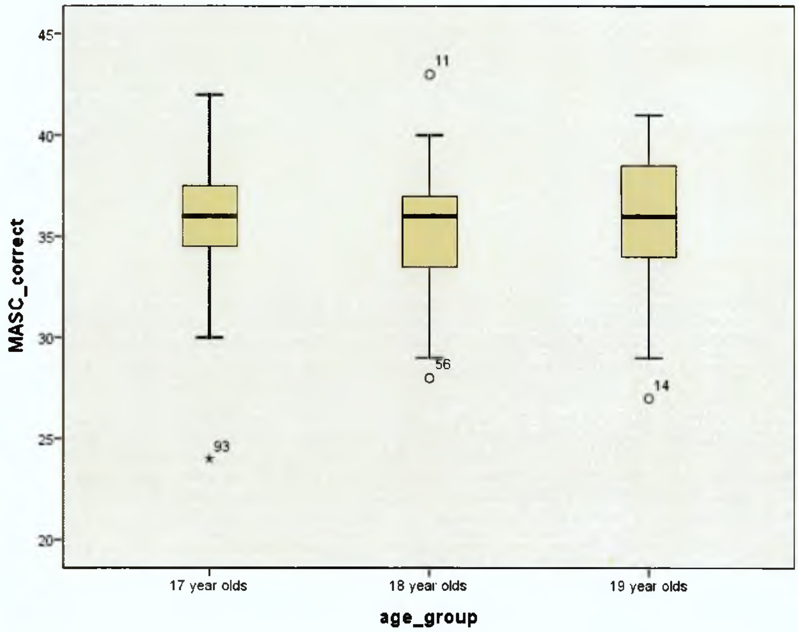




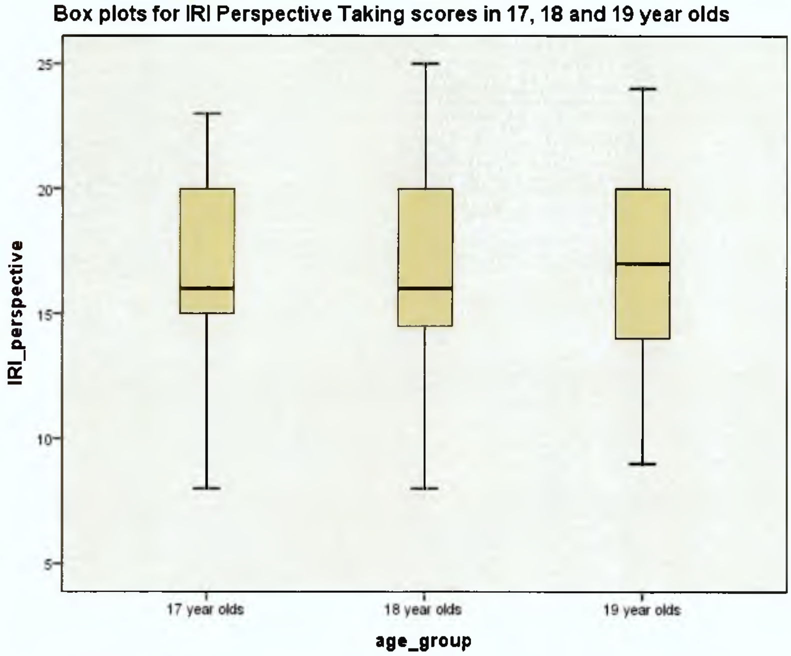

Box plots for Tower achievement score in 17, 18 and 19 year olds
Tower_achiementscore
22.5
20.0
17.5
15.0
12.5
17 year olds
18 year olds
19 year olds
age_group


Box plots for scores on the Eyes Test in 17, 18 and 19 year olds
eyes
35
30
25
20
15
10
100
56
69
64
17 year olds
18 year olds
19 year olds
age_group

Box plots for scores on the MASC in 17, 18 and 19 year olds



Box plots for IRI Perspective Taking scores in 17, 18 and 19 year olds



Appendix Section 4. Correlations between executive function and social cognition tasks at Time 1

