The Role of Domain-General and Mentalizing Processes in Spontaneous Visual Perspective-Taking

Gabriele Pesimena

A thesis submitted in partial fulfilment of the requirements of
Sheffield Hallam University
for the degree of Doctor of Philosophy

November 2022

I hereby declare that:

1. I have not been enrolled for another award of the University, or other academic or professional organisation, whilst undertaking my research degree.
2. None of the material contained in the thesis has been used in any other submission for an academic award
3. I am aware of and understand the University's policy on plagiarism and certify that this thesis is my own work. The use of all published or other sources of material consulted have been properly and fully acknowledged.
4. The work undertaken towards the thesis has been conducted in accordance with the SHU Principles of Integrity in Research and the SHU Research Ethics Policy.
5. The word count of the thesis is ...37394.

Please complete electronically:

Name	Gabriele Pesimena
Award	11/11/22
Date of Submission	11/11/22
Faculty	College of Social Sciences and Arts
Director(s) of Studies	Dr Alessandro Soranzo

Acknowledgements

First I want to thank my supervisory team and especially my Director of Study, Dr. Alessandro Soranzo, for his support and guidance throughout this PhD. Your investment in my personal development has provided me with invaluable skills and knowledge. In addition, I would like to acknowledge the Centre for Behavioural Science and Applied Psychology at Sheffield Hallam University's CEBSAP for funding this research. I would also like to thank my fellow PhD students group, in particular Rosie and Sarah. I have been lucky to share this path with such a supportive and wonderful group of people; creating memories and friendships that I will cherish for a long time. Thank you also to Jordan and Lee for their continuous help with the labs and the chats during coffee breaks. Lastly, I would like to thank my friends who have supported me and were often "forced" to hear my rants. My biggest thanks go to Inma, this could not have been possible without your presence, support, and patience. Thanks for always being there during my struggles, for coping with my mood swings and for always believing in me. Lastly, I would like to end by thanking my family, my father, my mother and my brother Antonio, thanks for your unconditional support during this journey. In spite of all difficulties, you are always there when I need you. I couldn't have asked for anything more.

Abstract

We cannot help but be influenced by the presence of others. Even when the others are not actively engaging with us, their mere view interferes with our focus hindering our actions or tasks. Two accounts have advanced an explanation of the processes underlying this interference effect. On one hand, this interference has been explained in terms of the implicit mentalizing process, a social process, thanks to which people can fast and unconsciously process others' visual perspectives. On the other hand, a second interpretation, known as sub-mentalizing, explains the interference by means of low-level domain-general cognitive processes such as involuntary attentional orienting driven by the other's directional features. By employing for the first time a set of bi-directional cues, it was possible to isolate the social features of the others and measure their relative contribution in generating this interference effect. The results of a series of experiments suggested that both mentalizing and low-level domain-general processes may be behind this phenomenon laying the basis of a novel interpretative model of the interference effect which provides a comprehensive framework for understanding this phenomenon. The novel model encompasses both interpretations by comprising two fast involuntary processes: an automatic attentional orienting process driven by the directional features of others; and a spontaneous mentalizing process driven by the social relevance and intentionality of others. The model also includes a voluntary decisional response selection process that modulates the interference depending on task demands and working memory resources.

Author's Note

The work presented in chapter 4 of this thesis has been previously published in Pesimena & Soranzo (2022). The methods section of the different experiments and the results' reporting style closely resemble the ones in Pesimena & Soranzo (2022). This aimed at improving the ease of reading for the reader by ensuring consistency across experiments. Furthermore, although it has been restructured, some sections of the introductions and general discussions have been informed by Pesimena et al. (2019). The content of the published material has been reproduced here with the permission of all authors. Preparation, execution, data analysis and interpretation of the published material are entirely my own work. All authors contributed to the editing of the published materials. This thesis followed the oxforddown template for R Markdown (Lyngs, 2019).

Contents

List of Figures

List of Tables

List of Abbreviations

DPT . . . . . . Dot Perspective Task.

RAS . . . . . . Reflexive Attentional Shift.

VPT . . . . . . Visual Perspective Taking.

VPT-1 . . . . . Level 1 Visual Perspective Taking.

VPT-2 . . . . . Level 2 Visual Perspective Taking.

SOA . . . . . . Stimulus onset asynchrony.

RTs . . . . . . Reaction Times.

ToM . . . . . . Theory of mind.

fMRI . . . . . Functional Magnetic Resonance Imaging.

ASD . . . . . . Autism spectrum disorders.

AL . . . . Anticipatory looking false belief tasks.

OSF . . . . . . Open Science Framework.

HDI . . . . . . Highest Density Interval.

ROPE . . . . . Region of practical equivalence.

lm . . . . Linear models.

SBF . . . . . . Sequential Bayes Factors.

BF . . . . Bayesian Factors.

ROMP . . . . Room Observer and Mirror Perspective test.

1 Introduction

1.1 Overview

People cannot help being affected by what others see. Several studies have demonstrated that human attention is profoundly affected by the presence of others, even when we are focused on our own actions and goals (Kampis & Southgate, 2020). For example, people instinctively and involuntarily mimic the gestures, stances, and facial expressions of others while watching them and better recall stimuli when these are relevant to the other person (Chartrand & Bargh, 1999; Dimberg et al., 2000). Similarly, the simple presence of another in the visual scene can cause people to spontaneously take into consideration the other's perspective, even when this is not relevant to their behaviour. In other words, the presence of a person facing another direction interferes with our focus hindering our actions or tasks. Whilst there is a general agreement on the processes underlying this interference effect when it is generated by directional cues, a fascinating case is when the cues have social relevance (e.g., another person). Taking into consideration the notion of Theory of Mind (Premack & Woodruff, 1978, ToM), it has been suggested that this interference effect is the result of Visual Perspective Taking processes (VPT; hence the title of this thesis). VPT is defined as the ability to take someone else perspective and understand how and what someone else sees (Flavell, 1977). To experimentally investigate VPT abilities, Samson et al. (2010) developed a paradigm known as the Dot Perspective Task (DPT). The task is an attention paradigm which employs behavioural measures such as Reaction Times (RTs) and error rates and assesses how the interference generated by the presence of others in the visual scene affects participants' judgement. Samson et al. (2010) argued that the interference effect shown in the DPT was due to an implicit mentalizing process that they called *Spontaneous Visual Perspective Taking*. According to the authors, we spontaneously infer the mental state of the other people present in the visual scene while determining our own perspective. In other words, we are unable to stop ourselves from mentally inferring what we believe others are seeing, thus causing interference between the two perspectives. Since then, two main accounts —one that supports Samson et al. (2010)'s view and the other that disputes it — have emerged to explain the interference produced in the DPT. On the one hand, the mentalizing account, in agreement with Samson et al. (2010), explains this interference by suggesting that when evaluating our own perspective, we automatically infer the mental state of the other person present in the visual scene. (e.g., Capozzi et al., 2014; Furlanetto et al., 2016; Morgan et al., 2018; Nielsen et al., 2015). On the other hand, the domain-general account argues that this interference is brought on by the directional features of the other person, such as their posture and facial orientation, disputing the involvement of Theory of Mind (e.g., Cole et al., 2015; Cole & Millett, 2019; Heyes, 2014; Langton, 2018; Wilson et al., 2017). The discussion is still ongoing with neither of the two sides able to fully rule out the other. Understanding the processes underlying the interference generated by the presence of others in the visual scene is important because VPT is thought to be crucial in both collaborative and competitive social situations. Evidence in favour of the mentalizing account and *Spontaneous Visual Perspective Taking* may demonstrate the existence of innate and difficult-to-inhibit special processes used to automatically process social relevant cues. Thus, VPT may be rooted in implicit cognitive processes and affected by social biases, such as intergroup attitude and shared group membership like implicit racial attitudes and androcentrism [1] (Lieberman et al., 2002; Simpson & Todd, 2017). On the contrary, evidence in favour of the domain-general account would exclude such processes and attribute this interference effect only to a reflexive attentional shift (RAS) elicited by the saliency of the directional information provided by the other present in the visual scene.

By using an innovative methodology involving original stimuli, and through a series of experiments developed in order to overcome previous studies' limitations and shortcomings, this thesis aims to shed light on the cognitive processes underlying this interference effect, providing the first cognitive model, which would explain the different processes underpinning this phenomenon.

The following sections present and discuss the notions at the base of the processes that may underline this phenomenon. The first paragraph introduces the concept of spatial visual attention, its underlying mechanism and the different ways in which attention is deployed and directed towards the target stimulus. The Posner's spatial cueing paradigm (Posner & Coehn, 1984), which shows that the presence of cues in a scene directs our attention, is also introduced in this paragraph. Gaze cueing is then presented, this refers to the shift of attention induced by the

[1] The tendency to view men as prototypical exemplars and women as non-prototypical exemplars of a given social group.

perceived gaze's direction which is often associated with ToM and mentalizing processes. This is then followed by an overview of the notion of ToM, how this notion became popular and its relationship with visuospatial and social information by means of Visual Perspective Taking, the ability to view the world from the viewpoint of another person, accounting for what (Level-1 VPT or VPT-1) and how (Level-2 VPT or VPT-2) they perceive it. The focus of the introduction is then shifted towards Spontaneous VPT-1 which is thought to arise implicitly and spontaneously as a result of an implicit mentalizing process. Pieces of evidence in favour and against this interpretation are advanced. In particular, the sub-mentalizing hypothesis states that in behavioural tasks (such as the DPT) employed to assess VPT-1, people are not engaging in VPT, but are rather employing attentional domain-general processes. This dichotomization lays the foundations of the discussion around the interference effect generated by the presence of the other in the visual scene. To this end, the subsequent paragraph introduces the reader to a detailed description of the DPT and of the status of the literature, including different studies supporting either the mentalizing or the domain-general account. Moreover, this paragraph introduces a range of studies which investigated whether inconsistent results present in the literature were due to specific characteristics of the DPT. The introduction then concludes by introducing the reasoning behind the creation of different novel cues employed across this thesis' experiments. These innovative cues are advanced for the first time in literature in this thesis and provide the means to assess the relative contribution of social and domain-general processes in generating this interference effect. Succeeding the introduction chapter, the general methods chapter presents the experimental approach employed across the different experiments included in this thesis. Here the novel methodology is presented to the reader before introducing the individual experimental chapters.

Specifically, the statistical approach, experimental procedure and sample plan. A general discussion follows then the experimental chapters. The purpose of this thesis, its research topics, and a literature review are all discussed in this chapter as well as suggestions for future research. It is then followed by a broad discussion that ties together the individual findings of each experiment, and lastly, presents a model that seeks to explain the different cognitive processes at the base of this interference effect.

1.2 Visual attention

Visual attention enables us to prioritize and selectively process the information that is located at a specific place (Carrasco, 2018). Our visual world presents us with a vast amount of information every time we open our eyes. However, we seem to comprehend it with ease. To understand a scene, we must detect, localize, and identify relevant information. This is clearly visible in a range of different situations. For example, as we drive, we direct our attention to the incoming traffic, informational signs, or the onset of dangerous stimuli such as a pedestrian suddenly crossing the road. In a more specific context, footballers quickly "scan" the fields and direct their attention towards their team-mates and their opponents, whilst at the same time easily ignoring external stimuli, such as the booing of the crowd. This is accomplished by the mean of a range of selective processes known as visual attention. Visual attention allows people to identify and select the most relevant information to their current behaviour (Chun & Wolfe, 2001; Wolfe, 2021). We are not passive observers of the information that strikes our retina, but rather active participants in our perceptual processes. By means of a visual attentional process, we choose specific, spaces, objects, features or components of a visual scene to focus on and control subsequent behaviour, whilst ignoring other less relevant and salient aspects (Kanwisher & Wojciulik, 2000). This is known as visual attention. Without these attentional processes, we would be overloaded by the amount of perceived information because the environment presents significantly more perceptual information than can be efficiently processed at any given time. What we perceive through vision is therefore determined by what we attend to (Chun & Wolfe, 2001). Whilst we perceive our experience of the world as complete and continuous, our ability to process all aspects of accessible visual information is severely constrained. For example, in the change-blindness and inattentional literature, it has been shown that we can miss large stimuli of the visual scene such as a 5-foot-tall gorilla (Simons & Chabris, 1999). This demonstrates the tendency of our brain to selectively process a certain subset of the input received from our sensory organs, which is, in most cases, the most relevant information to our behavioural goals. Visual information is first encoded by neurons along numerous spatial and featural dimensions, it is transduced in the retina and then transmitted through the visual system, such that the neurons can signal the identity and location of a virtually limitless number of stimuli (Chun & Wolfe, 2001). It's therefore not unexpected that due to this constraint, the factors impacting visual attention and the mechanisms that determine the object of these "selection processes" are among the most frequently studied topics in current psychology. While in fact the term attention is often widely used to suggest a homogeneous process, attention research has shown many diverse features of attentional regulation, both in terms of neural processes and behaviour. For example, visual attentional has been compared to a spotlight (Posner, 1980), to a zoom lens (Eriksen & Yeh, 1985), or to a Gaussian gradient (Downing, 1985), which improves visual processing within a defined space region (Wegener et al., 2014). The discussion around which type of representation is carried out to select task-relevant important stimuli whilst disregarding less relevant one, still represent today one of the more controversial and fundamental debates related to visual attention. Three factors have been suggested to drive visual attention: objects, features and spatial locations. Consequently, these features give the name to the different types of attention: feature-based attention, object-based attention and spatial attention. Feature-based attention refers to the ability to selectively attend to specific visual features such as colour, orientation, motion, or texture, among others. Feature-based attention can enhance the attended feature's processing and suppress the unattended feature's processing. For instance, when searching for a red target among green distractors, feature-based attention enhances the processing of the red colour and suppresses the processing of the green colour (Galashan & Siemann, 2017). Object-based attention refers to the ability to selectively attend to a particular object or group of objects, regardless of their location in space. Object-based attention can enhance the processing of the attended object and suppress the processing of the unattended object, even when they are located in different spatial locations. For instance, when searching for a red triangle among blue triangles and red circles, object-based attention enhances the processing of the red triangle and suppresses the processing of the other objects, even if they are spatially separated (Chen, 2012). Whilst they may appear similar, one key difference between feature-based and object-based attention is the level of processing at which they operate. Feature-based attention operates at the level of individual features or attributes, such as colour, orientation, or motion direction. This type of attention is driven by bottom-up sensory input, in which salient features automatically capture attention. In contrast, object-based attention operates at a higher level of analysis, selectively attending to entire objects or groups of objects. This type of attention is often driven by top-down cognitive factors, such as the goals and expectations of the observer (Egly et al., 1994; Yantis et al., 2002; Yantis, 1996). Lastly, spatial attention, spatial attention refers to the ability to selectively attend to a particular location in space, regardless of the features or objects present at that location. Spatial attention can enhance the processing of the attended location and suppress the processing of the unattended location. For instance, when searching for a target in a cluttered scene, spatial attention enhances the processing of the location of the target and suppresses the processing of the other locations (Carrasco, 2011, 2018; Egeth & Yantis, 1997; Posner, 1980). Whilst these three types of attention theories each addresses a different aspect of attention and perception, a more recent theory of attention was advanced to provide a framework for understanding how multiple types of attentional processes interact and compete. This is known as the biased-competition theory (Duncan, 1996). According to the biased-competition theory, these stimuli in the visual field compete for the limited available cognitive resources (Duncan, 1996). When observers attend a specific location, this competition is biased in favour of the neurons encoding information at the attended location, resulting in greater resource allocation to the attended site at the expense of available resources at the unattended site. This would therefore explain why we often struggle to remember the details of visual stimuli that were not important to our behavioural goals (Beck & Kastner, 2009; Beck & Kastner, 2005; Duncan, 1996; Kastner et al., 2001, 1998; Pinsk et al., 2004). Because it expands and integrates the prior theories' insights into a more substantial and powerful framework, the biased-competition theory can be seen as a more complex and comprehensive model of attention than the others. This does not imply, however, that the earlier theories are no longer relevant or true; on the contrary, they continue to be used and researched by scholars in the field and offer useful insights into particular facets of attentional processing.

To summarize, visual attention enables us to increase efficiency in visual tasks while overcoming the visual system's restricted capability. It enhances the use of the system's scarce resources by strengthening representations of the relevant and decreasing representations of the less important, places or aspects of our visual world. The next paragraph will introduce the modality in which visual attention can be deployed and allocated.

1.2.1 Visuospatial shift of attention.

Visual attention can be allocated either covertly or overtly. Covert attention refers to the ability to selectively attend to a particular location or feature of a stimulus without moving our eyes or our head. This type of attention can be voluntarily directed to a specific location or automatically captured by salient stimuli in the environment. Posner et al. (1980) showed how covert attention could facilitate the detection of a target stimulus at the cued location. Overt attention, on the other hand, involves directing the eyes or head towards a particular location or object. This type of attention allows for more precise and detailed processing of visual information in the attended location, and it can be influenced by both top-down (voluntary) and bottom-up (involuntary) factors (Kowler, 2011). A general consensus has been established in the literature on the role of the two types of attention and on how the two are deployed (Carrasco, 2011; Nakayama & Martini, 2011). People deploy covert attention in a variety of everyday circumstances, including searching for items, driving, participating in sports, etc. Covert attention allows us to examine our surroundings and subsequently directs our eye movements (overt attention) to areas of the visual field containing salient and/or important information (Carrasco, 2011). in addition to establishing a distinction between covert and overt shifts of attention, the literature frequently distinguishes between reflexive, externally driven (exogenous) and voluntary (endogenous) shifts of attention. These were initially described by James et al. (1890). Both covert and overt shift of attention can be reflexive or voluntary. For example, a reflexive eye movement in reaction to a quickly moving item that appeared in the outer reaches of the visual field would constitute an exogenous overt transfer of attention; The intentional decision to check both directions before crossing a busy road, instead, would indicate an endogenous overt shift of attention. (de Haan et al., 2008) It goes without saying that a covert shift of attention, either reflexive or voluntary would happen only when attention is shifted without moving our eyes or head (Posner, 1980). For both attention, while observers' expectations and intentions affect voluntary shifts, the reflexive attentional shift is driven by sensory stimulation and influenced mostly, but not only, by sudden and salient changes in the visual field. These changes can include sudden movements, loud noises, or bright lights. This is primarily due to the abrupt onset of stimuli, which elicit reorienting and saccadic eye movements (Driver et al., 1999; Posner, 1980). Exogenous (or Reflexive) attention is often referred to as 'transient' attention, whereas endogenous attention is referred to as sustained attention. The temporal aspect of each form of attention is explained by these terms: endogenous attention takes roughly 300 milliseconds to engage. Whereas observers appear to be able to maintain voluntary attention at a specific area for as long as it is required to complete a task, reflexive attention is transient, meaning it rises and falls fast, peaking at roughly 100–120 ms (Carrasco et al., 2008; Cheal et al., 1991; Liu et al., 2007). Evidence of the existence of different types of attention has been shown in a different number of seminal studies such as Briand & Klein (1987), Egeth & Yantis (1997), Posner (1980); Posner & Coehn (1984), Yantis (1996) and many more. The Posner's spatial cueing task

(Posner, 1980; Posner et al., 1980, Figure 1.1) represents one of the most popular paradigms for eliciting, assessing, and conceptually defining attentional orienting. This paradigm allows the experimenters to compare participants' performances in conditions in which attention can be experimentally manipulated.

