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Examining theories of cognitive ageing using the false memory paradigm

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Changes in memory performance with advancing age have been well-documented, even in the absence of brain injury or dementia. The mechanisms underlying cognitive ageing are still a matter of debate. The current paper describes a comparison between young (18-25 year old) and older (60+ years) adults using the Deese-Roediger-McDermott false memory paradigm and manipulating the number of words included in the memory lists. Two key theories of cognitive ageing (the Inhibitory Deficit Hypothesis and the Transmission Deficit Hypothesis) predict opposing patterns on this task. Results showed that longer lists increase the likelihood that a lure is retrieved and that older adults are more susceptible to false memories than are younger adults. We argue that these findings are supportive of the Inhibitory Deficit Hypothesis and cannot easily be reconciled with the Transmission Deficit Hypothesis account.

The decline of cognitive function associated with healthy ageing has been well-documented in the research literature. The findings from a number of studies indicate that declines are not uniform, however, and that ageing affects output more than input. For example, language comprehension skills and vocabulary size have been shown to change very little across adult life (e.g. MacKay & Burke, 1990; Light, 1991; Kemper, 1992; Tun & Wingfield, 1993; MacKay & Abrams, 1996; Burke, 1997). In contrast, older adults are prone to experiencing word finding difficulties (so-called Tip of the Tongue states, Brown & McNeill, 1966) with greater frequency than younger adults are. Another asymmetry in the cognitive performance of older adults is that memory for familiar and highly practised information is largely preserved (Burke, MacKay & James, 2000) but encoding and retrieval of new information is often compromised (Burke & MacKay, 1997). These specific patterns of performance have been accommodated in a variety of theoretical models of cognitive ageing. A full consideration of these models is beyond the scope of this paper, but interested readers are directed to the work of Burke and Shafto (2008) for a review. In brief, some theorists have proposed that the decline in cognitive performance can be explained by a general slowing of processing (Salthouse, 1985, 1996, 2000) or a decrease in the quantity of processing resources available to the individual (e.g. Baddeley, 1982; Wingfield, Tun & McCoy, 2005), while others have proposed that ageing affects the way that activation spreads across semantic networks (Burke & MacKay, 1997; Hasher & Zacks, 1988). In what follows, we examine the mechanisms proposed to account for cognitive declines in healthy ageing by the Transmission Deficit Hypothesis (Burke & MacKay, 1997) and the Inhibitory Deficit Hypothesis (Hasher & Zacks, 1988), and the assessment of these theories is the aim of the remainder of the paper. **To pre-empt the following discussion, this paper reports the findings of a study using the Deese-Roediger-McDermott paradigm (DRM; Deese, 1959; Roediger & McDermott, 1995) in two different age cohorts. In this task participants are presented with a list of words that share a common associate. The associate itself (called the *lure*) is never presented, yet participants will often report that the lure was part of the studied list. Roediger and McDermott (1995) reported that on 55% of occasions participants reported the lure during immediate free recall. That is, when they had been asked to learn a list of words such as *awake, doze, dream, snooze, bed*… participants often "remembered" SLEEP even though it was not among the presented stimuli. It is our position that the Transmission Deficit Hypothesis and the Inhibitory Deficit Hypothesis accounts would predict opposing patterns of performance on the DRM task in healthy ageing.**

Before we consider the two theories specifically, it is pertinent to briefly describe general semantic network theory (Collins & Loftus, 1975; Steyvers & Tenenbaum, 2005). The prevailing opinion is that information is stored in long term memory as a system of interconnected nodes. Each node represents a single word or concept. Every word is integrated into the network by a semantic (or associative) link with at least one other word. When a node is accessed, some activation is also passed to neighbouring nodes as a function of the strength of the link between them. This spread of activation prepares semantically related words in case they are needed, which leads to faster responses in priming tasks. There are two key mechanisms in the function of semantic networks. First is that a link between two nodes in the network is strengthened every time it is accessed (though see de Groot, 1989 for a discussion of this issue). Thus frequently associated pairs of words are connected by a stronger link than words that are seldom paired. Second is that activation of nodes is transitory, and levels of activation return to baseline once the node is no longer needed. This is achieved through inhibition. The action of inhibition serves to prevent intrusions from concepts that are not central to the task at hand. The Transmission Deficit Hypothesis (Burke & MacKay, 1997) considers that ageing alters link strength; the Inhibitory Deficit Hypothesis