	1	2	3	4	5	6	7	8	9	10	11
1. Eyes	1	0.41**	0.39**	-0.40**	-0.19	0.03	0.07	0.20	0.04	-0.01	0.09
2. Voices		1	0.34**	-0.30**	-0.24*	-0.02	0.14	0.19	0.02	0.00	0.18
3. MASC correct			1	-0.83**	-0.58**	-0.37**	0.25*	0.10	0.12	0.03	0.00
4. MASC excessive				1	0.13	0.04	-0.10	-0.18	-0.19	-0.09	-0.06
5. MASC insufficient					1	0.11	-0.24*	0.12	0.12	0.10	0.03
6. MASC no ToM						1	-0.25*	-0.06	-0.08	-0.01	0.09
7. IRI F							1	0.13	0.14	0.11	0.11
8. IRI PT								1	0.30**	0.02	0.19
9. IRI EC									1	0.27**	0.05
10. IRI PD										1	-0.20*
11. Hayling											1
12. Brixton											
13. Fluency											
14. Free sort correct											
15. Free sort desc											
16. Sort rec desc											
17. Desc verbal											
18. Desc perc											
19. Towers completed											
20. Tower Achievement											
21. Tower mean first move											

	12	13	14	15	16	17	18	19	20	21
1. Eyes	0.39**	0.19	0.03	0.08	0.08	0.14	-0.02	0.04	0.06	0.10
2. Voices	0.33**	0.12	0.22*	0.20*	0.25*	0.23*	0.21*	0.27**	0.04	-0.14
3. MASC correct	0.23*	0.28**	0.13	0.15	0.21*	0.10	0.24*	0.16	0.14	0.14
4. MASC excessive	-0.17	-0.18	-0.13	-0.17	-0.17	-0.14	-0.15	-0.20	-0.20	-0.12
5. MASC insufficient	-0.22*	-0.24*	-0.13	-0.10	-0.18	0.00	-0.27**	-0.08	0.03	-0.02
6. MASC no ToM	-0.01	-0.13	0.09	0.08	0.01	0.03	-0.02	0.11	-0.02	-0.12
7. IRI F	0.17	0.13	0.02	0.04	0.14	0.02	0.13	0.09	-0.01	0.10
8. IRI PT	0.21*	0.11	0.12	0.09	-0.01	0.05	0.03	0.02	0.07	0.09
9. IRI EC	0.08	0.13	-0.07	-0.07	0.01	0.01	-0.06	-0.15	-0.07	-0.10
10. IRI PD	-0.10	-0.10	0.00	0.00	-0.04	-0.03	0.01	-0.07	0.00	0.07
11. Hayling	0.04	0.04	0.09	0.04	0.04	0.00	0.08	0.07	0.12	-0.21*
12. Brixton	1	0.24*	0.21*	0.14	0.29**	0.20	0.23*	0.29**	0.06	0.02
13. Fluency		1	0.32**	0.23*	0.27**	0.32**	0.17	0.08	0.02	-0.13
14. Free sort correct			1	0.85**	0.67**	0.73**	0.70**	0.18	0.14	-0.17
15. Free sort desc score				1	0.62**	0.65**	0.63**	0.12	0.11	-0.11
16. Sort rec desc score					1	0.68**	0.78**	0.15	0.01	-0.12
17. Desc verbal score						1	0.27**	0.10	0.06	-0.16
18. Desc perc score							1	0.18	0.08	-0.05
19. Towers completed								1	0.41**	0.10
20. Tower Achievement									1	0.29**
21. Tower mean first move										1

*$p < 0.05$, **$p < 0.01$

Abbreviations: IRI F = Fantasy, IRI PT = Perspective Taking, IRI EC = Empathic Concern , IRI PD = Personal Distress, free sort desc score = free sort description score, sort rec desc score = sort recognition description score, desc verbal score = description score for verbal sorts , desc perc score = description score for perceptual sorts

Appendix Section 5. Means and standard deviations for executive function task performance of participants who reported cannabis use and participants who did not

	Participants who reported cannabis use (n = 30)	Participants who reported no cannabis use (n = 68)
Measures of response inhibition and rule detection		
Hayling scaled	5.97 (1.65)	5.47 (1.43)
Brixton scaled	7.53 (1.57)	7.13 (1.84)
Measure of strategy generation		
Verbal fluency	36.43 (9.01)	36.46 (7.65)
Measures of concept formation		
Free sorts correct	11.40 (1.75)	11.07 (1.98)
Free sort description score	42.47 (8.71)	42.21 (7.44)
Sort recognition description score	47.17 (6.93)	45.63 (7.40)
Verbal sorts description score	30.90 (6.93)	29.94 (8.15)
Perceptual sorts description score	60.03 (8.98)	57.71 (9.44)
Measures of planning		
Number of Tower items completed	8.30 (0.84)	8.29 (0.85)
Tower achievement score	17.77 (2.57)	18.18 (2.95)
Mean first move time	3.46 (1.48)	3.75 (1.75)
Time per move	2.66 (0.59)	2.74 (0.66)
Move accuracy	1.62 (0.31)	1.63 (0.46)