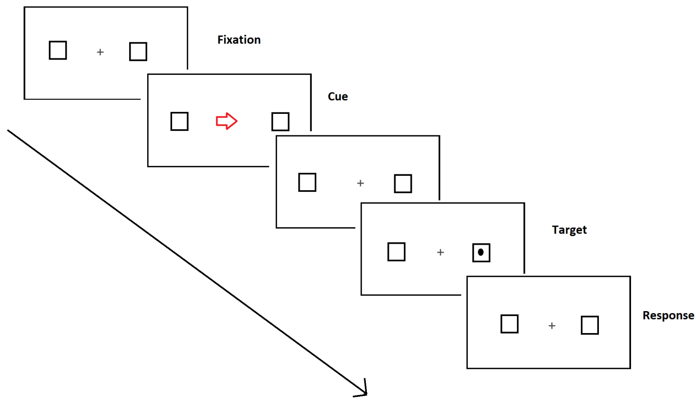


Figure 1.1: An example of a trial of the spatial cueing paradigm developed by Posner (1980). The central cue, in this case, an arrow, orients participants' attention towards either the left or the right side. At this point a target is presented to the participants. Participants have to press a key when the target appears on the screen. We are generally faster when the arrow is pointing towards the location in which the target will appear than when is pointing in the opposite direction.

In this task, participants are presented with a cue whose role is to direct participants' attention towards a specific direction. This is then followed by a target stimulus to which they have to respond as quickly as possible. Thanks to the use of a cue, it makes it possible to compare the effects of attention directed to one specific location (attended or endogenous condition), away from that location (unattended or exogenous condition) or distributed over the display (neutral or control condition). The cue is presented either centrally such as an informative central arrow pointing towards one of the possible stimulus locations; or peripherally uninformative cues such as a light beam appearing in one of the possible stimulus locations. The participants' performance in detecting the target is typically better (faster, more accurate or both) in trials in which the target appears at the cued location, this is usually known as cueing or validity effect. When the employed cue is non-predictive and peripheral, this effect is attributed to the reflexive orienting of spatial attention (Friesen & Kingstone, 1998; Müller & Rabbitt, 1989; Stevens et al., 2008). The typical finding is that when the target appears at the cued location within 300 milliseconds of the cue, the response time (RT) to the target is faster, but after that time frame, RT at the cued location is slower than at an uncued location. This phenomenon is known as inhibition of return (IOR).

When instead the employed cue is a central arrow, the validity effect was thought to be a consequence of volitional attention shift rather than a reflexive attentional shift. This is because the spatial effects of the central arrow were believed to occur only when the arrow is spatially predictive, and the observed attentional effects were attributed to volitional orienting of spatial attention (as noted in Jonides, 1981). In these instances, the typical result is that the reaction time (RT) to the target at the cued location is facilitated for all cue-target intervals that exceed 300 milliseconds, and there is no indication of inhibition of return (IOR) emerging. Thus, central non-predictive directional cues, such as arrows, were largely used to investigate endogenous (voluntary) shifts of attention (Gabay et al., 2012).

However, recent research suggests that arrows and other central spatially non-predictive directional stimuli can generate reflexive shifts in attention (Gabay et al., 2012; Pratt & Hommel, 2003; Ristic & Kingstone, 2006). Ristic & Kingstone (2006) showed that whilst a predictive centrally presented arrow generates a greater attentional shift than an unpredictive one, the latter is still able to generate an attentional shift. The authors, therefore, suggested that suggest that the orienting effect of a predictive arrow reflects an interaction between reflexive and volitional attention. Similarly, some researchers have proposed that the direction of one's gaze can trigger an involuntary shift of attention (Friesen & Kingstone, 1998; Kingstone et al., 2000). As these cues were not indicative of the target's position but still managed to shift attention, it was suggested that they elicit reflexive orienting.

For the aim of this thesis from now on, we will refer only to the exogenous attention. As it will be seen in the subsequent paragraphs, the reflexive (exogenous) attentional shift generated by the presence of a stimulus in the visual scene is at the centre of the discussion in this thesis. The following paragraphs will introduce different notions that are at the base of the different interpretations of the interference effect in the paradigm known as the Dot Perspective Task (DPT).

1.2.2 Gaze cueing

Building on Posner's spatial cueing paradigm, a surge in researchers' interest focused on defining the underlying processes that underpin gaze cueing of attention (Frischen et al., 2007). This phenomenon refers to the shift of attention elicited by the perceived direction of someone's gaze. This phenomenon plays a vital role in social interactions as people's eyes may convey a large amount of information about intentions and mental states. Different interpretations of gaze cueing have been advanced over the years. Baron-Cohen (1997a) suggested that, due to the adaptive social importance of detecting eye gazes in early life, there is a specialised module within the human brain that detects eye gazes. This is known as the "Eye Direction Detector", and according to the author is an evolutionary mechanism that we share with other primates. The presence of this module is often supported by studies that involve infants (Farroni et al., 2003) and by the infant's ability to detect, follow and act upon other humans' faces and eye movements. However, behavioural data from newborns also points to a more domain-general mechanism that responds to lateral motion of stimuli regardless of whether eyes are engaged (Farroni et al., 2000). Similarly to infants, the nature of the processes underlying gaze cueing in adults is still discussed. On one side, Driver et al. (1999), Langton & Bruce (1999) and Hietanen et al. (2008) have proposed that the perception of eye gazes may be unique and qualitatively distinct from the perception of other directional cues such as an arrow. Thus, their ability to reflexively and immediately elicit a shift of attention may be due to a unique and distinct neural mechanism which relays on the social nature of human interactions (Massaro & Friedman, 1990). On the other side, Ristic et al. (2002) and Tipples (2002) proposed instead, that the eye gaze is not unique in automatically eliciting orienting of attention, and that whilst eye gazing and directional cues (e.g., arrows) may be subserved by different brain systems, their attentional mechanism may still be similar. The former interpretation becomes extremely important whilst investigating the interference effect generated by a cue with social relevance. As a result of the social nature of the cue, if the attentional shift is due to the association of the gaze with the intention of the cue of looking at a specific spot, it would mean that this may be therefore mediated by specific ToM mechanisms and possibly a direct consequence of VPT. The encoding of other's gazes would allow people to access others' mental states, allowing them to predict their perspective and future behaviour (Baron-Cohen et al., 1997; Calder et al., 2002; Massaro & Friedman, 1990).

1.3 Theory of Mind

1.3.1 Overview

Theory of Mind (ToM), also known as mentalizing, can be defined as the ability to infer mental states such as beliefs and intentions to others in order to interpret, explain and predict the behaviour of others (Premack & Woodruff, 1978). This definition was first introduced by Premack and Woodruff in a seminal paper in which the ability of chimpanzees to attribute knowledge to others was investigated. Although Premack and Woodruff were specifically interested in studying the chimpanzees, their idea quickly became applied to humans, in particular, to children (Wimmer, 1983). Beliefs, desires, and knowledge are the key concepts of ToM. These form a coherent set of interrelated notions that help the subjects in explaining, predicting, and justifying others' behaviours (Apperly, 2012). This set of notions is vital for social interaction and communication (Sperber & Wilson, 1986), and its impairment may be part of the explanation for a variety of psychiatric and developmental disorders. Since Premack & Woodruff (1978)'s study in which ToM was first introduced, the concept of ToM has been largely investigated across different fields and contexts such as autism, schizophrenia, depression and anxiety (Baron-Cohen, 1997b; Berecz et al., 2016; Frith, 2005) but also differences within human infants and non-human species (Horowitz, 2011).

A vast part of the study around ToM aims to investigate when humans develop this "ability." In particular, most studies have investigated children's knowledge of the aforementioned mental states. In order to investigate children's knowledge about other's beliefs, Wimmer (1983) proposed a new experimental paradigm, known today as the false-belief paradigm[2] (VandenBos, 2015), which tests the ability to predict another person's behaviour on the base of their false belief. In this paradigm, a person places an object in a box (e.g., a blue box) before leaving the room and the box unattended. A second person moves then the object to a second box (e.g., a red box). At this point, the first person returns, and participants are asked where the first person would look for the object. The answer would clearly be in the first box (blue box). A series of findings showed however that children under 4 years old are not capable of understanding the scenario and therefore are not able to answer this easy question. This has often been interpreted as a lack of

[2]The reader may find in literature other names for this paradigm, such as unexpected-transfer test.

"Theory of Mind" in children under 4 years old. That is, they are unaware that individuals think and behave in line with how they cognitively depict the world rather than how the world actually is. As a result, young toddlers do not grasp that individuals might think something else to be true and act according to a different mental state representation that does not correspond to reality; thus, resulting in a false belief (Apperly & Butterfill, 2009; Baron-Cohen et al., 1985; Wimmer, 1983). Just like the pre-schooler children in these experiments, people without this ability will have difficulty understanding social interactions (Happé & Frith, 1995). ToM would make in fact easier to understand others' emotional states and behaviour. It is clear then that ToM plays an important role in social interaction and communication. It is not surprising therefore that a vast number of studies investigated ToM and its relationship with different cognitive processes. Among these, this thesis will focus on the relationship between Theory of Mind, visual attention, and its interference effect. It has been suggested that ToM is involved in what is known as *Spontaneous Visual Perspective Taking*, a cognitive mechanism that may be at the base of the interference effect phenomenon shown in the Dot Perspective Task. The next paragraph will describe the two components of VPT.

1.3.2 Level 1 and Level 2 Visual Perspective Taking

According to Flavell and his colleagues (Flavell, 1977; Flavell et al., 1986; Flavell, 1999), there are at least two different levels of knowledge about others' visual perception. The wider accepted theory about Visual Perspective Taking is that the ability to grasp another's visuospatial perspective is divided into two distinct levels: Level-1 Visual Perspective Taking (VPT-1) and Level-2 Visual Perspective Taking (VPT-2). The former (VPT-1) answers the question "What is the other seeing?" and entails mentally adopting another person's spatial viewpoint and comprehending how the world is portrayed from their visual perspective. For example, in Figure 1.2 by employing VPT-1, the observer understands that the cat is not visible from the perspective of the other whilst the dog is. VPT-2 instead, answers the question “How does the other see something?” and in addition to representing the world from someone else point of view, involves understanding how the world is perceived from their perspective For example, in Figure 1.2, the observer can take into account how the dog is seen by the other, therefore taking in consideration and understanding its relative position and features in relation to the other present in the visual scene.

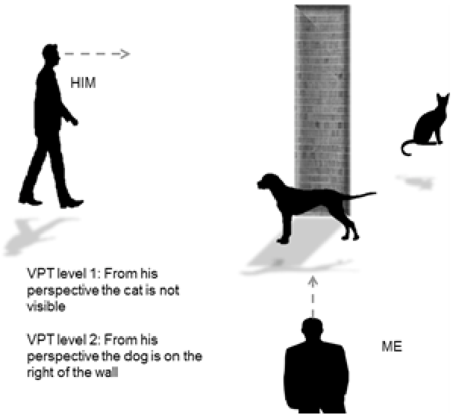


Figure 1.2: The two levels of VPT. In VPT-1 the observer understands that the cat is not visible from the perspective of the other present in the visual scene, whilst the dog is. In VPT-2, the observer can take into account how the dog is seen by the other. The dog is on the right of the wall from the other's perspective.

According to Flavell's studies and subsequent research, VPT-1 arises early in life, around age 2 and 3, with children in early development having no issues in understanding that another person may be seeing an object that it is not visible from their perspective (Frick et al., 2014; Kessler, 2010). On the contrary, there is no consensus on when VPT-2 arises, some authors state that it arises between ages 6 and 8 (Flavell et al., 1986; Masangkay et al., 1974) with others stating that it arises around ages 4 and 5 (Kessler, 2010). Regardless of this, children who did not develop VPT-2 are unable to understand how something is perceived from another's perspective. Interestingly, the mechanisms underlying the two levels of VPT become clear when children with autism spectrum disorders (ASD) and primates are taken into consideration. Whilst primates and children diagnosed with ASD do not experience difficulties with VPT-1 tasks, they often struggle with VPT-2 tasks[3] (Hamilton et al., 2009; Kessler, 2010). In particular, children with ASD do not develop VPT-2 (Hamilton et al., 2009), whilst primates seem capable of successfully completing only certain VPT-2 tasks (Tomasello et al., 2003,

[3]In general, adolescents with ASD and normal intelligence do as well as control participants in comparable false-belief tasks designed to probe VPT-2 tasks (Zimmermann et al., 2021).

2005). Over the years, different theories have been advanced in order to provide a clear distinction between VPT-1 and VPT-2. Among these, the most important for this thesis are the ones advanced by Surtees et al. (2013) and Samson et al. (2005). Surtees et al. (2013) suggested that the main difference between VPT-1 and VPT-2 is that the former process requires only visual information in form of a line of sight, whilst the latter, in addition to the visual information, requires an egocentric embodied transformation (i.e., the process of full transformation of our own viewpoint in the one of the other present in the visual scene, Pearson et al., 2013). Samson et al. (2010)'s interpretation is instead based on the nature of the two processes. According to the authors, VPT-1 can arise implicitly and spontaneously, as a consequence of an implicit mentalizing process; whilst VPT-2 would be due to a slower and voluntary explicit mentalizing process.

1.3.3 Mentalizing and Sub-Mentalizing

The view that humans are able to infer the mental state of other's is well known, largely accepted in literature and it is often said to be one of the cornerstones of efficient social interaction (Cole & Millett, 2019). New findings from the last 15 years, however, have challenged the notion that infants do not possess "Theory of Mind" (Poulin-Dubois & Yott, 2018; Tomasello, 2018; Wellman et al., 2001). These findings, which are reinvigorating the field, originated from implicit Theory of Mind tasks without direct oral instruction. The evidence from studies which employed these tasks indicates that basic forms of ToM and implicit mentalizing develop very early and therefore it should be possessed also by infants (Clements & Perner, 1994; He et al., 2012; Kovács et al., 2010; Southgate et al., 2007; Träuble et al., 2010). The largest body of evidence supporting the existence of the ability of humans to ascribe beliefs and mental states to others comes from anticipatory looking (AL) false belief tasks. These results seem to suggest that implicit ToM, despite not being an innate ability, emerges early and then remain in operation across humans' lifespan (Schneider et al., 2017; Senju et al., 2010). Two main theoretical accounts have been developed to explain the results arousing from AL false belief tasks. A nativists account or view of mentalizing, and the two-system account (Apperly & Butterfill, 2009; Scott & Baillargeon, 2017). Despite their differences, both accounts interpret the AL findings implying that there are early-developing, automated, and maybe modular versions of ToM. On the other hand, unlike these views that assume implicit ToM exists, the submentalizing account questions whether these implicit findings actually reflect a true type of ToM similar to the one shown in standard explicit tasks. The submentalizing account (Heyes, 2014; Kulke et al., 2019) supports the hypothesis that early selection tasks measure simple sensory and attentional processes (e.g., bottom-up domain general processes elicited by directional features such as gaze cueing to specific locations without engaging in perspective taking and or inferring another person's mental state) or use of behavioural rules (e.g., predicting a person's future behaviour based on a standard rule such as "a person will look for an object where he/she last saw it," Perner & Ruffman, 2005). Heyes (2014) argued that although previous experiments seem to show that adults and infants present behaviour that could be explained by implicit mentalizing, this does not mean that the cognitive processes underlying this behaviour are actually representing the others' mental states. These results may instead be due to a reflexive shift of attention elicited by domain-general processes. In other words, domain-general cognitive processes may simulate the effects of mentalizing and perspective taking in social contexts. This involuntary attentional orienting may be mediated by a variety of mechanisms, including spatial coding of response locations, object-centred spatial coding of stimulus locations, retroactive interference, and distraction (Heyes, 2014). The existence of a rapid and reflexive mentalizing process is often supported by the idea that explicit mentalizing is inefficient, cognitive demanding, and time-consuming for usage in a variety of everyday situations, such as in competitive sports, or in those situations where social connection is important, and people are required to take fast and concerted action and communicate quickly. Thus, showing the need for a different system which would not require conscious effort and would not be impacted by cognitive load or other factors that affect cognitive resources (Apperly & Butterfill, 2009). Heyes (2014) however, argues that it is possible that even in these cases, implicit mentalizing processes are not required, because the same duties may be done equally well by domain-general processes such as the aforementioned ones. These domain-general processes, which leads to enhanced object processing (in the DPT) and events (in the Southgate–Senju procedure) in front of an agent in social circumstances, in fact, will tend to align themselves to mental states. In other words, if two person's attention is driven to the same location, the two people are more likely to have the same belief about that location, regardless of whether they are representing the other's mental state. Therefore, whilst the behavioural result of these processes may resemble implicit mentalizing, these attentional domain-general processes are actually providing a substitute for mentalizing in many behavioural tasks, which is faster and less cognitive demanding and that can be used to navigate through a wide range of social situations without engaging in mentalizing. It must be noted however, that the definition of submentalizing did not go unchallenged (Gardner, Bileviciute, et al., 2018; Michael et al., 2018; Michael & D'Ausilio, 2015). In a series of experiments, both Gardner, Bileviciute, et al. (2018) and Michael et al. (2018) advanced and strongly supported the idea that in VPT-1 tasks such as the DPT, the participant's behaviour is due to subject's engaging in implicit mentalizing rather than it being due to simple domain-general processes such as spatial cueing.