(Hasher & Zacks, 1988) implicates inhibitory mechanisms in cognitive ageing, **suggesting that inhibition gets less efficient as we get older.**

The Transmission Deficit Hypothesis (Burke & MacKay, 1997) is a particularly influential theory of cognitive ageing, and many interventions aimed at preserving cognitive functioning in old age are based on its principles. It is focussed specifically on performance in language tasks, but its logic can be extended to any task involving access to semantic networks. Simply put, MacKay and Burke (1990) argue that ageing reduces the strength of all the connections between nodes in the semantic network. The consequence of this is that activation spreads through the network more slowly **in older adults** than in younger adults, and that weak links are lost earlier in the ageing process than well-practiced associations. The Transmission Deficit Hypothesis explains that age-related deficits in language production occur when a node fails to activate due to weak connections which impair the transmission of priming. This theory is consistent with observed neurobiological characteristics of ageing. For example, reduced connectivity has been linked to age-related white matter atrophy (eg. Marner, Nyengaard, Tang & Pakkenberg, 2003). Weaker connections have also been linked to the slowing of central and peripheral conduction time with ageing, observed in somatosensory event-related potentials (eg. Tanosaki, Ozaki, Shimaura, Baba & Matsunaga, 1999). The Transmission Deficit Hypothesis is able to provide an account for the spared and impaired language and memory functions in older adults, and is supported by some observed neurobiological characteristics of ageing. **Following this theoretical account, each successive word included in the DRM lists passes some activation to the lure. In older adults, however, the amount of activation that spreads from a presented word to the non-presented lure is less than for younger adults because the intra-network connections get weaker as we age. Therefore it could be predicted that a greater number of presented words would be required before the activation of the lure was sufficient to elicit false recall in older adults than in younger adults.**

An alternative theory is that ageing decreases the efficacy of inhibition processes. The Inhibitory Deficit Hypothesis (Hasher & Zacks, 1988) states that activation spreads across semantic networks exactly as it does in younger adults, but that unnecessary nodes no longer get ignored as efficiently. Consequently, irrelevant information is able to gain entry into working memory, and is not deleted. With too much information creating interference, more errors are likely to be made. For example, previous research has demonstrated that older adults are slower at reading aloud than younger adults when distractions are inserted in the text (Carlson, Hasher, Connelly & Zacks, 1995). A combination of irrelevant information gaining entry to working memory, and receiving more sustained activation than it would with intact inhibitory processes, leads to both poorer initial encoding of memories, and competition between related ideas. This in turn leads to reduced success in accessing required information from memory. The function of inhibitory processes to delete irrelevant information from the focus of attention has been demonstrated in studies involving explicit and implicit directed forgetting procedures. Older adults have been found to recall more irrelevant information than younger adults, and compared to 'to-be-remembered' information (eg. May, Zacks, Hasher & Multhaup, 1999; Zacks, Radvansky & Hasher, 1996). Studies of older adults' performance on go/no-go or stop-signal tasks have shown that older adults have a deficit in the inhibitory process of restraint, when compared with younger adults (eg. Bedard et al, 2002; Kramer, Humphrey, Larish, Logan & Strayer, 1994). The observed deficits in restraint may affect language processing in older age if the context points an individual towards a strong, yet incorrect, inference (Yoon, May & Hasher, 2000). The different functions of inhibitory processes can be described as related, but separable. More recent neuroimaging research has aimed to identify whether inhibitory functions map onto specific mechanisms, and to investigate the biological basis of these. Inhibitory functions have been linked to activation in anterior cingulate cortex, dorsolateral prefrontal cortex, inferior frontal gyrus, posterior parietal cortex, and anterior insula (Nelson, Reuter-Lorenz, Sylvester, Jonides & Smith, 2003; Sylvester et al, 2003; Wager et al, 2005). Neuroimaging data has also shown distinct areas of activation for the individual functions of inhibition. For example, Sylvester et al (2003) found that the deletion task activated left prefrontal and left parietal cortex, and the restraint task activated more medial subcortical regions and the frontal polar cortex, as well as the common network mentioned previously. **This theoretical account leads to the prediction of a different pattern of performance on the DRM task. Specifically, a decreased ability to reduce the level of activation for nodes in a semantic network that are not required for the task at hand would result in a greater level of residual activation in the lure following each successive word in a DRM list. If it is the case that inhibitory deficits of this nature are a consequence of cognitive ageing, fewer words would be required before the activation of the lure was sufficient to elicit false recall in older adults than in younger adults.**