$p > 0.05$

Appendix Section 6. Means and standard deviations for social cognition task performance of participants who reported cannabis use and participants who did not

	Participants who reported cannabis use ($n = 30$)	Participants who reported no cannabis use ($n = 68$)
Static visual stimuli		
Eyes	28.27 (2.99)	27.48 (4.23)
Auditory stimuli		
Voices	17.10 (2.04)	16.90 (2.51)
Dynamic visual and auditory stimuli with social interaction		
MASC correct	35.60 (2.72)	35.49 (3.71)
MASC excessive mental state inference errors	5.40 (2.51)	5.68 (2.67)
MASC insufficient mental state inference	2.50 (1.41)	2.54 (1.59)
MASC no ToM errors	1.50 (1.01)	1.29 (0.99)
Self-report empathy		
IRI Fantasy	17.45 (5.17)	17.71 (5.34)
IRI Perspective Taking	16.52 (3.53)	17.19 (4.09)
IRI Empathic Concern	20.45 (2.97)	20.82 (3.56)
IRI Personal Distress	12.86 (4.23)	14.12 (4.92)

all $p > 0.05$

Appendix Section 7. Descriptive statistics for executive function task performance participants who reported alcohol use and participants who did not report alcohol use

	Participants who reported alcohol use (n = 85)	Participants who reported no alcohol use (n = 13)
Measures of response inhibition and rule detection		
Hayling scaled	5.68 (1.51)	5.23 (1.54)
Brixton scaled	7.31 (1.62)	6.92 (2.60)
Measure of strategy generation		
Verbal fluency	36.24 (8.35)	37.85 (5.74)
Measures of concept formation		
Free sorts correct*	10.99 (1.83)	12.38 (2.06)
Free sort description score*	41.49 (7.55)	47.46 (7.76)
Sort recognition description score*	45.41 (7.15)	50.62 (6.58)
Verbal sorts description score*	29.53 (7.47)	34.85 (8.44)
Perceptual sorts description score	57.82 (9.19)	62.31 (9.60)
Measures of planning		
Number of Tower items completed	8.29 (0.87)	8.31 (0.63)
Tower achievement score	18.06 (2.83)	18.00 (2.97)
Mean first move time	3.73 (1.74)	3.20 (1.04)
Time per move	2.70 (0.65)	2.80 (0.61)
Move accuracy	1.62 (0.44)	1.65 (0.32)

* $p < 0.05$

Appendix Section 8. Descriptive statistics for social cognition task performance participants who reported alcohol use and participants who did not report alcohol use

	Participants who reported alcohol use ($n = 85$)	Participants who reported no alcohol use ($n = 13$)
Static visual stimuli		
Eyes	27.88 (3.48)	26.58 (6.16)
Auditory stimuli		
Voices	16.96 (2.24)	16.92 (3.20)
Dynamic visual and auditory stimuli with social interaction		
MASC correct	35.56 (3.20)	35.23 (4.82)
MASC excessive mental state inference errors	5.62 (2.60)	5.38 (2.79)
MASC insufficient mental state inference	2.51 (1.47)	2.69 (1.93)
MASC no ToM errors	1.31 (0.96)	1.69 (1.18)
Self-report empathy		
IRI Fantasy	17.70 (5.27)	17.15 (5.40)
IRI perspective	17.12 (4.00)	16.15 (3.44)
IRI empathic	20.49 (3.28)	22.15 (3.78)
IRI personal distress	13.43 (4.70)	15.77 (4.66)

all $p > 0.05$

Appendix Section 9. Descriptive statistics of executive function task performance for participants who reported consuming above and below the weekly alcohol guidelines