To investigate VPT-1 and the interference generated by the presence of an other in the visual scene, Samson et al. (2010) developed the Dot Perspective Task. Since then, modified versions of the DPT have been largely employed to investigate interference effect with contrasting results. Samson et al. (2010)'s DPT builds on the attentional gaze cueing paradigm, a well-known paradigm which was largely used in literature to investigate how social cues orientate attention (Driver et al., 1999). Gaze cueing has been widely investigated in relation to body position and neural responses (Perrett et al., 1992), gaze perception and joint attention (Allison et al., 2000). While developing the DPT, Samson et al. (2010) aimed to create a similar type of task to the ones which infants and chimpanzees can successfully perform such as Hare et al. (2000) and Sodian et al. (2007). The authors reasoned that the specific conditions under which different subjects were tested may explain why inhibiting one's own perspective is so difficult in some cases (so that adults exhibit egocentric bias as well) and so easy in others (in infants and chimpanzees, whose limited cognitive resources seem to overcome the biases), which might be explained by the specific conditions under which the subjects were tested. Infants and animals were asked to perform simpler and more basic tasks, making it possible for them to process the perspective of another person without engaging in intensive and explicit perspective-taking processes. With the DPT, the authors aimed to replicate simpler and basic tasks without engaging in explicit VPT. To accomplish this, the task had to tap into VPT-1. As aforementioned, VPT-1 Perspective Taking refers to the ability of a subject to judge whether someone else can see a specific visual scene. This represents a basic computational process which can be engaged effortless and does not require complex computation as the VPT-2

(Flavell, 1999). In Samson et al. (2010)'s DPT, participants are asked to verify if the number of target discs present in a visual scene, and visible from a given perspective, are equal to a previous prompted number. The visual scene consists of a 3D room in which the left, right and back walls are visible. At the centre of the room, a cue (a human avatar in Samson et al., 2010), representing the other present in the visual scene, has the role to orient participants' attention towards either the left or right wall. Participants are presented with a series of blocked trials. At the start of each trial, a perspective, either "YOU" or "SHE" is prompted, thus identifying the perspective that participants should adopt. This is then followed by a number, which represents the number of discs that should be verified in the visual scene, usually between one and three. And finally, the visual scene is presented to the participants (Figure 1.3). The participants are then asked to identify how many discs are visible, either from their own perspective or from the perspective of the cues, while neglecting the irrelevant perspective.

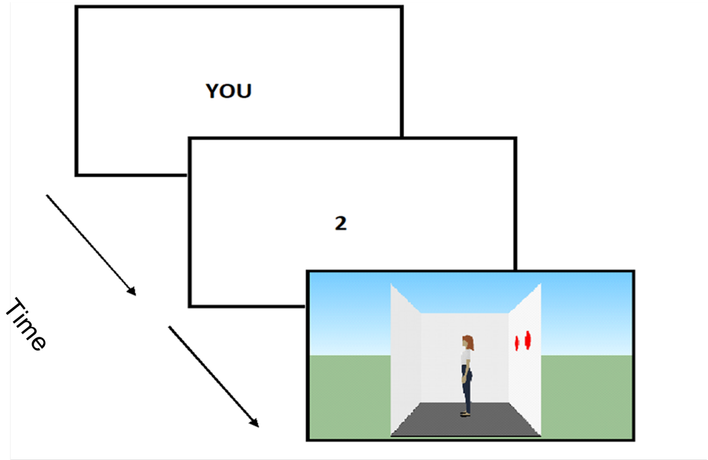


Figure 1.3: The timeline of the Dot Perspective Task. Participants are required to verify if the number of discs visible in a scene from a prompted perspective are equal to a previous shown number. In this example participants are asked to verify if two discs are visible from their perspective.

Each block of trials comprises two sets of types of trials, which are defined by the consistency between participants and cue's perspective. In consistent trials, participants and avatars see the same number of discs whilst in inconsistent trials they see a different number of discs (Figure 1.4).

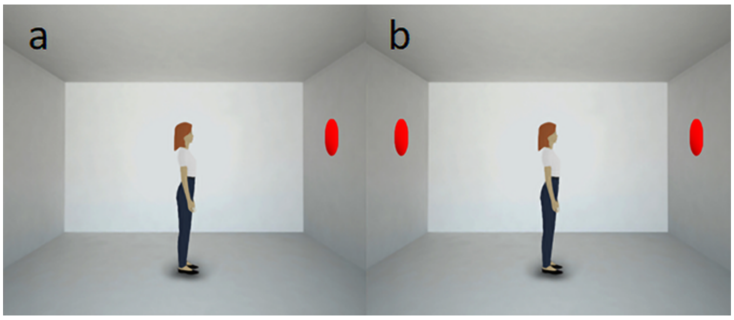


Figure 1.4: Types of trials in the DPT. a) Example of a consistent trial: both the participant and the avatar see the same number of discs (one in the figure). b) Example of an inconsistent trial: the participant sees two discs while the avatar sees only one disc.

More in particular, some of the discs are not visible to the cue while participants always see the total number of discs. Figure 1.3 shows the timeline of an inconsistent trial. In this trial participants and cue see a different number of discs. In order to investigate and assess the implicit and *Spontaneous Visual Perspective Taking* processes (i.e., the act of processing what another person or oneself perceives without making an explicit perspective judgement about it), Samson et al. (2010) aimed to measure the extent to which the irrelevant perspective interfered with participant's explicit judgement about the relevant perspective. This is obtained by comparing the differences in Reaction Times (RTs) and Errors rates between inconsistent and consistent trials. The authors hypothesized that if a *Spontaneous Visual Perspective Taking* process is involved, participants would score more errors and slower RTs in inconsistent trials than in consistent trials. This effect would be due to the automatic and involuntary computation by the participants of what the other can and cannot see. Participants were unable to prevent themselves from considering the perspective of the person in the scene, even when this information was irrelevant to the task at hand. Thus, the DPT allowed the researcher to investigate how different perspectives interfere when explicit judgements about what is visible from different perspectives are made. When judging the perspective of the other (the cue present in the visual scene), slower RTs and more errors in the inconsistent compared to the consistent condition would suggest that the participants' perspective interfered with their judgements of the cue's perspective. These results would be in line with previous research which already reported the existence of egocentric biases in different cognitive processes (e.g., Birch & Bloom, 2004; Epley et al., 2004). Previous studies have in fact shown that when reasoning about what someone else knows, believes, or observes, both adults and children have considerable biases toward their own perspective (Apperly & Butterfill, 2009;

Samson et al., 2010). Conversely, slower RTs and more errors in the inconsistent compared to the consistent condition when participants judged their own perspective would suggest, according to Samson et al. (2010), that participants spontaneously computed the cue's perspective, and that this one interferes with the participants' evaluation of their own perspective. These results instead, according to the authors, would have demonstrated the presence of a *Spontaneous Visual Perspective Taking* phenomenon which would cause this interference effect. Indeed, it would suggest that even when the perspective of the cue present in the visual scene is irrelevant to the task, we cannot prevent ourselves from computing what it sees and that this, therefore, interferes with explicit self-perspective judgements.

1.4 The Mentalizing and the Domain-General accounts

Employing the Dot Perspective Task, Samson et al. (2010) confirmed the existence of the egocentric intrusion. Moreover, and most importantly for the purpose of this thesis, the authors found that the presence of the other/avatar in the visual scene was interfering with participants judging their own point of view. To explain this interference, Samson et al. (2010) argued that this was the result of what they called *Spontaneous Visual Perspective Taking*. The authors suggested that this implicit process was likely to be similar to attentional cueing effects produced by human gazes in a wide range of visual tasks (Frischen et al., 2007). However, the authors emphasized that this phenomenon would not be due to directional information provided by the other/avatar (as demonstrated previously in the spatial cueing paradigms), but that it would be due to the cue being able to see the targets (Samson et al., 2010). The ability of the cue to see plays a key role therefore in Samson's interpretation; according to which, participants were able to quickly compute and incorporate in their explicit judgement the avatar's line of sight and what the avatar could see.

Following Samson et al. (2010)'s study, a wide range of research has been conducted in order to replicate their findings. Since then, two main accounts arose to explain the interference generated in the DPT, one that includes an involvement of social factors and one that negates it.

On the one side, in line with Samson et al. (2010), the mentalizing account explains this interference suggesting that when judging our own perspective, we reflexively infer the mental state of the other present in the visual scene. In other words, due to the social nature of perception and action, we cannot prevent ourselves from mentalizing what others are thought to see and their actions (e.g., Capozzi et al., 2014; Furlanetto et al., 2016; Morgan et al., 2018; Nielsen et al., 2015). On the other side, the domain-general account explains the interference suggesting that it is due to the other's directional features such as their body stance, posture, nose etc.(Cole et al., 2015; Cole & Millett, 2019; e.g., Heyes, 2014; Langton, 2018; Wilson et al., 2017).

The mentalizing account builds on Samson et al. (2010)'s findings and on previous studies that suggested that gaze following represents a basic perceptual processing of social stimuli and that the automated responses associated with it may be modulated by mental states (Nuku & Bekkering, 2008; Teufel, Alexis, et al., 2010; Teufel, Fletcher, et al., 2010). These studies, which employed different paradigms, showed that gaze cueing (the concept that observing another individual's attention can and does influence and direct the attention of the observer), may be due to perspective taking and mental state attribution. However, while several studies have shown that human and non-human attention can be oriented by other's eye gazes (Friesen & Kingstone, 1998; Marciniak et al., 2015; Shepherd, 2010; Téglás et al., 2012), this may not be sufficient to explain the results obtained by Samson et al. (2010) in their study. It can be argued in fact, that the interference generated in the DPT is simply due to the directional features of the cue present in the visual scene. Thus, the interference would be simply due to the directional features orienting participants' attention away from the target discs and not to *Spontaneous Visual Perspective Taking.*

Following this line of thought, the domain-general account argues that the interference recorded in Samson et al. (2010) and in further studies is simply due to domain-general processes elicited by the directional features of the cues. Santiesteban et al. (2014) investigated this phenomenon in a series of experiments by presenting a similar avatar to the one previously employed in the literature and an arrow presenting similar low-level features in others. Both avatars and arrows were shown in the study to be able to generate interference. Similarly, Wilson et al. (2017) showed that an arrow and a camera, which do not possess a mental state, are both able to orient attention and generate interference in a similar way as a human avatar. These results are further strengthened when MacDorman et al. (2013)'s study is taken into consideration. According to the mentalizing account, in order to elicit *Spontaneous Visual Perspective Taking* processes, a mentalizing process is needed.

Several studies have demonstrated that viewers have a difficult time taking the perspective of a computer-animated human character when it looks eerily realistic (Katsyri et al., 2015). MacDorman et al. (2013), therefore, investigated whether a character's eeriness and human-photorealism [4] may affect VPT-1 and therefore

[4] The term eeriness refers to the quality of an avatar to appear mysterious, different, strange, or unexpected. Human-photorealism, also named human likeness refers to the quality of a cue to appear human.

Spontaneous Perspective Taking in the Dot Perspective Task. The authors employed a series of modified versions of the DPT, in which they employed computer-generated avatars with different levels of eeriness and human photorealism such as a zombie, a bee, a bear, a man, a robot or even a chair. The authors found that cues with different levels of eeriness and photorealism still generate the interference found in the Dot Perspective Task by Samson et al. (2010). However, it may be claimed that because the figures employed varied greatly in form and look, it is possible that external influences, rather than the characters' human photorealism and eeriness, impacted accuracy and response times in the Dot Perspective Task. This limitation was assessed by the authors in a subsequent experiment which did not show any significant differences. It was concluded therefore that the possible moderating effects of the avatar human photorealism and eeriness were either undetectable or simultaneously small and inconsistent.

The aforementioned findings are further supported by Langton (2018). In his latest study, Langton employed one of the most known versions of the dot-perspective task. In this version, walls are placed between the human avatar that acts as a cue and the room's lateral walls. If a *Spontaneous Visual Perspective Taking* mechanism is involved, the interference generated in the DPT should disappear when the cue's line of sight is obstructed. However, this was not the case. The interference persisted even when the cue's line of sight was obstructed by the presence of side walls (Langton, 2018). Langton's findings follow Cole et al. (2015) and Cole et al. (2016), which employed a similar paradigm. In both in fact, the cue's point of view was obstructed by the presence of walls between the cue and the target. Interestingly, however, other similar paradigms that involved the obstruction of the avatar's point of view showed opposite findings. (Furlanetto et al., 2016). In summary, the mentalizing account is supported by evidence that when a rectangle distractor replaces the human avatar (the other), the interference disappears (as in Samson et al., 2010) suggesting that social relevance is essential to generate the interference. The domain-general account, on the other hand, is supported by evidence that directional cues lacking a mental state can generate interference, such as arrows (Santiesteban et al., 2014), cameras (Wilson et al., 2017), and even chairs (MacDorman et al., 2013). Accordingly, and in contrast to previous evidence, this suggests that the interference is not dependent on a cue's social relevance. The debate over which of the two processes is at play is still ongoing. Michael & D'Ausilio (2015) to test the two accounts suggested manipulating participants' beliefs about the avatar's ability to see. This should modulate the interference pattern. A variety of authors have considered this suggestion, but their results were not conclusive in favour of either the mentalizing or the domain-general account. Whilst an avatar believed to be unable of seeing still generated interference in Cole et al. (2015) and Wilson et al. (2017); it did not in Furlanetto et al. (2016). Following Teufel, Alexis, et al. (2010)' study, in Furlanetto et al. (2016) the avatar wore one of two sets of coloured goggles, each with mirrored lenses that made it impossible to view the wearer's eyes. Participants were instructed and persuaded to believe that one pair was transparent and that the other pair was fully opaque by using a belief induction approach. They reasoned that while one pair of goggles was worn, the avatar could see the discs on the wall, but when the other pair was worn, the avatar could not see the discs on the wall (non-seeing condition). The interference was noticed when participants judged their own perspective while the avatar was wearing transparent goggles, but not when it was wearing opaque goggles. These findings are consistent with the idea that the interference is the result of participants attributing mental states to the avatar, rather than being due to a spatial shift of attention elicited by the avatar's directional features. On the contrary in Wilson et al. (2017) where a similar manipulation was employed, a blindfolded avatar, therefore unable to see (really similar to Furlanetto et al., 2016 non-seeing condition), still generated the interference. Therefore, it appears that both manipulating participants' beliefs and using cues without social features failed to yield conclusive results. Hence, it is clear that neither of the two accounts can be fully ruled out. As a result, Capozzi & Ristic (2020) proposed a theoretical integrated account in which domain-general and mentalizing processes play a role in generating this interference effect. The interference may be generated by the directional features of the cues, but its magnitude may be modulated by the mental state attribution.

1.4.1 Factors that may contribute to generate the interference.

The emergence of contrasting findings in the literature has led several authors to investigate whether specific characteristics of the DPT may be contributing to these discrepancies. In addition to the theoretical dispute beyond the processes underlying the interference recorded in the Dot Perspective Task, other challenges to the different interpretations must be considered, before investigating the role of social and directional features in orienting attention, these are:

- Stimulus onset asynchrony
- Task Relevance
- The attribution of knowledge and intentionality to the other person present in the visual scene.

As aforementioned, while some authors suggest that interference in the DPT is due to a *Spontaneous Visual Perspective Taking* mechanism, others argue that the mere presence of another person in the visual field is not sufficient to reflexively determine where/what the other person is looking at (Bukowski et al., 2015; Cole et al., 2017; Gardner, Bileviciute, et al., 2018). The authors suggested that there may be other factors involved in generating the interference recorded in the Dot Perspective Task. Gardner, Bileviciute, et al. (2018) suggested that stimulus onset asynchrony (SOA) may play a role in the dot-perspective task. The SOA denotes the time between the onset of two different stimuli, or between a stimulus and a target. While some of the aforementioned studies recorded the interference even when stimuli and targets were presented at the same time, others showed that the original cue employed by Samson et al. (2010) induced attention shifts towards the direction faced by the cue when it preceded the target by at least 300 ms or 600 ms, but not 100 ms (Bukowski et al., 2015; Cole et al., 2017; Gardner, Bileviciute, et al., 2018; Gardner, Hull, et al., 2018). These data altogether seem to suggest that any agent-induced attentional shift requires some time to occur, meaning that the interference effect firstly recorded in Samson et al. (2010), may be due to a voluntary shift of attention rather than a spontaneous/automatic one. As per Cole et al. (2020) and Moors & De Houwer (2006), the notion of automaticity during the years has been associated with a large number of processes and mechanisms such as fast, goal independent, effortless and many more. To this end, Cole et al. (2016) argued that spontaneously taking someone else's perspective should not require assuming it, because the latter would not be a spontaneous process. It is worth mentioning however that contrarily to Cole et al. (2015) and Gardner, Bileviciute, et al. (2018), Bukowski et al. (2015) did find an orienting effect at an interval of zero ms when attention was artificially drawn to the avatar location. Bukowski et al. (2015) suggested that tasks similar to the Dot-Perspective Tasks may play a role in creating a social mindset in the participant that would automatically drive the participant to compute the other's perspective. This, however, would not be a reflexive or automatic process, instead, it would be due to participants narrowing down their attention towards the cue present in the visual scene due to their relevance to the task. In other words, Bukowski et al. (2015) advanced the idea that in a task like the dot-perspective task, participants, who are asked to judge the number of discs from either their own or the avatar's perspective, may represent the agent's perspective even when they are not explicitly instructed to do so due to their knowledge that perspective is an important part of the experiment. Folk et al. (1992) showed how top-down knowledge influences the orientation of attention towards specific features of a particular scene. This "attentional control setting" has demonstrated how a seemingly unimportant aspect of an element can become part of an observer's attentional set. In perspective-taking paradigms similar to the DPT, this form of top-down effect has been observed (e.g., Stephenson & Wicklund, 1983). This means that the simple instruction to take into consideration a specific perspective may induce the idea that the perspective of another in the visual scene may be also relevant. In response, Cole et al. (2016) and Conway et al. (2017) employed versions of the DPT in which participants were instructed to take only one perspective for the whole experiment. Their results showed that the interference persisted even in this version of the Dot Perspective Task. These results do not support the idea that participants are spontaneously taking into consideration the others' perspectives in the Dot Perspective Task due to its relevance to the task. The authors argued instead that these results are probably due to a spontaneous redirection of a viewer's attention by the observed gazes/directional features, which is unlikely to involve representations of the avatar/cue mental state. Lastly, Langton (2018), following Wiese et al. (2012), suggested that the contrasting results in the Dot-Perspective task may have been arising due to participants taking different stances towards the cues employed in the DPT. Wiese et al. (2012) suggested that people must adopt an intentional stance towards a cue before mentalizing processes can arise and represent the other's behaviour or perspective. This is a concept coined by philosopher Dennett (1981) to describe a cognitive strategy often used by humans to anticipate and explain the actions of other agents in the environment. The belief that another is an intentional system influences therefore the way we allocate resources. Allocating attention to where another person is attending helps to build shared intentionality (Tomasello, 2008; Wiese et al., 2012), which allows us to engage in collaborative activities by sharing our objectives, intentions, knowledge, and beliefs with others. Wiese et al. (2012) suggest that the intentional stance can influence attentional selection, or how we allocate attention to different stimuli in the environment. Specifically, they propose that when we ascribe intentions to others, we automatically prioritize information that is relevant to those intentions, even if that information is not directly relevant to our own goals. If in the DPT it is assumed that the interference is due to the cue's social features and to its social relevance, the attribution of knowledge and intentionality should be therefore taken into consideration. This refers to the degree to which the participant perceives the other person as having knowledge of the task and intentional control over their gaze direction, which could influence how the participant responds to the cue. Therefore, understanding these social and cognitive factors would be crucial for interpreting results in the DPT. As a result of the social nature of the cue, if the interference effect is due to the association of the social features (e.g., viewpoint) with the purpose/intention of the cue of looking at a specific spot, it would mean that this may be therefore mediated by specific Theory of Mind mechanisms. However, whilst this was further supported by Gardner, Hull, et al. (2018) who did not find any interference when participants were unaware that they were involved in a perspective taking experiment, it does not explain why the interference still persist in other studies in which intentionality cannot be attributed to the cue such as MacDorman et al. (2013); and Wilson et al. (2017). To summarize, different studies that have employed various versions of the Dot Perspective Task, have reported an interference effect when participants are judging their own perspective whilst an other (e.g., an avatar) is present in the visual scene. It is however still unclear whether this interference is due to humans spontaneously representing the visual perspective of other individuals; if it is due to lower-level domain-general attentional processes[5]; or if instead an integrated approach which takes the two types of processes in consideration is needed.