The empirical literature on the DRM task has included some evidence that hints that there may be effects of list length and age on memory performance. For example, Balota et al (1999) **used the standard DRM lists and** demonstrated that the likelihood of recalling lures was increased in older adults **relative to younger adults (though age-related differences in false recognition rates are not always observed in the DRM paradigm, e.g. Benjamin, 2001) .** Robinson and Roediger (1997) further demonstrated that the likelihood of reporting the lure was relative to the number of words in the list. They deleted words from the DRM lists in groups of 3 and reported that a significantly greater proportion of participants recalled the lure when they were presented with 12 words than when they saw 9 words. The proportion of lures recalled was lower again when lists only included 6 words. These findings can be accounted for with reference to spreading activation (see e.g. Roediger, Watson, McDermott & Gallo, 2001). Each word in the list presented to the participants was connected to the same lure, which was therefore partially activated by every individual item. Lures were recalled when the amount of activation accumulated during the presentation of the word list was sufficient for the lure to pass a recognition threshold. Longer lists provided more opportunity for activation to accrue in the lure node. **Of particular note is the study conducted by Gallo and Roediger (2003), which is the only previous work to assess the effects of both list length and age to our knowledge. In their study, participants were presented with 5, 10 or 15 item DRM lists. These lists had elicited the highest levels of false recognition responses in the Stadler, Roediger and McDermott (1999) norms. Participants were then asked to make old versus new judgements on a recognition test which included the non-presented lures. Gallo and Roediger (2003) reported that the likelihood of incorrectly categorising a lure as "old" was increased with increasing list length. Interestingly, though, there was no significant difference in false recognition rates between the older and younger adults in their study. We consider that this may be a consequence of their methodology. The Gallo and Roediger (2003) task used the DRM lists that were most likely to elicit false recognition responses in the first place. As a consequence, it may be that the association between the presented items and the lure was strong enough that there was no opportunity for any effect of cognitive ageing to be observed. That is, if the intra-network links were very strong then a) only extensive weakening of these links would result in any change in performance predicted by the Transmission Deficit Hypothesis and b) the level of inhibition that would be needed to avoid false recognition would be too great to achieve even in the absence of any inhibitory deficit and essentially inflate the false memory rate in younger adults too.**

Furthermore, Gallo and Roediger (2003) used a recognition task to measure the memory performance of their participants. It has been argued that the recognition task is somewhat simpler than a recall task because a recognition task supplies a cue for retrieval whereas recall does not. If that is the case, then Gallo and Roediger's (2003) findings may not reflect memory performance in cognitive ageing in a more general sense. Therefore it is worth studying the factors of age and list length again, but this time using lists that have not been specifically chosen as being likely to elicit false memories, and in recall rather than recognition.

As we suggested earlier, the Transmission Deficit Hypothesis and the Inhibition Deficit Hypothesis of cognitive ageing would predict opposite patterns of responses on the Robinson and Roediger (1997) word recall tasks. The Transmission Deficit Hypothesis would suggest that as the ageing process weakens connections between nodes in the memory system, it will take more associated words, therefore longer lists, for an older person than a younger person to ‘remember’ the lure. The Inhibition Deficit Hypothesis, however, would suggest that as ageing weakens inhibitory processes, older people may ‘remember’ the lure in lists with fewer words. As a result, administering this task to different age groups will provide data that may support one of these models, but not both.