	Participants who reported consuming above the weekly alcohol guidelines (*n* = 27)	Participants who reported consuming below the weekly alcohol guidelines (*n* = 70)
Measures of response inhibition and rule detection		
Hayling scaled	5.63 (1.60)	5.61 (1.50)
Brixton scaled	7.33 (1.98)	7.19 (1.67)
Measure of strategy generation		
Verbal fluency	34.44 (8.80)	37.23 (7.72)
Measures of concept formation		
Free sorts correct	10.70 (1.77)	11.31 (1.93)
Free sort description score	40.89 (7.08)	42.71 (8.05)
Sort recognition description score*	43.59 (7.52)	46.87 (6.85)
Verbal sorts description score	30.11 (6.67)	30.16 (8.19)
Perceptual sorts description score*	54.37 (9.52)	59.80 (8.79)
Measures of planning		
Number of Tower items completed	8.33 (0.62)	8.27 (0.92)
Tower achievement score	18.11 (2.74)	18.06 (2.89)
Mean first move time	3.90 (1.51)	3.59 (1.73)
Time per move	2.77 (0.48)	2.70 (0.69)
Move accuracy	1.56 (0.31)	0.65 (0.46)

* $p < 0.05$

Appendix Section 10. Descriptive statistics of social cognition task performance for participants who reported consuming above and below the weekly alcohol guidelines

	Participants who reported consuming above the weekly alcohol guidelines (*n* = 27)	Participants who reported consuming below the weekly alcohol guidelines (*n* = 70)
Static visual stimuli		
Eyes	28.15 (3.35)	27.59 (4.11)
Auditory stimuli		
Voices	17.00 (1.94)	16.97 (2.53)
Dynamic visual and auditory stimuli with social interaction		
MASC correct	35.52 (2.82)	35.60 (3.61)
MASC excessive mental state inference errors	5.52 (2.16)	5.57 (2.77)
MASC insufficient mental state inference	2.81 (1.30)	2.41 (1.61)
MASC no ToM errors	1.15 (1.13)	1.41 (0.93)
Self-report empathy		
IRI Fantasy	16.85 (5.33)	17.87 (5.27)
IRI Perspective Taking	17.38 (3.68)	16.87 (4.05)
IRI Empathic Concern	20.85 (2.72)	20.64 (3.63)
IRI Personal Distress	13.65 (4.74)	13.71 (4.78)

all $p > 0.05$

Appendix Section 11. Descriptive statistics of executive function task performance for participants who reported completing puberty and participants who reported not completing puberty

	Participants who reported completing puberty ($n = 35$)	Participants who reported not completing puberty ($n = 63$)
Measures of response inhibition and rule detection		
Hayling scaled	5.40 (1.36)	5.75 (1.59)
Brixton scaled	7.00 (1.83)	7.40 (1.73)
Measure of strategy generation		
Verbal fluency	35.69 (8.34)	36.87 (7.91)
Measures of concept formation		
Free sorts correct	11.29 (1.86)	11.11 (1.95)
Free sort description score	42.26 (8.57)	42.30 (7.41)
Sort recognition description score	45.80 (5.88)	46.27 (7.97)
Verbal sorts description score	30.40 (7.46)	30.14 (8.00)
Perceptual sorts description score	58.43 (8.26)	58.41 (9.92)
Measures of planning		
Number of Tower items completed	8.26 (0.89)	8.32 (0.82)
Tower achievement score	17.63 (2.61)	18.29 (2.94)
Mean first move time	3.68 (1.75)	3.65 (1.64)
Time per move	2.63 (0.60)	2.76 (0.66)
Move accuracy	1.65 (0.48)	1.61 (0.48)

all $p > 0.05$

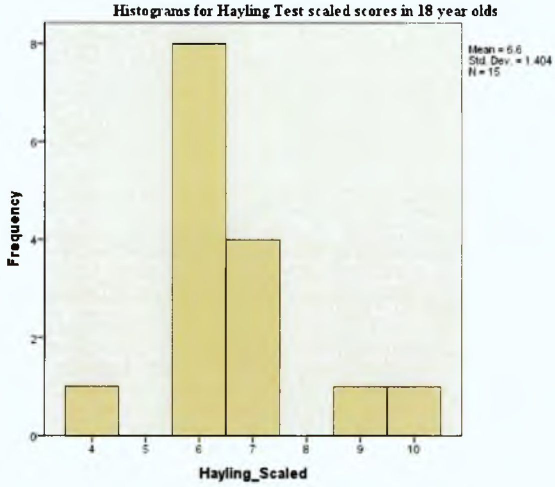
Appendix Section 12. Descriptive statistics of social cognition task scores for participants who reported competing puberty and participants who reported not completing puberty