This thesis aims at shedding light on the processes underlying this phenomenon investigating the relative contributions of domain-general and mentalizing processes. To this end, it presents a series of experiments where the social and directional features of the other will be experimentally manipulated.

1.5 The *Social_Only* cues

Following a review of the literature on RAS and VPT, of the DPT and of the two accounts which aim to provide an interpretation to how interference effect generated by the presence of others, their theoretical approaches as well as their findings, the following chapters will go on to report the experimental work of this thesis. For the purpose of investigating the relative contribution of domain-general and social processes, the experimental work of this thesis employed a unique novel

[5] Despite a larger body of studies that seems to push towards the mentalizing account, there are many reports of this interference happening when perspective-taking should not occur. As highlighted by Cole et al. (2020), this may be because positive evidence is far more likely to find itself in a journal.

methodology which includes:

- A different statistical approach to assess the predictions of the domain-general and mentalizing accounts. The data analyses presented in this thesis adopted the Bayesian approach. This will be described in Chapter 2 of this thesis.

- A set of original stimuli, to be employed in the DPT, developed to address the limits and flaws of earlier investigations.

Different studies have investigated how directional (e.g., arrows) and social cues (e.g., gazes) direct attention in a different number of tasks, either individually (Galfano et al., 2012; Kuhn & Kingstone, 2009; Mills & Dodd, 2016; Stevens et al., 2008), or presenting the two cues at the same time with one of them acting as a distractor (Fan et al., 2018; Nummenmaa & Hietanen, 2009); yet no studies have addressed the fact that any social cue still presents conjugated low-level directional features, which are conveyed regardless of the cue's social relevance. When we look at the cues employed as the other in the DPT in previous studies, their directional and social features that elicited domain-general and mentalizing processes were in fact always conjugated. That is, if one looks at the avatar in Figure 1.3, its posture, which signifies directionality, and its viewpoint, which conveys social relevance, both point in the same direction. The development of a novel set of stimuli therefore took into consideration the need to manipulate and isolate the directional and social features of the cues employed in the DPT.

Since it is challenging, if not impossible, to distinguish the social from the directional features of a cue, it was reasoned that giving the cue contrasting directional features may cancel out or attenuate the effect of the opposite directional features leaving only its isolated social features to orient attention. Thus, creating a set of cues named in this thesis *Social_Only*, thanks to which it is possible to isolate the social features and measure their relative contribution of the different features to the phenomenon and assess the individual predictions of the domain-general and mentalizing accounts. Figure 1.5 shows two of the cues employed in the experiments of this thesis. As can be seen, the contrasting directional feature is represented by an arrowed-shaped tail.

Figure 1.5: An example of cues presenting contrasting directional features. The arrowed-shaped tail represents the contrasting directional feature. The effect of the tail in both cues cancels out (or reduces) the directional effect of their body stance. It must be noted how the tail harmoniously follows the body shape of the cues. In this way the contrasting directional feature is perceived by the participants as part of the cue and not as a second individual directional cue.

To achieve the desired effect, the size of the contrasting directional feature was assessed through a set of preliminary experiments (presented at the end of each experimental chapter) using the Posner spatial cueing paradigm (Posner & Coehn, 1984). The size of the added contrasting directional feature and its saliency were manipulated until the cue did not generate any cueing effect in the Posner spatial cueing paradigm. Hence indicating that the desired effect (of contrasting the effect of the directional features to leave the social features to orient attention) was achieved and that the contrasting directional features were cancelling out the effect of the cue's directional features. Furthermore, the newly developed cues should have met two requirements. First, the added contrasting features should follow the shape of the cue harmoniously and easily recognized by the participants as a natural part of the body of the cue. Secondly, the chosen cue should be known and easily recognizable by the participants. A set of control cues without contrasting directional features was also developed. These can be seen in Figure 1.6

Figure 1.6: The cues employed as control. This set of cues, similar to cues previously employed in literature present conjugated social and directional features.

Furthermore, another cue having contrasting directional and social features (Figure 1.7) was developed to investigate the involvement of mentalizing processes in the interference effect. To achieve this, the attribution of intentionality to the cue was manipulated by adding as contrasting feature a pointing arm, which conveys both directional and social information. Previous studies have shown that ambiguous social stimuli, such as ambiguous faces, or faces presenting incongruent face's position and gaze directions may cause cognitive conflict when assessing the mental status of stimuli (Abubshait et al., 2020; Qian et al., 2013).

Figure 1.7: The cue presenting contrasting directional and social features. The extended arm conveys directional and social information, both of which point towards the opposite side of the cue's viewpoint. This cue should cancel out (or reduce) the effect generated by both set of features, directional and social.

Lastly, it was reasoned that just like the addition of contrasting features may cancel out the effect of both directional and social features, the interference effect could also be modulated by the salience and strength of the directional features of the other when it exudes unambiguous intentionality and presents more salient directional features. To this end, the added features were congruent with the cue body stance and viewpoint, rather than contrasting them.

Figure 1.8: The cues employed in Experiments 4 and 3. The two cues present clear and confounding social and directional features and saliency is increased by the addition of an extra feature. In experiment 4, this feature is represented by the straight pointing arm, which possesses both, directional and social relevance. In experiment 3, it is instead represented by the overarching tail. This extra feature conveys only directional information.

1.5.1 The *Social_Only* cues and the experimental chapters

By employing the novel set of cues this thesis aims to investigate the relative contribution of directional and social features and assess the predictions of the domain-general and social accounts across a series of experiments. The first experiment aims to replicate the DPT paradigm whilst employing a Bayesian approach. The second experiment is the first experiment in which a novel cue presenting contrasting directional features is employed. This experiment aims to provide a first insight into the relative contribution of the two different sets of features in causing the interference effect and advance the need for an integrated account. The third experiment seeks to replicate the findings of experiment 2 to provide more evidence in favour of this integrated account. It aims to investigate the idea that the directional features of a cue should affect only RTs and not error rates by experimentally manipulating the directional features of the cue employed in the task and the saliency of its directional features. Lastly, building on the results arising from previous chapters, experiment 4 focuses on experimentally manipulating also the social features of the cue. To accomplish this, the attribution of intentionality to the cue by the participants will be manipulated. Finally, Chapter 6 will present a general discussion bringing together the experiments' findings and providing a comprehensive model, which would explain the different processes underpinning this phenomenon.

2
General Methods

This chapter introduces the general methods employed across the different experiments of this thesis. The first section describe the statistical approach. Here the Bayesian approach and its advantages over the more common frequentist approach are introduced. Sampling plan, stimuli presentation and procedure conclude then the chapter.

2.1 The advantages of a Bayesian approach

The data analysis performed in this thesis used the Bayesian rather than the frequentist approach to assess the predictions of the various accounts. The most well-known and appealing alternative to the widely used traditional "frequentist inference" approach based on confidence intervals and *p values* is Bayesian parameter estimation and Bayesian hypothesis testing. The Bayesian approach can indeed gather evidence for a null outcome and distinguish between absence of evidence and evidence of absence (Dienes, 2014). Furthermore, the Bayesian approach provides a credible interval reflecting the most credible points of the distribution of the variable under investigation. This allows for a weighted evaluation of the outcomes rather than a binary choice. These features are attractive for analysing the mentalizing and domain-general accounts because:

- both accounts draw conclusions based on a null effect, and
- it allows an estimation of their relative contribution.

In addition, the Bayesian approach provides a credible interval indicating the points of the distribution of the variable under consideration that are most credible. This allows a weighted evaluation of the results rather than a dichotomous decision. These characteristics are appealing for the aim of assessing the mentalizing and the domain-general accounts because i) both accounts draw conclusions based on a null effect, and ii) it allows an estimation of their relative contribution. A in detail discussion of the current debate between Bayesian and frequentist approach can be found in the appendix of this thesis.

A common method used to summarize the uncertainty and the distribution of the posterior is the one based on the *Highest Density Interval* (HDI). The HDI refers to the technical terminology of "probability density" instead of the colloquial but accurate term "credibility". It represents a credible interval and indicates the points of the distribution of the variable under consideration that are most credible. The HDI summarises the distribution and its uncertainty by defining an interval which covers a predetermined percentage of the distribution; usually 95% or 89% (Kruschke, 2018, 2013; Makowski et al., 2019; McElreath & Safari, 2020, Figure 2.1). All the possible parameters of the distribution comprised within this range represent the most credible values, or in a more accurate way, the parameter values with the highest probability density. Every point inside of the HDI has therefore higher credibility than any other point outside of it.

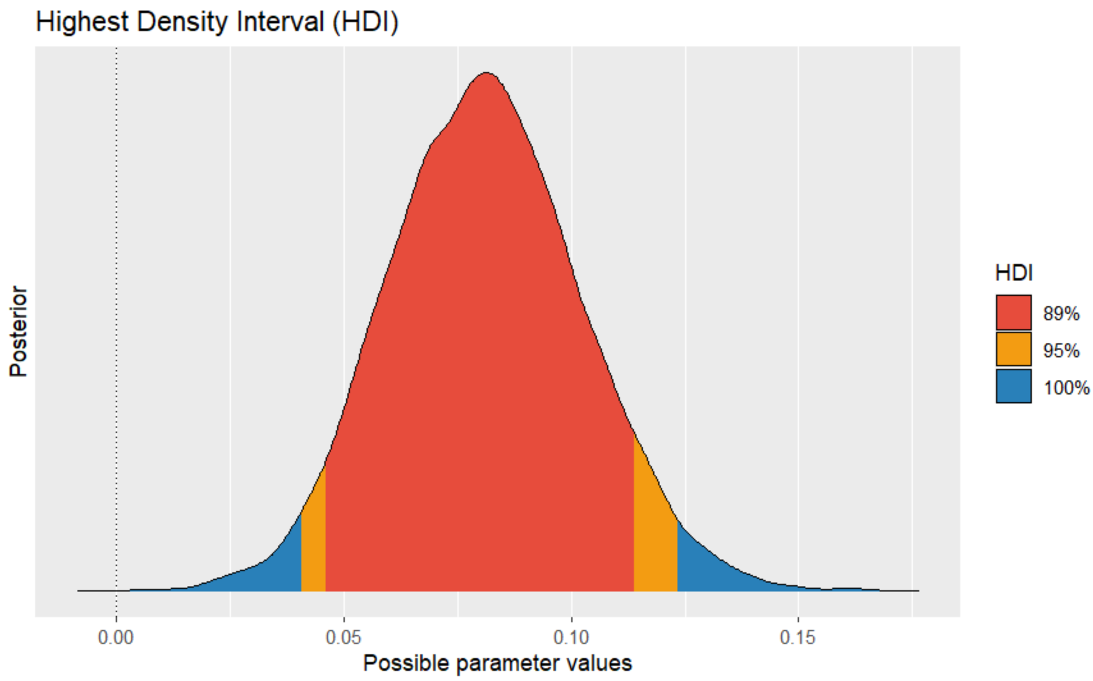


Figure 2.1: An example of 89 and 95 percent HDI of a posterior distribution. The red area under the gaussian curve represents the 89% most probable value of this distribution. Similarly, the orange and blue sections represent the same area when different less stable cut off values are employed.

2.1.1 The HDI+ROPE method to assess Null Hypothesis

Using the HDI is possible to assess the most credible values of a specific parameter of interest such as the Null values. Kruschke & Liddell (2018b) advanced a procedure, which in addition to the HDI, relies on establishing a region of practical equivalence (ROPE) around the null value. This region defines all the values around the null that can be considered equivalent to the null for practical purposes[1].

This method can be used to:

1) Make a dichotomous decision about the null value. In this case, Kruschke & Liddell (2018b) delineated the following decision rules:

- If the 95% HDI falls entirely outside of the ROPE, we reject the null value

[1]This approach is similar to the frequentist Equivalence testing advance by Lakens (2017).

for practical purposes;

- If the 95% HDI falls entirely within the ROPE, we accept the null value for practical purposes;
- Else, withhold a decision.

2) Identify the percentage of the most probable values of the distribution that are practically equivalent to the null. Thus, providing the probability of H0 over H1.

It should be emphasised that the ROPE reflects an arbitrary value that the researcher constructs around the null. This logic is based on the fact that the probability of a posterior distribution differing from a single point (such as 0) is mathematically infinite. As a result, the ROPE was designed to allow researchers to choose a reasonable set of values around the null value that are equivalent to the null value for practical purposes (Kruschke, 2018, 2013; Kruschke, 2015; Makowski et al., 2019). Despite the fact that it is an arbitrary range that will vary depending on the factors, according to Kruschke (2018), the ROPE might be set by default to a range of -0.1 to 0.1 of a standardised parameter (negligible effect size according to Cohen, 1988), which would vary depending on statistical analysis (Makowski et al., 2019). For linear models (lm), for example, it was recommended as follows:

$$-0.1SDy, 0.1SDy$$

Because the outcomes of this thesis may be based on the null hypothesis, the Bayesian HDI+ROPE method will be used throughout the various experiments to provide evidence in favour of the relative probability of either the Null or the Alternative hypothesis. Additionally, unlike the decision rules delineated by

Kruschke & Liddell (2018b), an 89% HDI will be used in this thesis; Makowski et al. (2019) and McElreath & Safari (2020) suggested that an 89% HDI should be used when this method is employed because the 89% HDI is considered to be more stable.

2.2 Sampling plan and stopping rule

For each experiment in this thesis, the sample size was determined using the Sequential Bayes Factors (SBF) procedure (Schönbrodt et al., 2017). The SBF entails calculating subsequent Bayesian Factors (BF) following each new data collection, up to the accomplishment of an a priori set BF value. Jeffreys (1961) proposes continuing data gathering until a BF of 10 is attained in favour of one of the hypotheses. This value is regarded as "strong" evidence in favour of the proposed hypothesis. Before beginning the tests, it was planned to end data collection based on the "stopping guidelines" listed below:

1) Achieving a minimum of 16 participants for each type of cue [i.e., the same number of participants collected in earlier attentional interference studies, (e.g., Samson et al., 2010)]. Furthermore, a prospective power analysis conducted by Wilson et al. (2017) revealed that a sample size of 16 participants per condition would yield strong power (0.8) to detect the expected effect.

2) Obtaining a BF in favour of one of the hypotheses for either RTs or an error rate of 10 (as proposed by Jeffreys, 1961). Hence, data collection in each experiment was carried out until the predefined stopping condition was achieved at the moment of checking. Each experiment presented in this thesis will describe the sample size collected and the relative BF10 at the point data collection was halted in the relative section.

2.3 Stimuli and procedure

The stimuli creation and general procedure of the experiments employed in this thesis is presented below. The general procedure was similar across all the experiments with small deviations due to the cue's features. Deviations from the main procedure presented below will be individually introduced in their relative experiment's chapter and sections.

2.3.1 Stimuli

The Adobe Photoshop software (Version: 23.0.1 20211105.r.68 96a498e x64) from the Adobe Creative Cloud software collection was used to produce each stimulus (Version 5.9.0.372). According to the Dot Perspective Task's traditional design (Samson et al., 2010), the stimuli showed a three-dimensional image of a room. The 3D room included a view of the side and back walls as well as of the ceiling and the floor. The different walls' colours ranged across different values on a grey scale based on their relative position on the stimulus (e.g., foreground vs background). This gradient was selected in order to reproduce as accurately as possible the differences in lightness in a real-life room and enhance the participants' feeling of seeing the reproduction of a real room. This is clearly visible in Figure 2.2 below, where an example of the stimuli employed in this thesis is shown. The cues employed in this thesis were always presented at the centre of the room. A shadow was added at the bottom of each cue in order to enhance photorealism and render the scene more realistic looking. From a viewer's standpoint, shadows assist in establishing an object's size and relative position in a scene. Cues for experiments 1 and 4, where a human avatar was employed, were extracted and developed from single pictures, which were input in Adobe Photoshop. Cues for experiments 2 and 3 were created, sketched, manipulated, and eventually coloured in Adobe Photoshop. Red discs were employed as targets. Either 1, 2 or 3 discs were presented in each trial. The discs' size was chosen based on the following rationale: when 3 discs are presented, all three discs should fit on the same wall in a straight row. Furthermore, they should be equally distant from each other and the background and foreground. Moreover, the discs were always vertically aligned with the cue's viewpoint, to clearly show that they were always visible from the cue's perspective.