Method

Participants

Fifty-six participants were recruited for this study. Half of the participants were students at Sheffield Hallam University (mean age 22.9 years, SD = 3.04). The remaining 28 participants were recruited from the local community to form a healthy ageing group (mean age 71.5 years, SD = 7.55). All participants were native speakers of English, without dyslexia and with normal or corrected-to-normal vision. In addition, the healthy ageing participants scored **above the cut-off score for their chronological age and level of education** on the Mini-Mental State Examination (Folstein, Folstein & McHugh, 1975) and had not suffered a stroke or other brain injury.

Design

A mixed 2 (age) x 4 (list length) design was implemented. The dependent variables considered were the proportion of words on the list that were correctly recalled (veridical recall hereafter) and the proportion of lures falsely reported.

Materials and Procedure

The stimuli for the experiment consisted of 24 lists of words from Roediger and McDermott (1995). The full lists from the original study contained 15 words each, which represent the most frequently reported words offered when the lure word is used as a cue for word association. To create the shortened (6, 9 and 12 item) lists, groups of three words were deleted in reverse order of associative strength. Thus the longest lists contained the 15 most common associates for a lure, the second longest lists contained the 12 most common associates for a lure, and so on. **The 24 lists were presented in the same predetermined random order for all participants.** For counterbalancing purposes the DRM lists were split into 4 groups of 6 lists by random number generator, and each group of lists was presented at the same list length. This was rotated on a participant by participant basis by Latin Square. Each participant was presented with each list at only one of the possible list lengths. Each word was presented individually on the screen for a duration of 2 seconds, and controlled by the computer's internal clock. At the end of each list, the participant was given 40 seconds to complete 4 simple mental arithmetic sums as a distractor task. The participant was then given up to 90 seconds to recall as many words as possible from the previous word list. This procedure was followed for each of the 24 word lists.

Results

The number of words correctly recalled by each participant for a list of a given length was converted to a proportion of the number of words that were presented. Thus, recalling 5 words from a 6 item list was scored as 0.83; recalling 5 items from a 15 item list scored 0.33. The number of lures reported by each participant was also converted to a proportion prior to analysis. In the case of false recall the proportion represented the number of lures recalled for lists of a given length divided by 6 (because participants saw 6 lists of each length during the study).

The mean proportion correctly recalled, and the mean proportion of lures incorrectly reported, are presented in Table 1, separated by list length and age group. Standard deviations are also included. Correct recall scores decreased as list length increases while false recall increased with list length. Older adults reported a greater number of lures than younger adults. They also recalled fewer words correctly than did younger participants.

[Table 1 about here]

Veridical Recall

A 2 (age) x 4 (list length) mixed ANOVA was computed with proportion of words correctly recalled entered as the dependent variable. Mauchly's test determined that the assumption of sphericity was violated in the current dataset, and hence a Greenhouse-Geisser correction was applied at $\varepsilon = .729$. The ANOVA revealed a significant main effect of list length [$F(3, 162) = 261.212$, $MSe = .004$, $p < .001$, $\eta p^2 = .829$]. Post hoc t-tests with a Bonferroni correction applied ($\alpha/6$) determined that recall proportions were significantly different for each consecutive pair of list lengths, with six item lists eliciting significantly better recall than nine item lists, nine item lists outscoring twelve item lists, and with the recall of fifteen item lists dropping further still (all $p < .001$). A significant effect of age group was also exhibited [$F(1, 54) = 129.995$, $MSe = .017$, $p < .001$, $\eta p^2 = .707$] such that correct recall was significantly poorer in the older participants than in their younger counterparts. The age x list length interaction was non-significant.