	Participants who reported completing puberty (n = 35)	Participants who reported not completing puberty (n = 63)
Static visual stimuli		
Eyes	27.85 (4.11)	27.65 (3.80)
Auditory stimuli		
Voices	16.74 (2.73)	17.08 (2.16)
Dynamic visual and auditory stimuli with social interaction		
MASC correct	35.17 (3.19)	35.71 (3.56)
MASC excessive mental state inference errors	6.03 (2.81)	5.35 (2.48)
MASC insufficient mental state inference	2.40 (1.44)	2.60 (1.58)
MASC no ToM errors	1.40 (1.06)	1.33 (0.97)
Self-report empathy		
IRI Fantasy	17.20 (5.20)	17.87 (5.32)
IRI perspective	16.86 (4.49)	17.06 (3.61)
IRI empathic	20.31 (3.07)	20.94 (3.55)
IRI personal distress	14.63 (4.61)	13.24 (4.78)

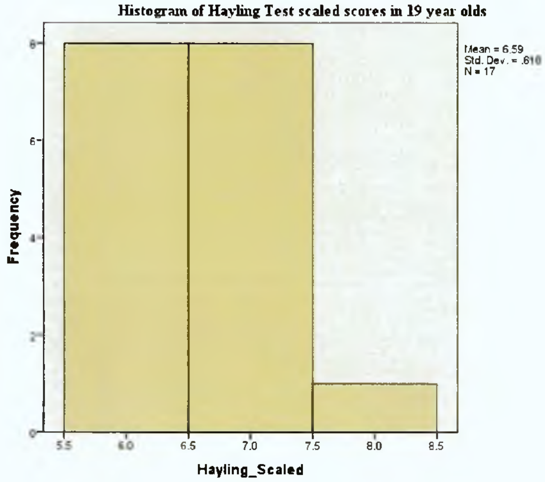
all $p > 0.05$

Appendix Section 13. Examples of histograms showing executive function and social cognition task scores in 18, 19 and 20 year olds at Time 2.

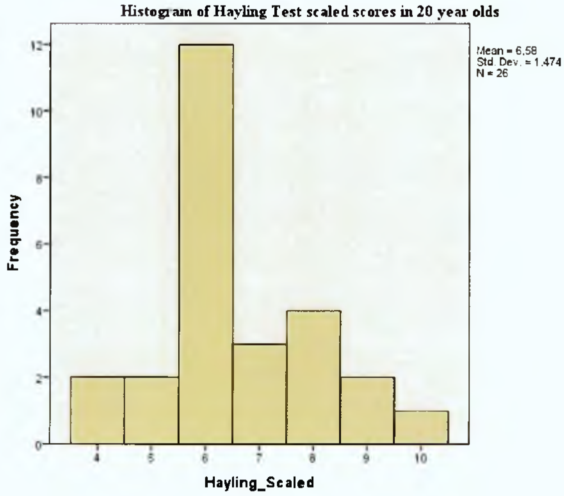
Histograms for Hayling Test scaled scores in 18 year olds



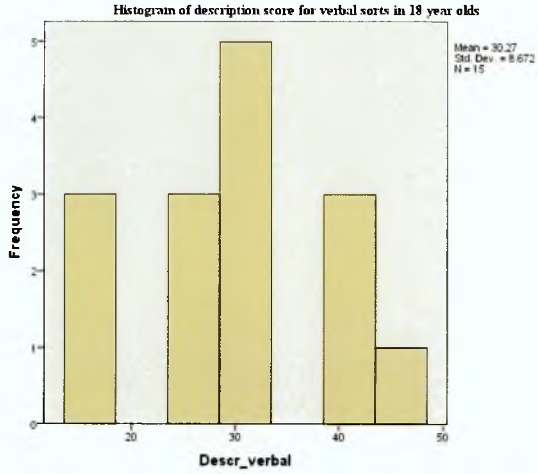
Histogram of Hayling Test scaled scores in 19 year olds



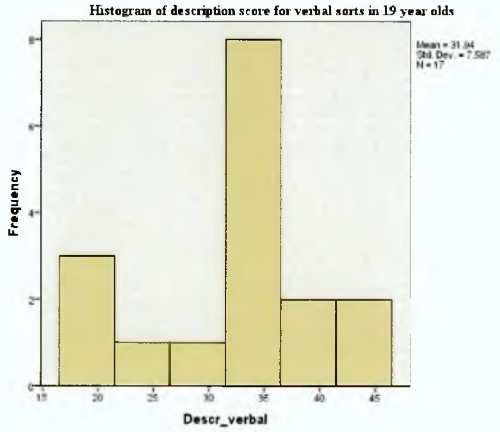
Histogram of Hayling Test scaled scores in 20 year olds