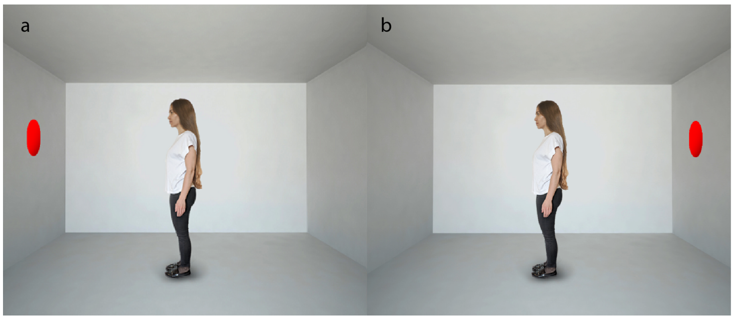


Figure 2.2: An example of the type of cues employed in this thesis. As it can be seen, the room is shaped by grey walls. Shades are used to mimic the light present in a real-life room and enhance participants' feeling of seeing a real room. A shadow at the bottom of the cue is employed in order to enhance photorealism. A cue without a shadow would be perceived as floating in the room.

2.3.2 Presentation

Stimuli created using Adobe Photoshop (version: 21.1.2) were presented using Psychopy (version: 3) software and its online repository Pavlovia (Peirce et al., 2019). Due to the current COVID-19 situation, the use of Pavlovia via browser was the best option to carry out the studies. As shown in Bridges et al. (2020), PsychoPy/PsychoJS recorded a precision of under 4 ms in every browser/OS combination; the precision improved even more (less than a millisecond) when Chrome was used as a browser in either Windows or Linux. Participants were therefore instructed on the information page to run the experiment using these Oss and browser; furthermore, they were instructed not to run any other software or browser pages while running the experiment as these may have interfered and caused lags in recording response times. Stimulus presentation followed the dot-perspective task standard sequence (e.g., Samson et al., 2010).

2.3.3 Procedure

Participants were gathered by convenience sampling by distributing the studies' links on social media and via the Sheffield Hallam Psychology Research Participation Scheme, which is based on the Sona Systems web platform. Through this scheme students can sign up to engage in research in exchange for academic credits. Afterwards, participants were redirected to a Qualtrics questionnaire containing the experiment's information sheet and consent form. Upon accepting the experiment, participants were redirected to their respective Pavlovia webpage, where the experiments were conducted. A fixation cross was shown for 750 ms at the beginning of each trial. Then, after 500 ms, pronouns indicating the participant's or cue's perspective appeared on-screen and were displayed for 750 ms. The pronouns presented in each experiment are introduced in their respective chapters and sections. Following the prompt and a further 500 ms, a number, either 1, 2 or 3, was presented for 750 ms. Participants were asked to verify if these numbers of discs were visible from the prompted perspective. The stimuli were then presented at the centre of the screen until the participant responded by pressing on the keyboard either "A" (YES; from the given perspective, the stated number of discs are visible) or "L" (NO; from the given perspective, the stated number of discs are not visible). If the participant did not respond within 2000 ms, the next trial started, and the trial was considered as an error. The combination of types of trials (consistent vs inconsistent) and perspective (Self vs. Other) options generated four different types of trials for each type of cue. Furthermore, trials can be divided into YES and NO responses. It is important to note that while all consistent YES trials, inconsistent YES trials and Inconsistent NO trials require participants to evaluate at least one perspective, a potential confounding arises from all consistent NO trials as the number of discs presented to the participant does not match the number visible from either perspective. In light of this, the analysis was limited to the YES trials (see Samson et al., 2010). Prior to the start of the experiments, participants completed a small number of trials to become acquainted with the task. The tests lasted around 20 minutes on average.

2.4 Ethics

The Psychology Research Ethics Panel at Sheffield Hallam University authorised this project (nr. ER12646660).

3
Experiment 1

3.1 Introduction

Experiment 1 aims to replicate the standard Dot Perspective Task whilst approaching the data analysis by adopting a Bayesian approach. Because the current debate in the literature focuses on the ability of different types of cues to generate the interference effect phenomenon and conclusions can be drawn based on the absence of differences between two cues, the Bayesian approach represents an ideal approach to analyse data from the Dot Perspective Task as described in chapter 2. This experiment will follow the standard procedure of the Dot Perspective Task employed in similar research in literature such as Samson et al. (2010) and Wilson et al. (2017). To this end, a human figure, precisely the photo of a woman, will be used as a central cue this experiment (Figure 3.1).

3.1.1 Accounts' predictions

Human avatars, pictures of humans, or even 3D representation of humans have often been used in literature to demonstrate that the presence of the other in the visual scenes generate an interference effect in the viewer. Despite providing contrasting explanations of the processes underlying the phenomenon, researchers supporting either the mentalizing or the domain-general account, have consistently shown the existence of this effect when a standard human cue is employed in the Dot Perspective Task. Hence, despite providing different interpretations, the two accounts would predict the same outcome from the analysis of the results:

- Both the mentalizing and the domain-general accounts predict that the cue generates interference.

Figure 3.1: The cue employed in experiment 1. A photo of a woman from a side view. The woman looks straight in front of her and has her arms lined up with her body.

3.2 Methods

3.2.1 Sampling plan and stopping rule

The sampling plan and stopping rule followed the Sequential Bayes Factors (SBF) procedure (Schönbrodt et al., 2017) presented in chapter 2 of this thesis. This data collection continued until the predetermined stopping criterion was reached at the point of checking. Sampling was stopped after collecting 26 participants as one of the BF10 was higher than 10 (specifically, the BF10 of the interference in the RTs was BF10 = 816.322).

3.2.2 Participants

Twenty-six (26) participants took part in this study (age range 23 to 52) of which 14 were females. Participants were naïve to the purpose of the study and received no remuneration for taking part. Informed consent was obtained from each participant through the Qualtrics online platform (https://www.qualtrics.com) in accordance with the University's ethical procedures.

3.2.3 Design

The variables used in the study were: Consistency (Inconsistent vs Consistent) and Perspective (Self vs Other). Both variables Consistency and Perspective were measured within-subjects as the standard Dot Perspective Task requires.

3.2.4 Stimuli and Procedure

Stimuli presentation and procedure were accordingly to the general procedure presented in chapter 2 of this thesis. In this experiment, the pronouns YOU and SHE were employed to prompt participants respectively with the "Self" or "Other" perspective. In total, 124 trials were presented to each participant. These comprised 60 YES and 64 NO response trials. 60 were Consistent trials, 60 were Inconsistent trials and 4 were fillers, in which no discs were presented. Furthermore, 62 trials had as prompted perspective YOU while the remaining 62 had SHE. Before the start of the experiment, participants took part in a small practice of 14 trials to familiarize themselves with the task. The experiment lasted on average between 15 and 20 minutes.

3.3 Results

3.3.1 Descriptive Statistic

Table 4.1 and Figure 4.2 illustrate the means and standard deviations for both RTs and error rate. Following Whelan (2008), trials in which RTs are faster than 100 ms were deemed to be considered non-genuine. There were no RTs under 100 ms in this experiment. Given the required cut-off of 2000 ms on all trials, no trimming was performed on higher RTs.

Table 3.1: Mean and SD for RTs and Error Rates.

Perspective	Consistency	Mean	sd
RTs			
Other	Inconsistent	0.902	0.324
	Consistent	0.819	0.286
Self	Inconsistent	0.971	0.323
	Consistent	0.832	0.286
Errors			
Other	Inconsistent	0.315	0.465
	Consistent	0.049	0.216
Self	Inconsistent	0.217	0.413
	Consistent	0.078	0.269

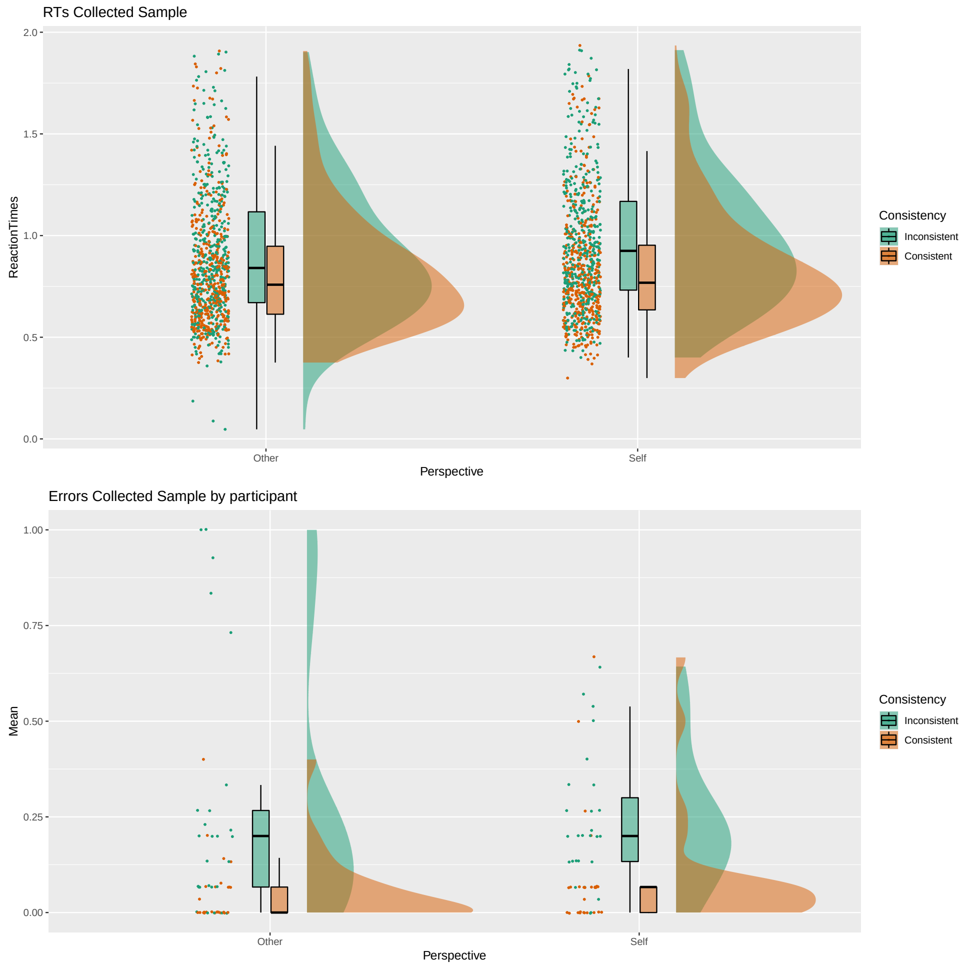


Figure 3.2: Rain plots reporting Mean and SE of distribution for sample's RTs and Error Rates for each combination of stimulus presentation (Consistent vs. Inconsistent) and perspective adopted (Self vs Other). Error rates are averaged also by Subject.

As it can be seen, for the RTs an interference pattern (intended as the mean difference between the Inconsistent and the Consistent trials) emerged for both the level of the Perspective variable. More in detail, the mean interference was 0.140 seconds (sd 0.140) for the Self and 0.088 (sd 0.121) seconds for the Other condition. A similar interference pattern emerged for the error rate with 0.142 (sd 0.152) for the Self and 0.228 (sd 0.314) for the Errors.

3.3.2 Data Analysis

Data were analysed with mix-models (Judd et al., 2012) to enable generalisation across stimuli and participants; specifically, Bayesian mix-models were created in Stan computational framework (Carpenter et al., 2017) accessed with the high-level interface "brms" package 2.10.0 (Bürkner, 2017, 2018) in R version 3.6.2 (R Core Team, 2020). Two models were run, one for the RTs and another for the error rate. For both models, the variables Perspective and Consistency - together with their interaction - were inputted as population-level factors and the variable Subject as group-level factor. Moreover, as each combination of the conditions was presented in more than 1 trial, the variable Trials was also inputted in the models as a group-level factor nested within the variable Subject. The two models were therefore similar in their formulae; however, the Weibull family distribution was utilized for the RTs (Logan, 1992; Palmer et al., 2011; Rouder et al., 2005) and the Bernoulli family distribution for the error rate (Bürkner, 2018). For testing opposite predictions, flat priors were chosen for the population level effects and weakly informative priors for the intercept [student_t(3, 0.7, 2.5)] and for the group level effects [student_t(3, 0.7, 2.5)]. For model estimation, four chains with 4000 iterations (2500 warmup) were used. Convergence was checked via Gelman & Rubin (1992) convergence statistics (Rhat close or equal to 1.0) and by visual inspection of the posterior distribution of all the coefficients and their chain convergence.

3.3.3 Reaction Time Analysis

Table 3.2 shows the results of the Bayesian linear mixed-effects model. Figure 3.3 shows the estimated marginal means of the interaction between Consistency and Perspective.

Table 3.2: Population level effects of the brms model.

Covariate	Estimate	Est.Error	l-95% CI	u-95% CI
Intercept	-0.11	0.04	-0.19	-0.03
PerspectiveSelf	0.07	0.02	0.03	0.10
ConsistencyConsistent	-0.10	0.02	-0.14	-0.07
PerspectiveSelf:ConsistencyConsistent	-0.04	0.03	-0.09	0.01

It emerged a main effect of Perspective with longer RTs for the Self trials [0.07, SE 0.02 95% CI (0.03, 0.10)] and also an effect of Consistency with faster RTs in the Consistent trials [-0.10, SE 0.02 95% CI (-0.14, -0.14)]

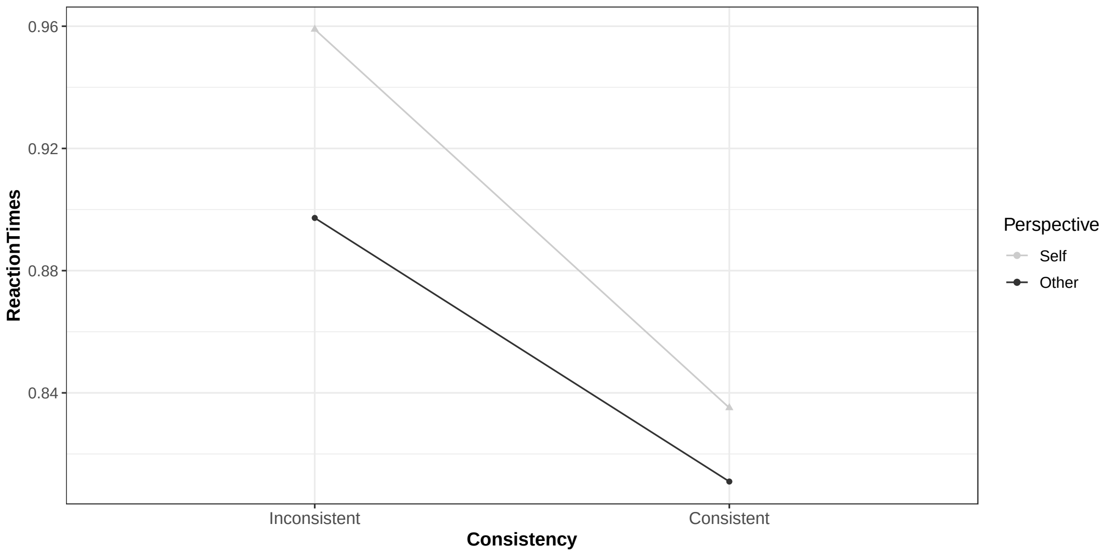


Figure 3.3: Estimated marginal means for each combination of stimulus presentation (Inconsistent vs Consistent) and perspective adopted (Self vs Other) for the RTs.

3.3.4 Error Rate analysis

Table 3.3 shows the results of the Bayesian mixed-effects model and Figure 3.4 shows the estimated marginal means of the interaction between Consistency and Perspective.

Table 3.3: Population level effects of the brms model.

Covariate	Estimate	Est.Error	l-95% CI	u-95% CI
Intercept	-0.89	0.20	-1.29	-0.49
PerspectiveSelf	-0.58	0.17	-0.90	-0.25
ConsistencyConsistent	-2.39	0.26	-2.91	-1.90
PerspectiveSelf:ConsistencyConsistent	1.14	0.34	0.48	1.81

A main effect of Perspective emerged, with lower error rate for the Self condition [-0.58, SE 0.17, 95% CI (-0.90, -0.25)]. A main effect of Consistency also emerged, with lower error rate for the Consistent trials [-2.39, SE 0.26, 95% CI (-2.91, -1.90)]. In addition, emerged an interaction effect between Perspective and Consistency, with lower error rate in the Self - Consistent condition [1.14, SE 0.34, 95% CI (0.48, 1.81)].

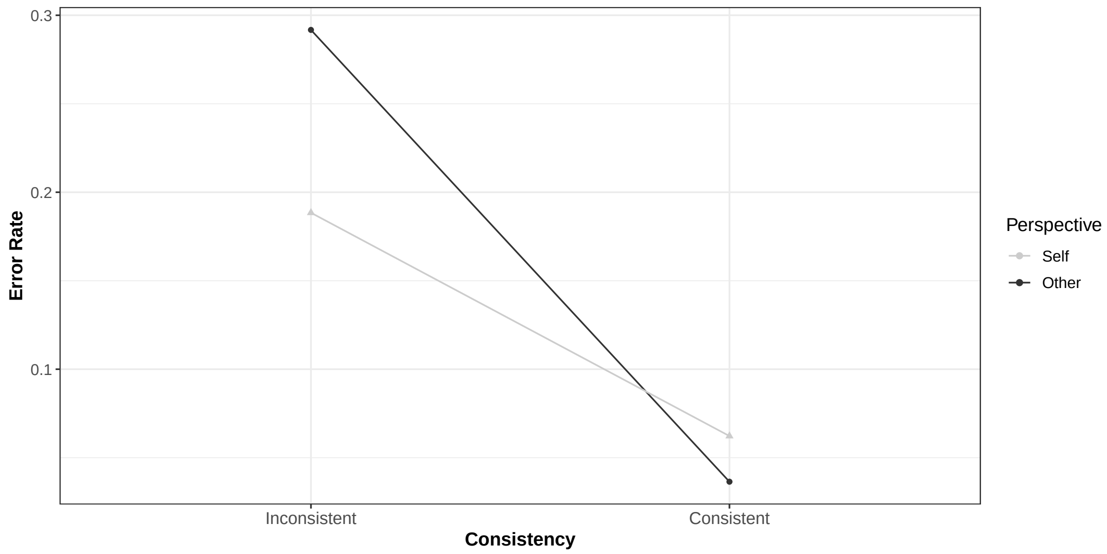


Figure 3.4: Estimated marginal means for each combination of stimulus presentation (Inconsistent vs Consistent) and perspective adopted (Self vs Other) for the error rates.