False Recall

A second 2 (age) x 4 (list length) mixed ANOVA was computed with proportion of lures falsely recalled as the dependent variable. Again, a sphericity violation necessitated the application of a Greenhouse-Geisser correction ($\varepsilon = .832$). It was determined that the proportion of false recall was significantly affected by list length [$F(3, 162) = 63.580$, MSe

= .057, $p < .001$, $\eta p^2 = .541$]. Bonferroni corrected post hoc tests revealed that false recall rates increased significantly in each consecutive list length (six items = .14; nine = .37; twelve = .53; fifteen = .69; all $p < 0.005$). A significant main effect of age was also observed [$F(1, 54) = 60.947$, MSe = .064, $p < .001$, $\eta p^2 = .530$]. Older participants were significantly more likely to report the non-presented lures than younger participants. A significant interaction was also found between list length and age [$F(3, 162) = 4.865$, MSe = .057, $p < .005$, $\eta p^2 = .083$]. The interaction is depicted in Figure 1 below.

The interaction was explored formally by computing separate one-way repeated measures ANOVAs to assess the effect of list length on the responses of participants within each age group. Both of these ANOVAs showed significant main effects of list length on false recall scores [young group $F(3, 81) = 27.299$, MSe = .054, $p < .001$, $\eta p^2 = .503$; older group $F(3, 81) = 38.290$, MSe = .100, $p < .001$, $\eta p^2 = .586$]. The young group reported significantly fewer lures in six item lists (.10) than in nine item lists (.22; $p < .001$), and significantly fewer lures in twelve item lists (.35) than in fifteen item lists (.54; $p < .001$). There was no significant difference between nine and twelve item lists ($p > .1$). In contrast, the healthy ageing group reported significantly fewer lures in six item lists (.18) than nine item lists (.52; $p < .001$), with a further significant increase from nine to twelve item lists (.72, $p < .001$). The proportion of lures recalled among fifteen item lists (.83) was not significantly greater than in twelve item lists ($p > .1$). Bonferroni corrected independent t-tests also revealed that significantly greater proportions of lures were recalled by older adults at nine, twelve and fifteen item list lengths ($p < .001$ in each case) but that there was no significant difference in false recall for six item lists ($p > .1$).

[Figure 1 about here]

Figure 1 - Proportion of lures falsely reported by participants in each age group as a function of list length. Error bars show 95% confidence intervals.

Finally, we performed correlation analyses comparing the level of veridical recall and the number of lures falsely reported for each age group. It was determined that there

was no significant relationship between these measures for either the older adults [r(26) = .035, p = .859] or the younger adults [r(26) = .081, p = .683]. In our view, this indicates that there are separate processes that underpin the effect of list length on veridical and false recall. We return to this in the discussion.

Discussion

The current study aimed to adjudicate between two prevailing theories of cognitive ageing - specifically the Inhibitory Deficit Hypothesis (Hasher & Zacks, 1988) and the Transmission Deficit Hypothesis (Burke & MacKay, 1997) - by using the DRM paradigm (Deese, 1959; Roediger & McDermott, 1995). The findings of the study can be summarised as follows. Firstly, the proportion of words correctly recalled decreased with increasing list length. Secondly, the proportion of lures incorrectly recalled increased as list length increased. Third, the performance of a group of healthy ageing participants was significantly poorer than for a group of undergraduate participants, in that they recalled a) fewer correct words and b) a greater proportion of lures. In our view, this pattern of results is best accommodated by the Inhibitory Deficit Hypothesis as we shall explain below.

Our findings relating to list length precisely mirror the effects reported by Robinson and Roediger (1997) for both the veridical recall and the false recall of lures. With regard to the increase in reporting "lures," Robinson and Roediger argued that this pattern was a consequence of spreading activation in semantic networks. To reiterate from the introduction, each word in a particular list partially activates the node representing the lure in memory. If, over the course of a list, the amount of activation accrued is sufficient it is as if the lure was actually presented. The likelihood of the threshold being reached is greater when a larger number of words are presented, because there are more opportunities for the lure to be activated. It is also more likely that the threshold will be reached if the spread of activation through the network is not inhibited appropriately - a greater amount of activation will be passed on by each individual word in the list. By this reasoning, participants who have inhibitory deficits will recall a greater proportion of lures at a given list length, just as our healthy ageing group did in the current study. This is exactly as predicted by the Inhibitory

Deficit Hypothesis (Hasher & Zacks, 1988), but is not easy to reconcile with the Transmission Deficit Hypothesis (Burke & MacKay, 1997).