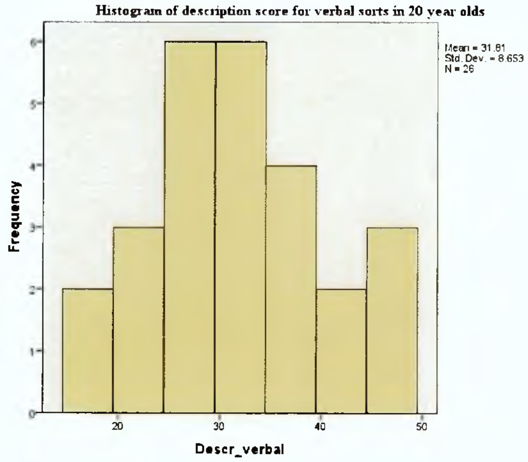
Histogram of description score for verbal sorts in 18 year olds



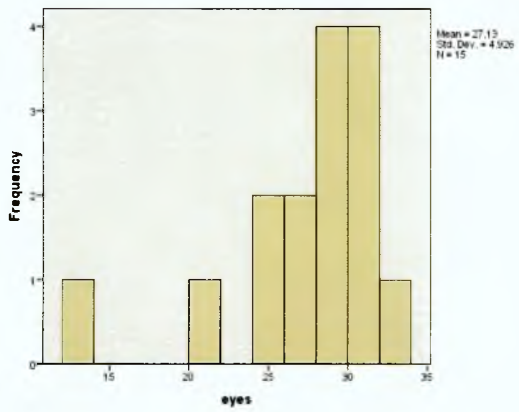
Histogram of description score for verbal sorts in 19 year olds



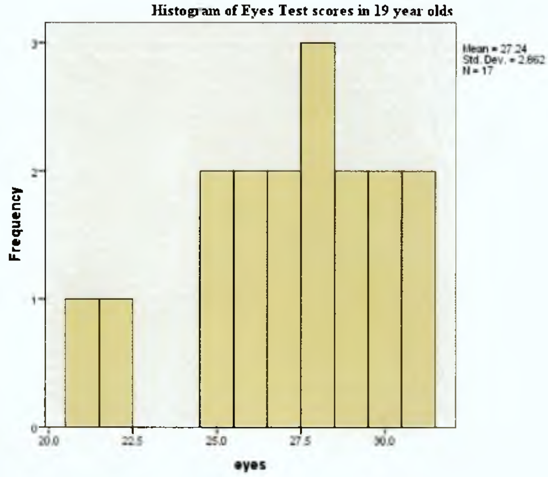
Histogram of description score for verbal sorts in 20 year olds



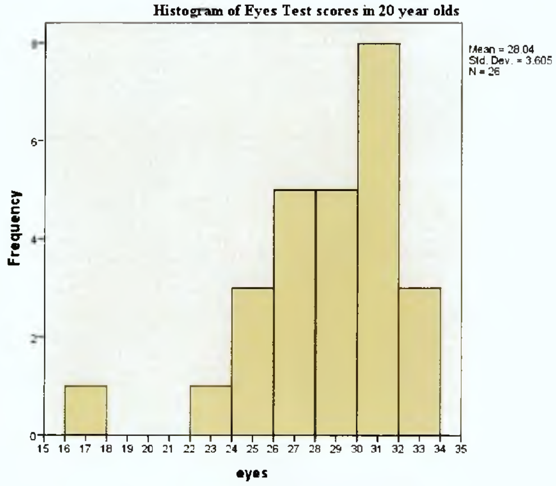
Histogram of Eyes Test scores in 18 year olds



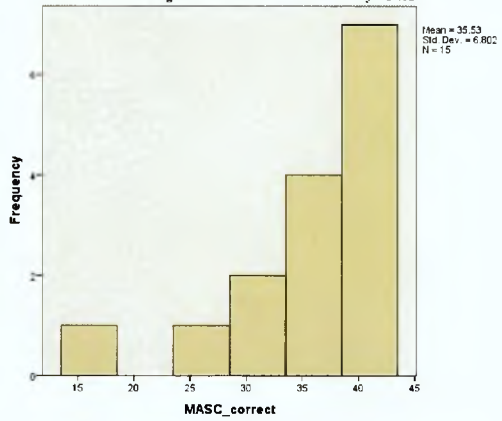
Histogram of Eyes Test scores in 19 year olds