3.4 Planned post-hoc comparisons

Because predictors in models are conditional to all other factors with which they interact, they do not provide the desired comparisons. As specified in the introduction, to assess the mentalizing and the domain-general accounts only the Self level of the Perspective variable is relevant. Within this level of the Perspective variable, the comparison between Inconsistent and Consistent trials for both RTs and Errors was conducted. Post-hoc comparisons were extracted using the emmeans package version 1.5.4 (Lenth, 2021) and the Easystats package version 0.2.0 (Lüdecke et al., 2020). Decisions on the comparisons were based on the relative positions of the Highest Density Interval (HDI, Box & Tiao, 1992; Chauhan et al., 2017; Hespanhol et al., 2019) and the predefined regions of practical equivalence (ROPE) of 89% (Kruschke & Liddell, 2018a, 2018b; McElreath & Safari, 2020). In agreement with Kruschke & Liddell (2018a) the ROPEs were defined as +/- 0.1*SD for the contrasts.

3.4.1 Reaction Time analysis

Table 3.4 and Figure 3.5 show the interference (intended as the RTs difference between the Inconsistent and Consistent levels of Consistency variable)

As expected, the human photograph employed as a cue generates an attentional interference in the Dot Perspective Task. The entire HDI falls in fact outside of the ROPE indicating that 89% of the most credible values of the interference are different from the null value.

Table 3.4: Interference for the Type of cue variable.

Parameter	Mean	89% HDI	89% ROPE	% in ROPE
Inconsistent - Consistent, Self	0.12	[0.10, 0.15]	[-0.03, 0.03]	0%

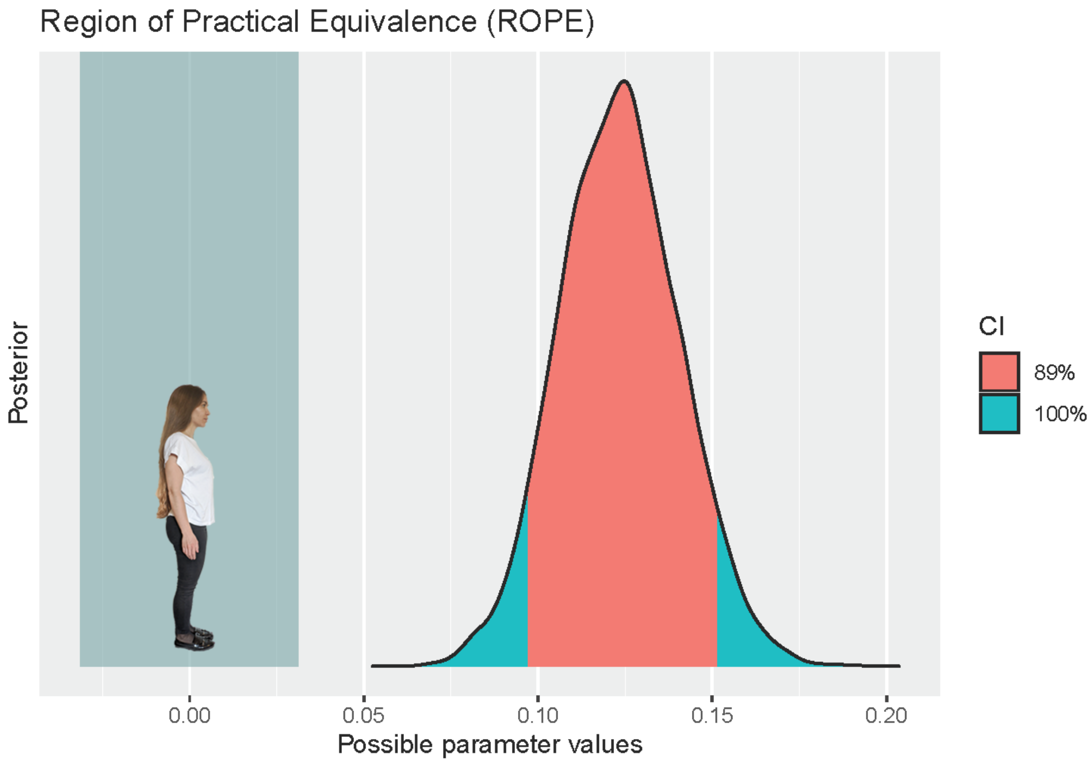


Figure 3.5: ROPE and HDI of the contrast between Inconsistent and Consistent trials for RTs.

3.4.2 Error Rates Analysis.

Table 3.5 and Figure 3.6 show the interference generated by the cue in the error rates. Similarly to the RTs, as expected, the entire HDI falls outside of the ROPE indicating that the totality of the 89% of the most credible values of the interference are different from the null value.

Table 3.5: Interference for the Type of cue variable.

Parameter	Mean	89% HDI	89% ROPE	% in ROPE
Inconsistent - Consistent, Self	0.13	[0.08, 0.17]	[-0.04, 0.04]	0%

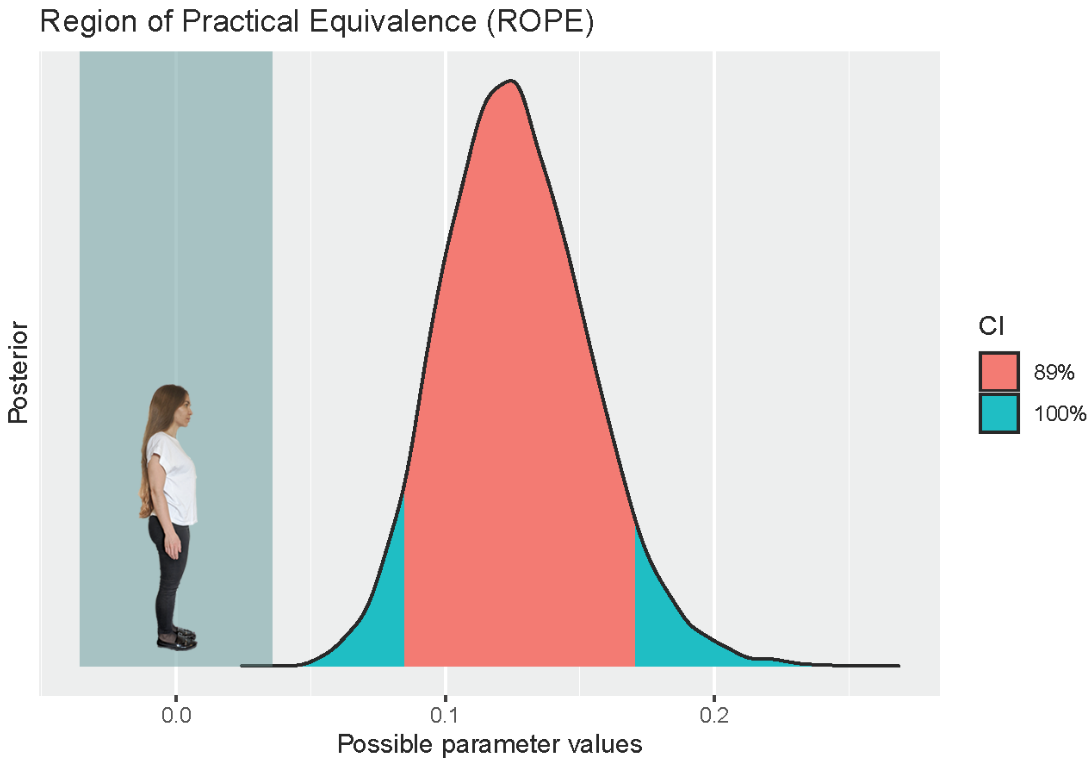


Figure 3.6: ROPE and HDI of the contrast between Inconsistent and Consistent trials for the error rates.

3.5 Discussion

Experiment 1 aimed to replicate previous results present in the literature (e.g., Cole et al., 2016; Samson et al., 2010; Wilson et al., 2017) whilst applying a Bayesian approach. Although both the domain-general and mentalizing accounts expect the cue employed in this experiment to generate interference, the two account's explanations of the phenomenon conflict. Whilst experiment 1 does not clarify which cognitive processes underlay the interference effect generated by the presence of others in the visual scene, it is essential to lay the groundwork for the application of the Bayesian approach to data resulting from the Dot Perspective Task. As mentioned in the general methods chapter, the Bayesian approach can gather evidence of a null result and distinguish between the absence of evidence and evidence of absence (Dienes, 2014). Additionally, the Bayesian technique offers a credible interval that identifies the most reliable points in the distribution of the variable under investigation. This enables a weighed assessment of the outcomes as opposed to a binary choice. These qualities are appealing for the purpose of evaluating the mentalizing and the domain-general explanations because (1) they provide an evaluation of their respective contributions, and (2) both accounts draw conclusions based on a null effect. As it was foreseeable, results were in line with previous literature that showed that a simple human figure or avatar presented from its side view in the visual scene does generate attentional interference for both the behavioural measures recorded in the dot perspective task, Reaction Times and Error Rates. As aforementioned, there is no consensus on the cognitive processes underlying the interference when participants judge and report what they personally observe. On the one hand, the mentalizing account explains this interference by arguing that while participants are evaluating their own viewpoint, they automatically take the perspective of the other person (e.g., Furlanetto et al., 2016; Morgan et al., 2018; Samson et al., 2010). The domain-general account, on the other hand, contends that the cause of this interference is the directional features of the other present in the visual scene, such as their posture and facial orientation (e.g., Cole et al., 2016; MacDorman et al., 2013; Wilson et al., 2017), denying therefore the participation of the Theory of Mind. As will be seen in the introduction paragraph of experiment 2, both accounts are supported by a range of experimental evidence. The mentalising account is backed by evidence that the interference disappears when the human avatar is substituted with a “rectangle distractor” (as in Samson et al., 2010), demonstrating that the social significance of the cue is required for the interference to occur. However, the fact that the interference can be generated also by directional stimuli devoid of a mental state, such as arrows (Santiesteban et al., 2014), cameras (Wilson et al., 2017), or even chairs, supports the domain-general account (MacDorman et al., 2013). The next chapters will assess the relative contribution of both mentalizing and domain-general processes in generating attentional interference by manipulating the cues employed in the dot perspective task.

4
Experiment 2

4.1 Introduction

Experiment 1 replicated previous results present in literature by showing that the presence of an other in the visual scene generate an interference effect, when we are judging our own perspective (e.g., Samson et al., 2010; Wilson et al., 2017). As anticipated, there is no consensus on the cause of this phenomenon occurring when participants report what they see themselves. Two accounts arose trying to explain the cognitive processes underlying this phenomenon. Whilst the mentalizing account interprets this interference effect as the result of visual perspective taking, the domain-general account interprets this interference effect as the results of domain-general processes. The former, building up on the notion of egocentric intrusion and on Theory of Mind, named this phenomenon altercentric intrusion (from the Latin alter “Other”)(e.g., Capozzi et al., 2014; Furlanetto et al., 2016; Morgan et al., 2018; Nielsen et al., 2015). The latter instead, suggests that the other’s directional features such as their posture and face orientation, are the cause of this interference (e.g., Cole et al., 2015; Cole & Millett, 2019; Heyes, 2014;

Langton, 2018) disputing the involvement of Theory of Mind and the concept of altercentric intrusion. As aforementioned in chapter 2, neither of the two accounts were able to fully rule out the other. In light of this, Capozzi & Ristic (2020) suggested an integrated approach: both domain-general and mentalizing processes may play a role in generating this interference effect. While directional cues may generate interference, a mental state attribution would modulate its magnitude.

This experiment assessed the role of the mentalizing and of the domain-general processes in generating an interference effect and their relative contribution. To do this, we focus on the features of the cue. In previous cues, the directional and social features that elicited domain-general and mentalizing processes were conjugated. That is, consider the avatar of Figure 1.3, the directional features -signified by its posture- and the social features - signified by its viewpoint- both indicate the same direction. As it is difficult, if not impossible, to disentangle the social from the directional feature of the avatar, it was reasoned that it can be possible to cancel out or attenuate the directional feature by providing the avatar with contrasting directional information. To this end, a bidirectional cue was developed. This cue consists of a dragon with an arrow-shaped tail pointing to the opposite direction of its muzzle (Figure 4.1a). In the dragon with the arrow-shaped tail, the social features of the muzzle (viewpoint) are isolated because the conjugated directional features are contrasted by the directional features of the tail[1] .The purpose of the tail was to cancel or attenuate the directional features of the dragon's posture (i.e.,

[1]Nielsen et al. (2015) suggested that the arrows should be considered as "semi-social" cues. In support of their claim, the authors refer to the works of Kingstone et al. (2004); Ristic & Kingstone (2012); Zwickel (2009). However, it is unclear how these works support this claim. These works show that both arrows and social cues direct attention. In addition, and most importantly, Nielsen et al.'s claim contrasts with Massironi & Bruno (2001)'s explanation: "The communicative power of arrows lies in the fact that they can convey information about orientation, intensity, and direction of a force, and they can do so in non-ambiguous, perceptually eloquent fashion, these perceptual features are readily detected by low-level, bottom-up visual processes" (p. 167).

muzzle, wings, paws, etc.). For this reason, the size of the tail was chosen to achieve similar directional effects to those of the posture. This was assessed by means of a preliminary experiment using the Posner spatial cueing paradigm (Posner & Coehn, 1984). In this task, participants are presented with a directional cue followed by a target stimulus which can appear either in the cued location (congruent) or in the opposite (incongruent). Participants are asked to detect as quickly as possible when the target appears. Typically, this task shows a cueing effect: slower RTs in the incongruent condition. No cueing effect emerged in this task when the dragon with arrow-shaped tail was employed as a cue whilst the effect emerged when the tail was removed. Thus, confirming the role of the tail to cancel out the directional features of the posture (see the "Preliminary Experiment section of this chapter). As the directional features of this cue are cancelled out or attenuated by the tail, this cue was referred to as the *Social_Only* cue. The reason of choosing a dragon with an arrow-shaped tail instead of any other bi-directional cue or combinations of cues (e.g., a human-avatar and an arrow pointing in the opposite direction) is because the dragon has the following desiderata:

- Fantasy creatures, such as a dragon, can orient attention in the same way as human avatars (MacDorman et al., 2013).
- As the dragon is present and inherited in every culture (Blust, 2000; Khalifa-Gueta, 2018), attention orientation is not affected by the lack of familiarity with the cue;
- As the arrow-shaped tail follows the body harmoniously, it is not recognized as an additional cue, attention orientation is not affected by the complexity of a scene with multiple cues. The effects of the *Social_Only* cue were compared

with those of a similar dragon without the arrow-shaped tail (Figure 4.1b)[2] . In this case, the directional features of the body's posture are not contrasted by any other directional features. Therefore, both social and directional features of the head conjugately orient attention. This cue was named as the *Social+Directional* cue. The preliminary experiment confirmed that this cue directs attention (see the Preliminary Experiment section of this chapter).

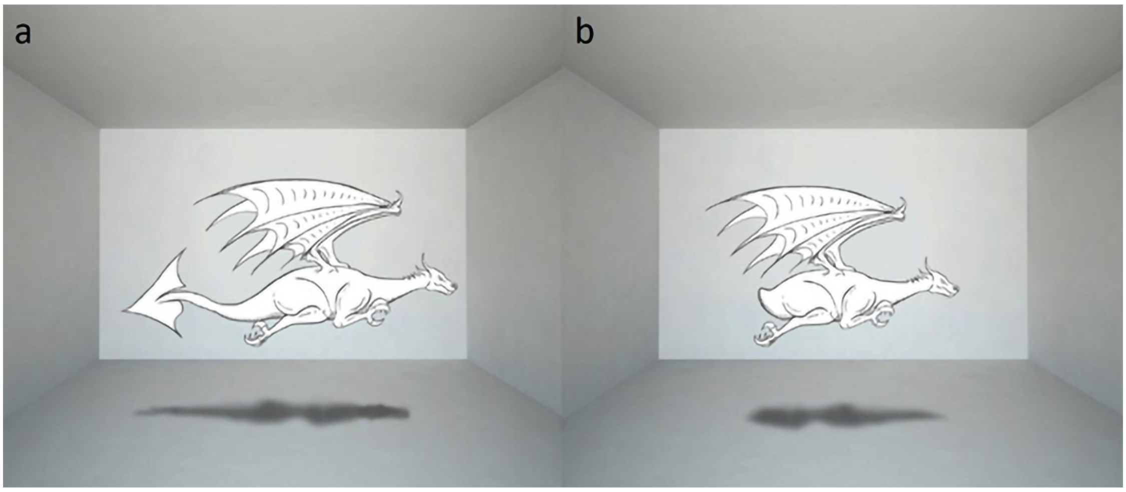


Figure 4.1: Cues used in this experiment. a) *Social_Only* cue: A dragon with an arrowed shaped tail pointing to the opposite direction of the muzzle. The role of the tail is to contrast the directional features of the dragon's muzzle leaving only its social features. b) *Social+Directional* cue: same dragon but without the arrowed shaped tail. The directional feature of the muzzle is not contrasted by any directional features.

4.1.1 Account's predictions

Hence, by using the aforementioned cues in the dot perceptive task, it is possible to clarify the relative contribution of social and directional features and discriminate the predictive validity of the mentalizing and domain-general accounts in generating interference effect. Specifically, when participants are judging their own perspective,

[2]The effects of the *Social_Only* cue were not compared, instead, with those of a dragon without the muzzle (e.g., a "Directional_Only" cue). This condition would have been superfluous for the aim of comparing the two accounts. As pointed out by Cole & Millet (2019), showing that a directional-only cue generates interference does not rule out the mentalizing account because different processes may give rise to a similar effect.

the two accounts make different predictions:

- The mentalizing account predicts that both *Social_Only* and *Social+Directional* cue generate the same amount of interference. This is because according to this account; the directional features on their own are not sufficient to generate interference, but the social features need also to be present in the cue;

- The domain-general account predicts that the *Social_Only* cue should generate less or no interference because the directional features of the body posture are cancelled out or attenuated by the tail, leaving no directional features to orient attention[3].