The finding that the performance of the healthy ageing group was significantly poorer than the undergraduate participants replicates the pattern reported by previous research (Balota et al., 1999; Norman & Schacter, 1997; Tun et al., 1998). Tun et al (1998) posited that older adults are more likely to rely on gist-based processing, and hence weight the activation of specific list items lower when completing the task. We argue that this explanation does not accommodate the findings related to the manipulation of list length in the current study. If the healthy ageing participants are extracting the general "theme" of a list and using that information as a method by which to make their responses, then (as observed here) false recall proportions may well increase as the list length increases, and the search area is better defined. For example, in a 6 item list containing the words FAST, LETHARGIC, STOP, LISTLESS, SNAIL, CAUTIOUS it is not necessarily obvious that the overarching theme of the list is "slow." Once a further 9 related words have been presented, it becomes easier to identify that "slow" is the linking concept. However, a gist-based strategy would also potentially increase the level of veridical recall in long versus short lists - a larger number of words related to the gist of the list will be included in the scoring responses, and hence there is a greater likelihood that a guess will be correct. This pattern was not observed in our data. **It would also be likely that gist-based processing would lead to a tendency for those older adult participants who recalled more lures to also recall more of the words from the studied lists, as described above. We observed no such correlation between veridical and false memory scores in our participants.** Our explanations for the memory performance of the healthy ageing group in this study are more closely allied with those of Balota et al (1999). These authors argued that false memory recall is a result of a deficit in an attentional control mechanism (their explanation of this mechanism specifically implicated inhibition as a key factor). Again, the pattern of false recall seems to fit with the pattern that would be expected by the Inhibitory Deficit Hypothesis.

The manipulation of list length in the current study has provided some additional evidence for the influence of inhibitory deficits in false memory elicitation. At the shortest list length, there were no significant differences between age groups in the number of lures reported. It is likely that this is because a 6-item list does not afford sufficient opportunity for the lure to accumulate activation that spreads from the presented words. When the lists included 9 words, there was a significant increase in the proportion of false lures recalled by both the young and the older adults. The increase was sharper among the older adult group, such that now their false recall scores were significantly higher than their younger counterparts. The same pattern continued in the 12 item lists - a greater increase in false memory elicitation for older adults. We argue that this is a good indication that the inhibition of activation across the semantic network is less efficient in the older adults. Longer lists offer more opportunity for activation to be passed from the presented items to the critical lure, and each word in the list appears to have a greater influence on the likelihood that the lure is recalled for older adults.

Previous discussions of the DRM paradigm have suggested various mechanisms by which false memory effects could occur, and although the precise nature of these mechanisms has been contentious, the general principle is that there are two processes which work in tandem. Arndt and Gould (2006) refer to these as an error-inflating process and an error-editing process. Error-inflating processes are those that serve to increase the likelihood that a false memory is elicited. In the context of the experiment we have reported here, the error-inflating process is the spread of activation from the presented words to the non-presented lure (as suggested previously by Roediger, Watson, McDermott & Gallo, 2001). Varying the list length has its impact on the overall activation accrued by the lure, and hence is an influence on error-inflating processes. This mechanism, we suggest, is common to participants of both age groups and hence explains the main effect of list length we have observed. The number of false memories that are actually elicited is reduced by the action of error-editing processes. In Roediger et al's (2001) framework, the error-editing process is referred to as "monitoring." This process involves the examination of memory traces for specific items. The lure, of course, will not have had a specific encoding as part of the studied list, and hence this monitoring procedure will trigger inhibitory processes that prevent lures from being incorrectly reported. In relation to the current study, we argue that the deficits in inhibition that are argued to be a consequence of cognitive ageing by the Inhibitory Deficit Hypothesis affect this error-editing process in older, but not younger, adults. In this way, the main effect of age group that we have observed reflects a