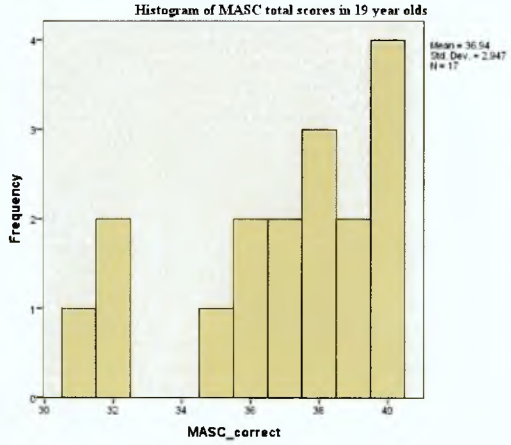
Histogram of Eyes Test scores in 20 year olds



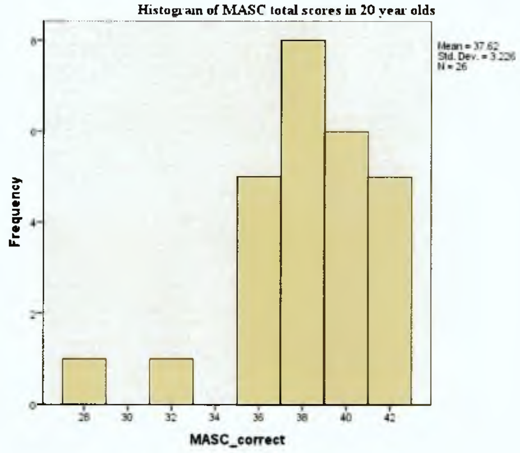
Histogram of MASC total scores in 18 year olds



Histogram of MASC total scores in 19 year olds



Histogram of MASC total scores in 20 year olds



Appendix Section 14. Correlations between executive function and social cognition tasks at Time 2

	1	2	3	4	5	6	7	8	9	10	11
1. Eyes	1	0.56**	0.66**	-0.42**	-0.54**	-0.53**	0.13	0.20	-0.12	0.06	-0.03
2. Voices		1	0.49**	-0.26*	-0.31*	-0.56**	0.32*	0.39**	0.07	0.10	0.16
3. MASC correct			1	-0.76**	-0.70**	-0.72**	0.13	0.37**	-0.02	0.13	0.03
4. MASC excessive				1	0.21	0.26*	-0.09	-0.29*	-0.04	-0.08	-0.07
5. MASC insufficient					1	0.44**	-0.12	-0.16	0.02	-0.24	0.03
6. MASC no ToM						1	-0.08	-0.35**	0.09	0.04	-0.01
7. IRI F							1	-0.41**	0.28*	0.20	0.09
8. IRI PT								1	0.34**	0.09	0.01
9. IRI EC									1	0.30*	-0.01
10. IRI PD										1	-0.25
11. Hayling											1
12. Brixton											
13. Fluency											
14. Free sort correct											
15. Free sort desc score											
16. Sort rec desc score											
17. Desc verbal score											
18. Desc perc score											
19. Towers completed											
20. Tower Achievement											
21. Tower mean first move											