So far it was assumed that an interference emerges in both the RTs and error measures. However, this might not be the case. As mentioned, discordant results between RTs and errors emerged in the studies of Cole et al. (2015); Langton (2018); O'Grady et al. (2020), where an interference emerged in the RTs but not in the error rate. In this regard, Prinzmetal et al. (2005) suggest that there are two processes whereby spatial cues capture attention: A voluntary process, affecting both RTs and errors, and an involuntary process, affecting RTs only. The involuntary process represents an instinctive orienting response to the cue whilst the voluntary process strategically allocates perceptual resources. If this is the case, it can be hypothesized that the involuntary process, affecting RTs only, is driven by the directional features of the cue, whilst the voluntary process, affecting both RTs and errors, is driven by the social features of the cue. Consequently, with the *Social_Only* cue the interference should emerge in the error rate, whilst

[3]The scenario in which the interference generated by the *Social+Directional* cue is smaller than that generated by the *Social_Only* cue is not plausible. It would mean that the arrow-shaped tail orient attention opposite to where it points.

it should be reduced in the RTs because only the voluntary process is at play. This result would support the integrated approach advanced by Capozzi & Ristic (2020) because it would imply that both the mentalizing and the domain-general processes are playing a role in the dot perspective task.

4.2 Methods

4.2.1 Sampling plan and stopping rule

Sampling plan and stopping rule followed the Sequential Bayes Factors (SBF) procedure (Schönbrodt et al., 2017) presented in chapter 2 of this thesis. Thus, data collection continued until the predetermined stopping criterion at the point of checking was reached. Sampling was stopped after collecting 16 participants per each type of cue as one of the BF10 was higher than 10 (specifically, the BF10 of the interference for the *Social+Directional* cue was equal to 141).

4.2.2 Participants

32 Participants took part in this study (age range 22 to 47) of which 20 females. Participants were naïve to the purpose of the study and received no remuneration for taking part. Informed consent was obtained from each participant through the Qualtrics online platform (`https://www.qualtrics.com`) in accordance with the University's ethical procedures.

4.2.3 Design

The variables used in the study were: Consistency (Inconsistent vs Consistent), Perspective (Self vs Other) and Types of cue (*Social_Only* vs *Social+Directional*). While the variables Consistency and Perspective were measured within-subjects – as the dot-perspective task requires – the variable Types of cue was measured between-subjects. This was to control for the "experimental subordination" phenomenon (Asch, 1956; Gilchrist, 2020). If the same participants would have seen a dragon with and without the tail, they might have adjusted their answers according to what they thought they were expected to respond.

4.2.4 Stimuli and Procedure

Stimuli presentation and procedure were accordingly to the general procedure presented in chapter 2 of this thesis. In this experiment, the pronouns YOU and DRAGON were employed to prompt participants respectively with the "Self" or "Other" perspective. In total, 80 trials were presented to each participant. These comprised 36 YES and 44 NO response trials. 36 were Consistent trials, 36 were Inconsistent trials and 8 were fillers, in which no discs were presented. Furthermore 40 trials had as prompted perspective YOU while the remaining 40 had DRAGON[4]. Before the start of the experiment, participants took part in a small practice of 12 trials to familiarize with the task. The experiment lasted on average 15 minutes.

4.3 Results

4.3.1 Descriptive Statistic

Means and standard deviations for both RTs and error rate are shown in Table 4.1 and Figure 4.2.As per Whelan (2008), trials in which RTs are faster than 100 ms should be considered non-genuine. No RTs lower than 100 ms were present in this study. No trimming was conducted on higher reaction times, given the imposed cut-off of 2000 ms on all trials.

[4]Note that Wilson et al. (2017) found that impersonal pronouns generate the same amount of interference as personal pronouns therefore the prompt DRAGON was used (see also MacDorman et al., 2013).

Table 4.1: Mean and SD for RTs and Error Rates.

Perspective	Consistency	TypeofCue	Mean	sd
RTs				
Other	Inconsistent	Social_Only	0.780	0.276
		Social+Directional	0.761	0.231
	Consistent	Social_Only	0.695	0.262
		Social+Directional	0.695	0.242
Self	Inconsistent	Social_Only	0.731	0.229
		Social+Directional	0.789	0.259
	Consistent	Social_Only	0.728	0.306
		Social+Directional	0.708	0.231
Errors				
Other	Inconsistent	Social_Only	0.097	0.297
		Social+Directional	0.196	0.398
	Consistent	Social_Only	0.028	0.165
		Social+Directional	0.084	0.278
Self	Inconsistent	Social_Only	0.232	0.424
		Social+Directional	0.167	0.374
	Consistent	Social_Only	0.105	0.307
		Social+Directional	0.021	0.144

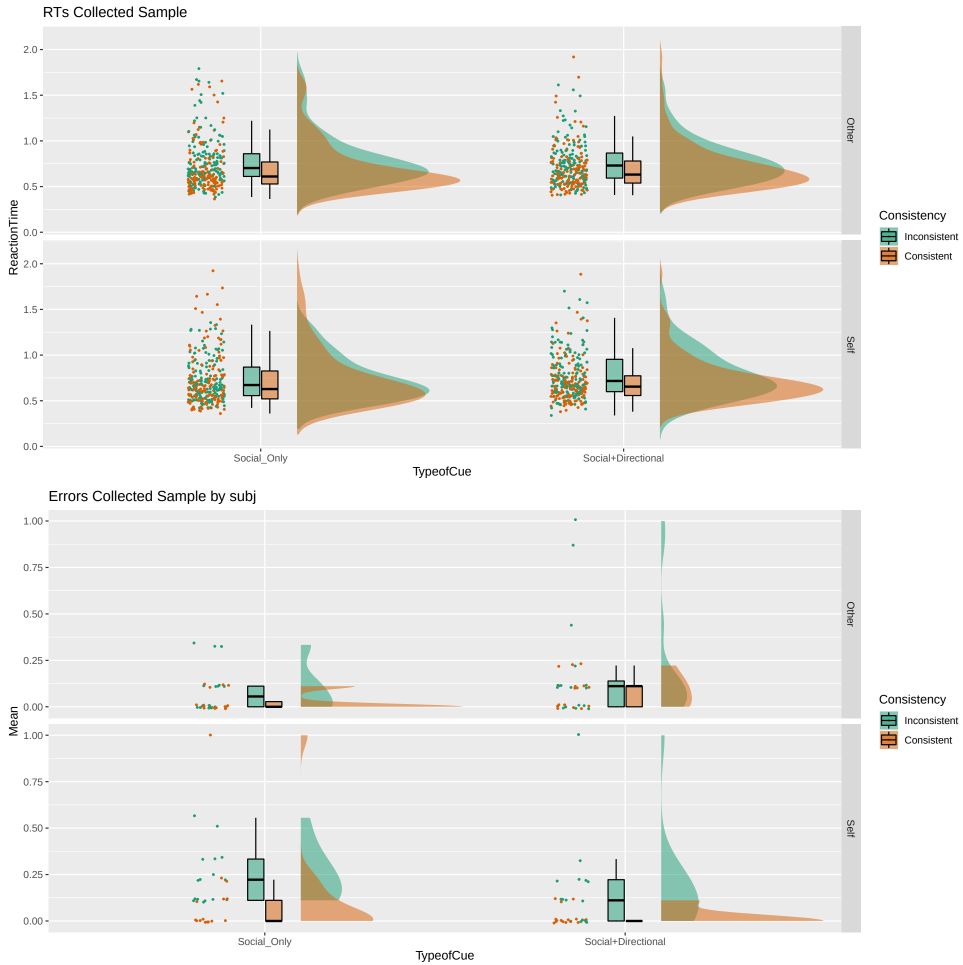


Figure 4.2: Rain plots reporting Mean and SE of distribution for sample's RTs on the left and Error Rates on the right for each combination of stimulus presentation (Consistent vs Inconsistent) and perspective adopted (Self vs Other) for the two types of cues (*Social+Directional* vs *Social_Only*). Error rates are averaged also by Subject.

As it can be seen, for the RTs an interference pattern (intended as the mean difference between the Inconsistent and the Consistent trials) emerged for both the level of the Perspective variable. In addition, for the Self, the interference was much higher in the *Social+Directional* cue than in the *Social_Only* cue, where it was negligible (0.081 seconds and 0.003 seconds on average, respectively).

A similar interference pattern emerged for the error rate. However, for the Self condition of the Perspective variable the interference was alike for the two types of cue, with a mean error rate of 0.146 (sd 0.23) and 0.127 (sd 0.12) for the *Social+Directional* and *Social_Only* cues, respectively.

4.3.2 Data Analysis

To enable generalization across stimuli and participants, data were analysed with mix-models (Judd et al., 2012); specifically, Bayesian mix-models were created in Stan computational framework (Carpenter et al., 2017) accessed with the high-level interface "brms" package 2.10.0 (Bürkner, 2017, 2018) in R version 3.6.2 (R Core Team, 2020). Two models were run, one for the RTs and another for the error rate. For both models, the variables Perspective, Consistency and Types of cue - together with their interaction - were inputted as population-level factors and the variable Subject as group-level factor. Moreover, as each combination of the conditions was presented in more than 1 trial, the variable Trials was also inputted in the models as a group-level factor nested within the variable Subject. The two models were therefore similar in their formulae; however, we utilized the Weibull family distribution for the RTs (Logan, 1992; Palmer et al., 2011; Rouder et al., 2005) and the Bernoulli family distribution for the error rate (Bürkner, 2018). For testing opposite predictions, we set flat priors for the population level effects and weakly informative priors for the intercept [student_t(3, 0.7, 2.5)] and for the group level effects [student_t(3, 0.7, 2.5)]. For model estimation, four chains with 4000 iterations (2500 warmup) were used. Convergence was checked via Gelman & Rubin (1992) convergence statistics (Rhat close or equal to 1.0) and by visual inspection of the posterior distribution of all the coefficients and their chain convergence.

4.3.3 Reaction Time Analysis

Table 4.2 shows the results of the Bayesian linear mixed-effects model. Figure 4.3 shows the estimated marginal means of the interaction between Consistency and Perspective split by the two types of cues. It emerged a main effect of Perspective with shorter RTs for the Self trials [-0.06, SE 0.03, 95% CI (-0.11 -0.01)] and of Consistency with shorter RTs for the Consistent trials [-0.13, SE 0.03, 95% CI (-0.18, -0.08)]. It emerged also an effect of the interaction between Perspective and Consistency with longer RTs in the Self and Consistent trials [0.12, SE 0.04, 95% CI (0.04, 0.19)] and between Perspective and Type of cue with longer RTs in the Self and *Social+Directional* trials [0.10, SE 0.04, 95% CI (0.03, 0.18)]. There was also an effect of the three-way interaction that is further explored in the planned comparisons.

Table 4.2: Population level effects of the brms model.

Covariate	Estimate	Est.Error	l-95% CI	u-95% CI
Intercept	-0.29	0.07	-0.41	-0.16
PerspectiveSelf	-0.06	0.03	-0.11	-0.01
ConsistencyConsistent	-0.13	0.03	-0.18	-0.08
TypeofCueSocialPDirectional	-0.01	0.09	-0.19	0.18
PerspectiveSelf:ConsistencyConsistent	0.12	0.04	0.04	0.20
PerspectiveSelf:TypeofCueSocialPDirectional	0.10	0.04	0.02	0.18
ConsistencyConsistent:TypeofCueSocialPDirectional	0.04	0.04	-0.03	0.12
PerspectiveSelf:ConsistencyConsistent:TypeofCueSocialPDirectional	-0.14	0.06	-0.25	-0.03

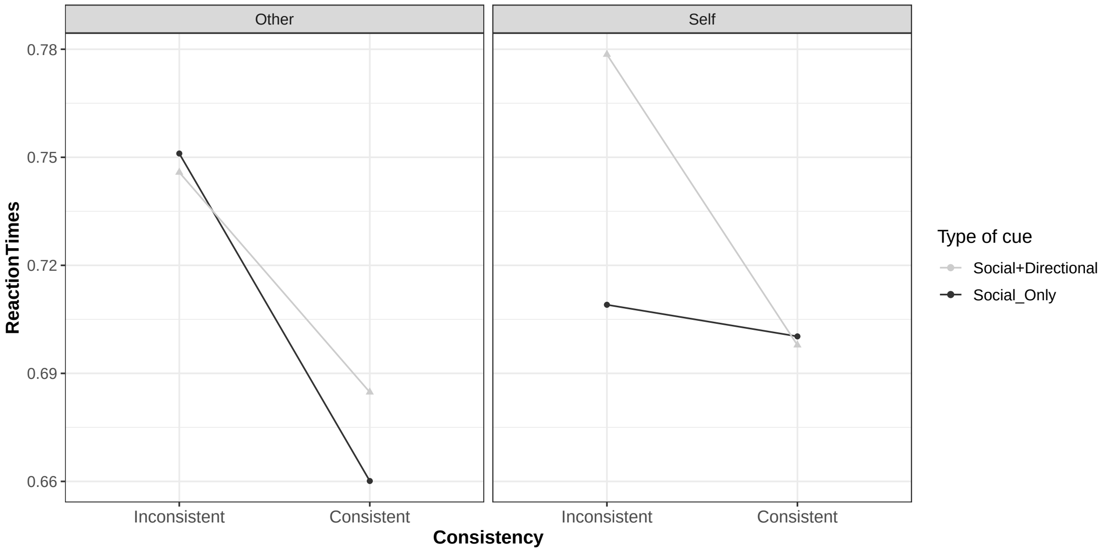


Figure 4.3: Estimated marginal means for each combination of stimulus presentation (Inconsistent vs Consistent) and Type of cue (*Social+Directional* vs *Social_Only*) for perspective adopted (Self vs Other).

4.3.4 Error Rate analysis

Table 4.3 shows the results of the Bayesian mixed-effects model and Figure 4.4 shows the estimated marginal means of the interaction between Consistency and Perspective split by the two types of cue. A main effect of Perspective emerged, with higher error rate for the Self condition [1.21, SE 0.37, 95% CI (0.49, 1.94)]. A main effect of Consistency also emerged, with lower error rate for the Consistent trial [-1.49, SE 0.62, 95% CI (-2.81, -0.34)]. In addition, an interaction effect between Perspective and Types of cue emerged, with lower error rate in the Self - *Social+Directional* condition [-1.47, SE 0.50, 95% CI (-2.45, -0.50)].

Table 4.3: Population level effects of the brms model.

Covariate	Estimate	Est.Error	l-95% CI	u-95% CI
Intercept	-2.58	0.41	-3.42	-1.80
PerspectiveSelf	1.20	0.37	0.50	1.95
ConsistencyConsistent	-1.50	0.61	-2.78	-0.37
TypeofCueSocialPDirectional	0.88	0.55	-0.19	1.97
PerspectiveSelf:ConsistencyConsistent	0.42	0.70	-0.91	1.84
PerspectiveSelf:TypeofCueSocialPDirectional	-1.46	0.51	-2.48	-0.50
ConsistencyConsistent:TypeofCueSocialPDirectional	0.30	0.74	-1.11	1.78
PerspectiveSelf:ConsistencyConsistent:TypeofCueSocialPDirectional	-1.84	1.06	-4.00	0.22

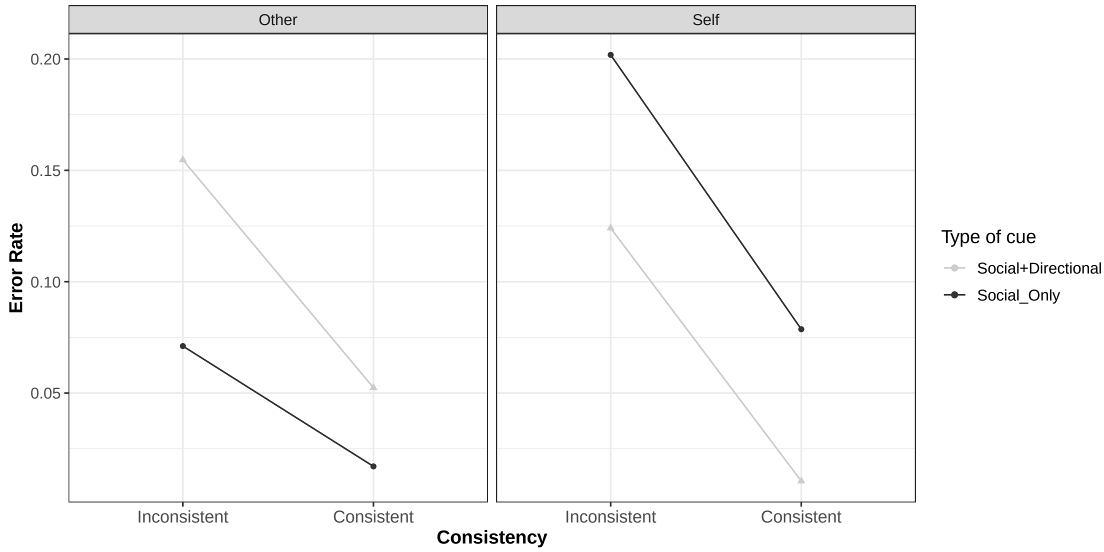


Figure 4.4: Estimated marginal means for each combination of stimulus presentation (Inconsistent vs Consistent) and Type of cue (*Social+Directional* vs *Social_Only*) for perspective adopted (Self vs Other).

4.4 Planned post-hoc comparisons

Because predictors in models are conditional to all other factors with which they interact, they do not provide the desired comparisons. As specified in the introduction, to assess the mentalizing and the domain-general accounts only the Self level of the Perspective variable is relevant. Within this level of the Perspective variable, the following comparisons were conducted:

- Inconsistent vs Consistent within the *Social+Directional* type of cue;
- Inconsistent vs Consistent within the *Social_Only* type of cue;
- Between the interferences of the two cues (Inconsistent - Consistent in the *Social+Directional* cue vs Inconsistent - Consistent in the *Social_Only* cue). Post-hoc comparisons were extracted using the emmeans package version 1.5.4 (Lenth, 2021) and the Easystats package version 0.2.0 (Lüdecke et al., 2020). Decisions on the comparisons were based on the relative positions of

the Highest Density Interval (HDI, Box & Tiao, 1992; Chauhan et al., 2017; Hespanhol et al., 2019) and the predefined regions of practical equivalence (ROPE) of 89% (Kruschke & Liddell, 2018a, 2018b; McElreath & Safari, 2020). In agreement with Kruschke & Liddell (2018a) the ROPEs were defined as +/-0.1*SD for the contrasts.