difference in error-editing processes. The interaction we observed in the false memory data goes further to suggest that error-inflating and error-editing processes are functioning equivalently in the two age groups we tested. Simply put, the increase in list length acts to increase the activation of the lure in both age groups but the error-editing inhibition process is not working as efficiently in older adults as it does in their younger counterparts. As a result, increasing list length is more likely to cause an increase in likelihood of reporting the lures for older versus younger adults, precisely as we have reported here. The non-significant correlations between veridical recall and false recall rates in younger and older adults seem to further indicate that the two measures reflect independent processes. It is worth noting that the weakening of intra-network connections that the Transmission Deficit Hypothesis emphasises in cognitive ageing would serve to influence error-inflating processes while having little impact on error-editing processes. Thus, for the Transmission Deficit Hypothesis to be supported, we argue that any age x list length interaction would have to reflect smaller difference between age groups at longer list lengths. Again, this is not in line with our observations.

We note that there are some potential caveats to our findings. The first is methodological. The DRM lists were originally created to include the 15 most commonly produced responses when each lure was presented as a cue for a word association task. However, this has implications for the use of these lists in studies of cognitive ageing. It has been consistently demonstrated that the word association patterns of young and older adults differ (Fitzpatrick, Playfoot, Wray & Wright, 2013; Hirsh & Tree, 2001; Tresselt & Mayzner, 1964). For example, Tresselt and Mayzner (1964) reported that 80% of participants aged between 18 and 33 offered "white" as a response to the cue BLACK, whereas only 61% of the participants in the 50-87 year old bracket responded in the same way. As a consequence, it may be that the strength of the associations between the words presented in the lists and the lure was not matched across age groups. That said, if the links between words is weaker among the older adults (as seems to be the case in published word association studies), then it would mean that each of the presented words would pass less activation to the lure for these participants than for the younger adults. This would require that a larger number of words would be required before the criterion level of activation was accrued by the lure, and a lower proportion of false recall in older than younger adults. This is not the pattern we observed.

Nevertheless, it would be worth considering this variable in future studies in the area. Furthermore it is possible that there are differences between lists in terms of the overall semantic relatedness of the stimulus items. The list for MUSIC, for example, begins with *note, sound* and *piano.* These words not only relate to the lure, but also to each other quite closely. Less of a relationship is shared by the first words in the list for the FOOT lure (*shoe, hand* and *toe*). In this case it may be that the likelihood of recalling the lure is influenced by second-order relationships (*note* activates MUSIC; *sound* activates MUSIC and also *note,* which in turn activates MUSIC). This, in itself, is unlikely to differentially affect the performance of older versus younger adults, but may disguise the true nature of false memory elicitation. **It is also the case that the method we used to shorten the DRM lists (and the method that was used by Robinson & Roediger, 1997) deletes the words that are the least associated with the lure. In doing so, it is likely that the overall sense of the list does not change much at longer list lengths, but the number of words that are presented increases the burden on memory processes in and of itself. It would therefore be useful, in future, to attempt to determine whether the false memory effects are caused by memory load or by associative strength by either a) contrasting the effects of reducing list length by deleting words from the top versus the bottom of the DRM list or b) by manipulating the overall associative strength of the words in the list rather than the absolute number of words presented.**