	12	13	14	15	16	17	18	19	20	21
1. Eyes	0.25	-0.02	-0.14	-0.11	-0.12	-0.04	-0.14	0.05	0.35**	0.27*
2. Voices	0.16	-0.02	0.02	0.04	0.19	0.06	0.13	0.16	0.32*	0.09
3. MASC correct	0.36**	-0.03	-0.11	0.03	0.10	0.11	0.02	0.13	0.30*	0.15
4. MASC excessive	-0.19	0.14	0.07	-0.05	-0.06	-0.15	0.04	-0.10	-0.16	-0.09
5. MASC insufficient	-0.36**	-0.17	0.00	-0.09	-0.05	-0.09	-0.03	0.03	-0.18	-0.14
6. MASC no ToM	-0.26*	0.05	0.18	0.08	-0.12	0.04	-0.07	-0.22	-0.35**	-0.12
7. IRI F	0.17	0.32*	0.22	0.15	0.15	0.18	0.09	0.15	0.13	-0.08
8. IRI PT	0.15	0.02	0.11	0.19	0.27*	0.22	0.18	0.11	0.21	-0.02
9. IRI EC	0.06	0.03	0.15	0.05	-0.04	0.14	-0.11	0.00	-0.04	-0.05
10. IRI PD	-0.13	0.13	-0.03	-0.06	-0.15	-0.01	-0.15	0.03	-0.01	0.08
11. Hayling	0.08	0.08	-0.04	-0.02	0.19	-0.03	0.15	-0.17	0.12	-0.05
12. Brixton	1	0.22	-0.02	0.12	0.19	0.19	0.08	0.00	0.30*	0.20
13. Fluency		1	0.15	0.12	0.19	0.01	0.24	-0.01	0.10	-0.38**
14. Free sort correct			1	0.90**	0.48**	0.65**	0.55**	0.07	0.12	-0.15
15. Free sort desc score				1	0.64**	0.76**	0.68**	0.11	0.15	-0.15
16. Sort rec desc score					1	0.57**	0.83**	0.12	0.25	-0.18
17. Desc verbal score						1	0.23	0.15	0.03	-0.04
18. Desc perceptual score							1	0.06	0.29*	-0.23
19. Towers completed								1	0.39*	-0.14
20. Tower Achievement									1	0.11
21. Tower mean first move										1

$*p < 0.05$, $**p < 0.01$ Abbreviations: IRI F = Fantasy, IRI PT = Perspective Taking, IRI EC = Empathic Concern , IRI PD = Personal Distress, free sort desc score = free sort description score, sort rec desc score = sort recognition description score, desc verbal score = description score for verbal sorts , desc perc score = description score for perceptual sort

Appendix Section 15. Correlations between age, IQ and mood state variables in the whole cohort at Time 1

	Verbal IQ	Perf IQ	Full IQ	PA	NA	Depression	Anxiety
Age	-0.14	-0.02	-0.09	0.17	-0.32**	<0.01	-0.23*
Verbal IQ	1	0.33**	**0.82****	-0.05	-0.05	-0.20	0.02
Perf IQ		1	**0.80****	-0.12	-0.20	0.06	-0.14
Full IQ			1	-0.10	-0.15	-0.08	-0.07
PA				1	-0.11	-0.17	<0.01
NA					1	0.12	0.31**
Depression						1	0.31**
Anxiety							1

**$p < 0.01$ * $p < 0.05$

Figures in bold show correlations higher than 0.80 indicating mutlicollinearity

Abbreviations: Perf IQ = Performance IQ, PA = positive affect, NA = negative affect

Appendix Section 16. Correlations between executive function task scores at Time 1

	Brixton Scaled	Letter Fluency	Free sort description score	Tower Achievement score
Hayling Scaled	0.04	0.04	0.04	0.12
Brixton Scaled	1	0.24*	0.14	0.06
Letter Fluency		1	0.23	0.02
Free sort description score			1	0.11
Tower Achievement score				1

*$p < 0.05$

Key to functions: Hayling Scaled = inhibition, Brixton Scaled = rule detection, Letter Fluency = strategy generation, Free sort description score = concept formation and Tower Achievement score = planning.

Appendix Section 17. Correlations between age, IQ and mood state variables at Time 2 in the whole cohort

	Verbal IQ	Perf IQ	Full IQ	PA	NA	Depression	Anxiety
Age	-0.17	0.05	-0.08	0.18	-0.29*	-0.25	-0.20
Verbal IQ	1	0.20	0.78**	-0.18	0.13	0.17	0.18
Perf IQ		1	0.77**	0.15	<0.01	-0.07	-0.03
Full IQ			1	-0.01	0.07	0.03	0.06
PA				1	-0.21	-0.27*	-0.20
NA					1	0.26*	0.51**
Depression						1	0.64**
Anxiety							1

**$p < 0.01$ *$p < 0.05$

Abbreviations: Perf IQ = Performance IQ, PA = positive affect, NA = negative affect

Appendix Section 18. Correlations between executive function task scores at Time 2 in the total cohort

	Brixton Scaled	Letter Fluency	Free sort description score	Tower Achievement score
Hayling Scaled	0.08	0.08	-0.02	0.12
Brixton Scaled	1	0.22	0.12	0.30*
Letter Fluency		1	0.12	0.10
Free sort description score			1	0.15
Tower Achievement score				1

*$p < 0.05$

Key to functions: Hayling Scaled = inhibition, Brixton Scaled = rule detection, Letter Fluency = strategy generation, Free sort description score = concept formation and Tower Achievement score = planning.