We also note that the research using the false memory paradigm does not allow for the locus of the false memory elicitation to be determined. It might be that the words in the list activate the lure sufficiently that the participant is fooled into thinking that it was presented, and hence their reporting of the lure is an accurate retrieval of an inappropriately encoded word. It might also be that the words that the participant produces during the recall phase activate the lure at this stage. Under those circumstances, the list has been encoded accurately, but lures are added by spreading activation during retrieval. Determining which of these memory processes are working incorrectly may be of importance for cognitive ageing theory, and have applications for cognitive training programmes designed to maintain memory function into old age. One way to adjudicate between these possibilities might be to capitalise on the perceptual interference effect (e.g. Mulligan, 1996; 2000). The perceptual interference effect refers to the finding that memory for words that are briefly presented, and then obscured by a backward mask, is better than for words that do not get masked. It has been argued that perceptual interference improves item-specific encoding, but restricts participants in performing relational processing. We have argued, as did Robinson and Roediger (1997) that the elicitation of false memories in the current task relies upon the relationship between the words in the list and the lure. Masking the words in the list should reduce the processing of these relationships, hence preventing the lure from being activated during encoding. If the proportion of lures recalled is the equivalent with and without interference at encoding, then it is likely that inhibition during retrieval is the cause of the incorrect recall.

In summary, we have demonstrated that longer lists increase the likelihood that a lure is retrieved even though it was not presented and that older adults are more susceptible to false memories than are younger adults. Further, we have shown that this difference is likely to be driven by a failure to efficiently inhibit the activation that spreads across lexical networks. Our findings, therefore, offer support for the Inhibitory Deficit Hypothesis (Hasher & Zacks, 1988) and pose a challenge to the Transmission Deficit Hypothesis (Burke & MacKay, 1997).

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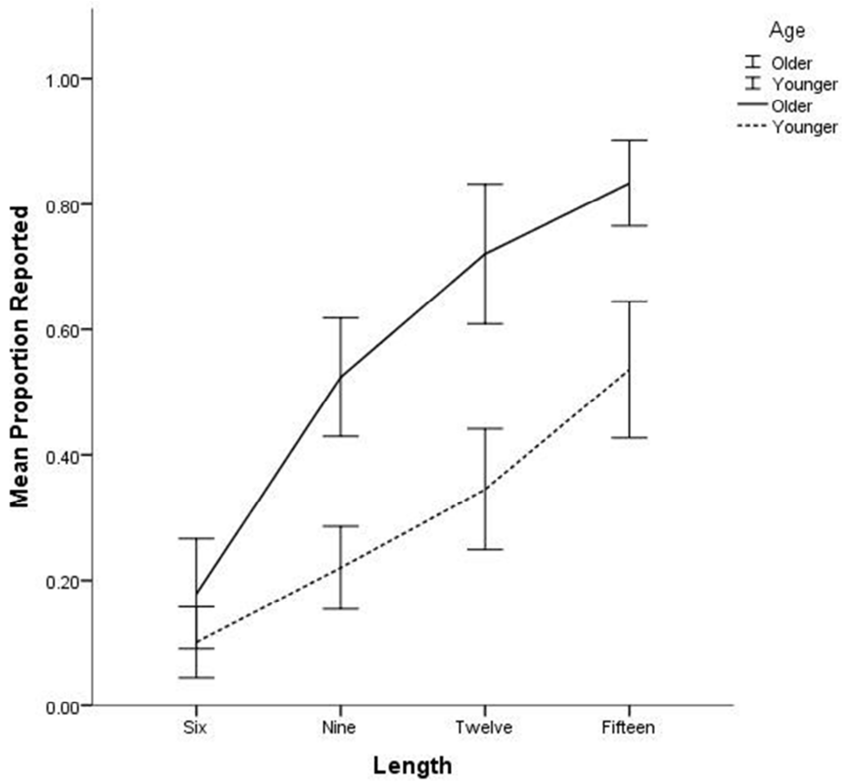
Table 1 - Mean and standard deviation statistics for the proportion of words recalled correctly, and proportion of lures reported, for each list length in each age group.

		Student		Healthy ageing	
		Mean	**SD**	**Mean**	**SD**
Veridical	**Six**	0.73	0.11	0.52	0.09
	Nine	0.59	0.08	0.38	0.07
	Twelve	0.51	0.09	0.31	0.04
	Fifteen	0.46	0.08	0.28	0.04
Lures	**Six**	0.10	0.15	0.18	0.23
	Nine	0.22	0.17	0.52	0.24
	Twelve	0.35	0.25	0.72	0.29
	Fifteen	0.54	0.28	0.83	0.18



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