4.4.1 Reaction Time analysis

Table 4.4 and Figure 4.5 show the interference (intended as the RTs difference between the Inconsistent and Consistent levels of Consistency variable) generated by the two cues. The *Social+Directional* cue clearly generates an interference; the entire HDI falls outside of the ROPE indicating that 89% of the most credible values of the interference are different from the null value. There is instead only a 15% probability that the *Social_Only* cue generates interference; 85% of the HDI falls within the ROPE, indicating that 85% of the most credible values of the interference are practically equivalent to the null value.

Table 4.4: Interference for the Type of cue variable.

Parameter	Mean	89% HDI	89% ROPE	% in ROPE
Inconsistent - Consistent, Social_Only, Self	8.50e-03	[-0.02, 0.04]	[-0.03, 0.03]	85.07%
Inconsistent - Consistent, Social+Directional, Self	0.08	[0.05, 0.11]	[-0.03, 0.03]	0%

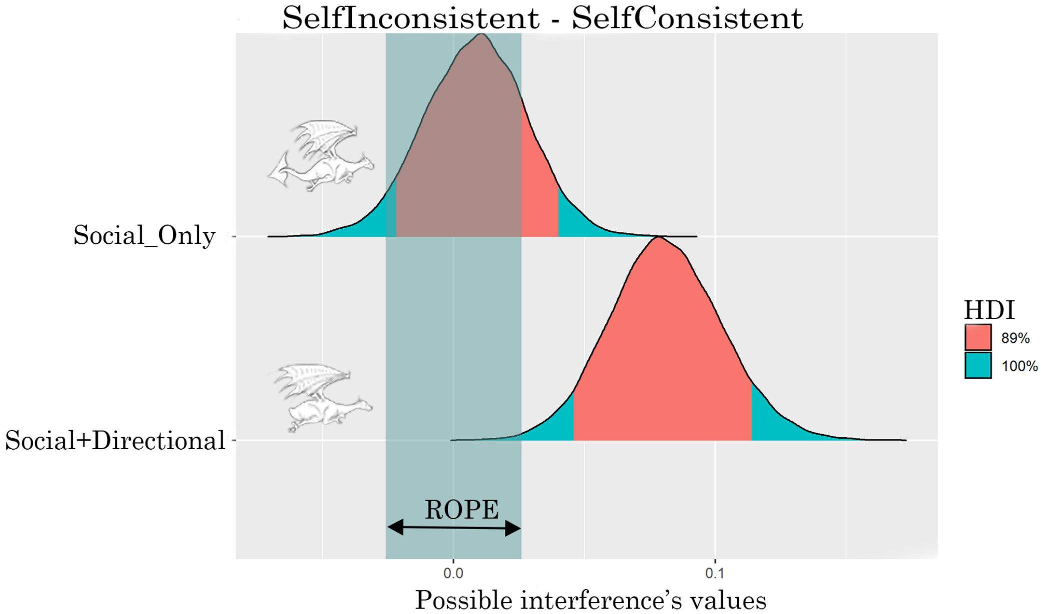


Figure 4.5: ROPE and HDI of the interaction for a) *Social+Directional* cue; b) *Social_Only* cue.

The comparison between the two interferences (i.e. the interferences generated by the two types of cue) is shown in Table 4.5 and Figure 4.6 . It can be seen that the *Social+Directional* cue generated much more interference than the *Social_Only* cue. The entire HDI falls outside of the ROPE indicating that 89% of the most credible values of the difference between the interferences are different from the null value.

Table 4.5: Interference difference between the two cues.

Parameter	Mean	89% HDI	89% ROPE	% in ROPE
Inconsistent - Consistent, Social_Only - (Social+Directional), Self	-0.07	[-0.12, -0.03]	[-0.03, 0.03]	0%

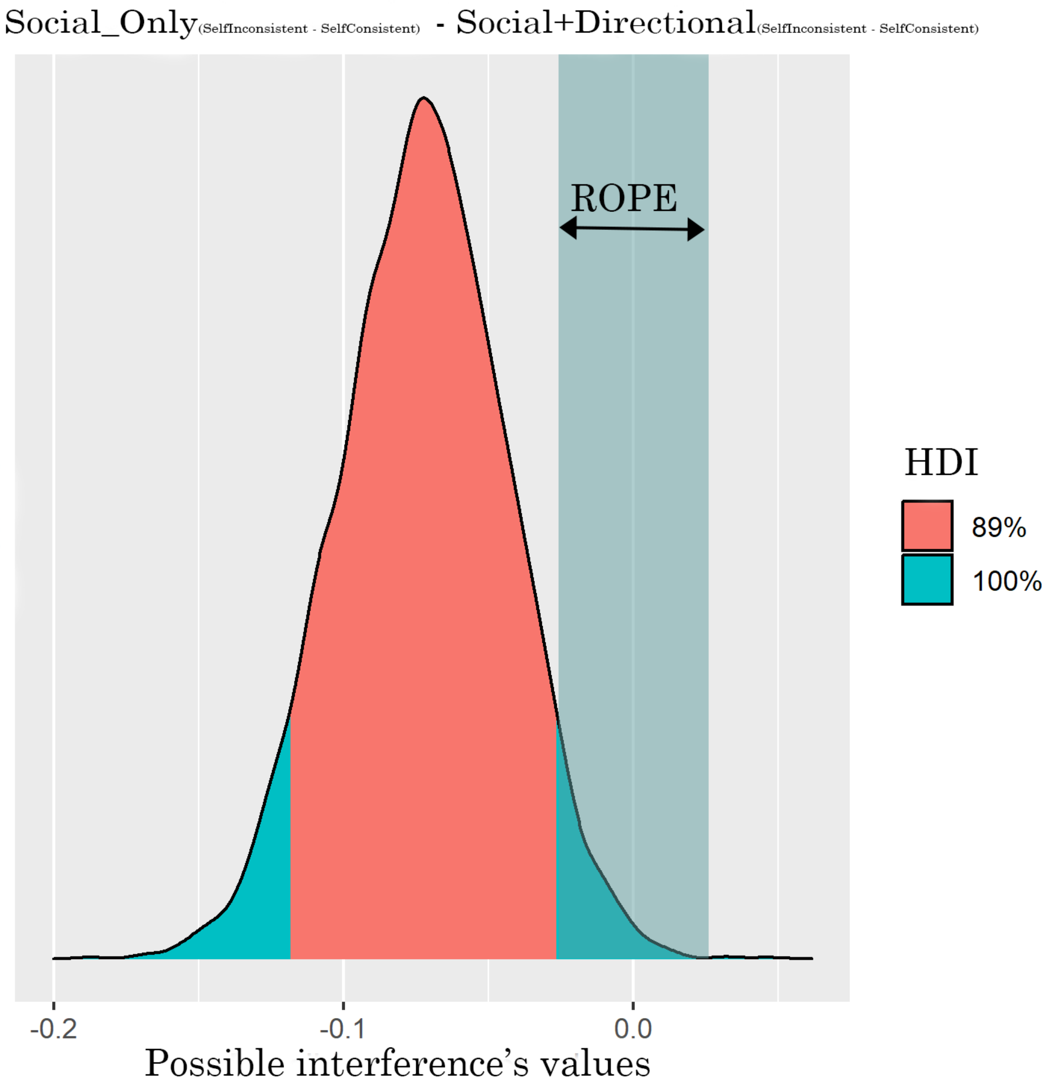


Figure 4.6: ROPE and HDI of the difference between the interference of the two types of cues.

4.4.2 Error Rates Analysis.

Table 4.6 and Figure 4.7 show the interference generated by the two cues. Both cues show an interference pattern. For both cues, the entire HDI falls outside of the ROPE indicating that 89% of the most credible values of the interference are different from the null value.

Table 4.6: Interference for the Type of cue variable.

Parameter	Mean	89% HDI	89% ROPE	% in ROPE
Inconsistent - Consistent, Social_Only, Self	0.12	[0.05, 0.20]	[-0.03, 0.03]	0%
Inconsistent - Consistent, Social+Directional, Self	0.12	[0.05, 0.17]	[-0.03, 0.03]	0%

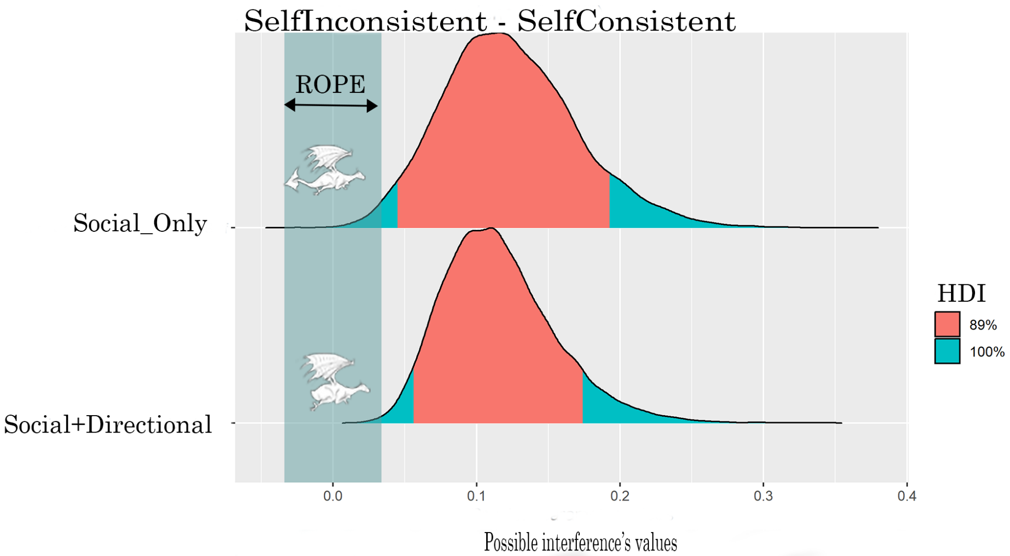


Figure 4.7: ROPE and HDI of the interaction for a) *Social+Directional* cue; b) *Social_Only* cue for error rates.

The comparison between the interferences generated by the two types of cue is shown in Table 4.7 and Figure 4.8. It can be seen that the two types of cue generated a similar amount of interference with no evident difference between the two cues.

Table 4.7: Interference difference between the two cues.

Parameter	Mean	89% HDI	89% ROPE	% in ROPE
Inconsistent - Consistent, Social_Only - (Social+Directional), Self	7.72e-03	[-0.09, 0.11]	[-0.03, 0.03]	47.65%

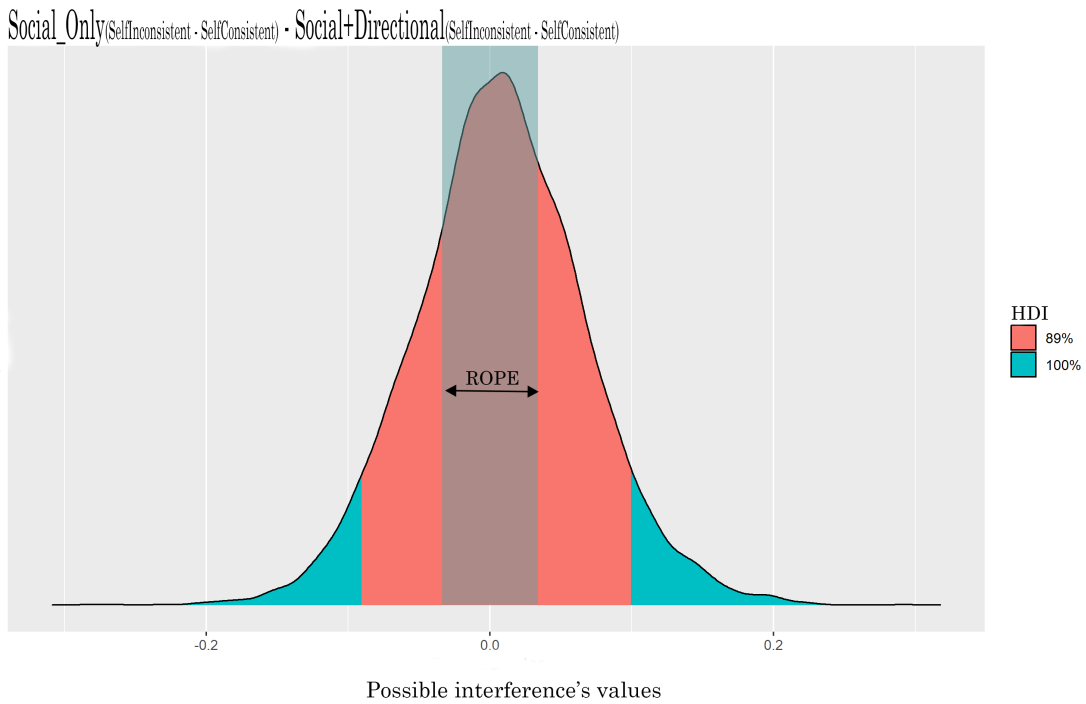


Figure 4.8: ROPE and HDI of the difference between the interference of the two types of cues.

4.4.3 Control Analysis on Errors

As the analysis of the errors was not in line with the RTs analysis, further investigations were conducted. First, it was thought that the incongruence between RTs and error rate may have something to do with the arrangement of the scene. There were two types of Inconsistent trials, one in which the targets were presented all in the same wall and a second one in which the targets were presented in both walls. The differences in Errors between the two types of trials were investigated for both cues through a Bayesian mixed-effects model. The model included the variables Consistency and Types of cue - together with their interaction – and Walls as population-level factors and the variable Subject and Trials nested within Subject as group-level factor. Table 4.8 show the results of the model. As can be seen, no effect of the number of walls emerged.

Table 4.8: Population level effects of the brms model.

Covariate	Estimate	Est.Error	l-95% CI	u-95% CI
Intercept	-0.68	0.62	-1.93	0.54
ConsistencyConsistent	-1.39	0.41	-2.21	-0.61
TypeofCueSocialPDirectional	-0.63	0.56	-1.77	0.44
Walls	-0.53	0.36	-1.23	0.16
ConsistencyConsistent:TypeofCueSocialPDirectional	-1.56	0.82	-3.28	-0.06

4.5 Discussion

Experiment 2 aimed to investigate and assess the relative contribution of social and directional features of a cue in generating the interference effect recorded in the dot perspective task. As seen in Experiment 1, this interference is due to participants reflexively shifting their attention towards the direction faced by the cue. Using a human avatar as a cue, however, may not be ideal to compare the two accounts because both the social and the directional features of the avatar jointly point to the same direction. Instead of a human avatar, therefore, a bidirectional cue represented by a dragon with an arrow-shaped tail pointing oppositely to its posture was employed in Experiment 2. It was hypothesized that the directional features of the tail would cancel out or attenuate the directional features of the muzzle, isolating therefore the social features. This has been confirmed by a preliminary experiment (Preliminary experiment section of this chapter), which showed that the directional features of this cue have scarce effect in orienting attention. This cue was named *Social_Only* cue. Two clarifications must be made. The first pertains the social features of the dragon. It may be objected that a dragon shaped avatar is different from a human avatar as it does not resemble a human figure and it is a fantasy creature; hence, it may be claimed that it does not have any social feature. It should be noted that different studies showed that non-human animals as well as mascots and fantasy creatures do orientate attention in the same way as human avatars (Dujmovi & Valerjev, 2018; MacDorman et al., 2013; Simon et al., 1976). In particular, MacDorman et al. (2013) showed that the eeriness of the others does not stop people to take their perspective, whereas this can be affected by previous exposure/familiarity to them. As the dragon is present and inherited in every culture (Blust, 2000; Khalifa-Gueta, 2018), it can be assume that it is a familiar cue in which participants can identify a viewpoint, which signifies its social feature. Second, Nielsen et al. (2015) claimed that arrows also include some social features and should be considered as semi-social cues. This would imply that the arrow-shaped tail of the *Social_Only* cue should attenuate the social features in addition to its directional features. This claim is not empirically supported and contrasts with Massironi & Bruno (2001)' s explanation of the role of arrows (see footnote 1). Even conceiving that arrows embed some social features, these are surely secondary to their directional features. In our main experiment, the effects of the *Social_Only* cue were compared with those of a similar cue devoid of the tail. The directional features of this cue were not contrasted by anything else, resulting in a *Social+Directional* cue. A preliminary experiment (see Appendix A) confirmed that the directional features of this cue do direct attention. Results of the main experiment showed a different pattern of interference between RTs and error rate. From the analysis of the RTs, it emerged that whilst the *Social+Directional* cue generated a strong interference, the *Social_Only* cue did not. This result clearly supports the domain general account because the social features of the cue alone were not capable of generating the interference. It should be also stressed that the effect of the arrow-shaped tail in cancelling out the interference was particularly strong considering that the tail was irrelevant for the task. Participants in the *Social_Only* condition were never asked to pay attention to the dragon's tail, nor the tail was mentioned in the instructions or in any other moment of the experiment. The analysis of the errors, however, was not in line with that of RTs. Inconsistency between RTs and errors is not new. More errors were performed by participants in the Inconsistent trials than in the Consistent trials with both cue types. This indicates that the interference persisted even when the social features were isolated. Differently from the analysis of RTs, this result supports the mentalizing account. There is, however, another interesting outcome emerging from the analysis of the errors: overall there were more errors in the *Social_Only* cue than in the *Social+Directional* cue. The following sections will offer an interpretation of 1) why the *Social_Only* cue generated more errors than the *Social+Directional* cue; 2) why the interference was observed for the errors but not for the RTs in the *Social_Only* cue.

4.5.1 Higher errors in the *Social_Only* cue: speed/accuracy trade-off

In a first instance, it was hypothesised that the higher number of errors in the *Social_Only* cue could have been caused by a confounding variable. In some of the Inconsistent trials, the targets appeared all in one wall but in other they appear in two walls. A dedicated analysis, however, showed that this was not the case: the difference of errors between the two conditions, one wall vs two walls, was similar. The speed/accuracy trade-off, however, can explain the result. When the time constraint is short (2 seconds in our case) and the task is more complex, participants may focus on speed rather than accuracy. In our experiment, the *Social_Only* cue – having two contrasting directional features – can be thought as more complex than the *Social+Directional* cue. As the speed resulted to be similar for the two cues, a decrease in accuracy must emerge in the more complex cue.

4.5.2 *Social_Only* cue: Interference in errors but not in RTs.

The speed/accuracy trade-off hypothesis cannot however explain the interference in the errors of the *Social_Only* cue. This would have generated a similar number of errors in both Consistent and Inconsistent trials. The presence of an interference in errors but not in RTs favours the hypothesis that the two measures reflect different processes (Prinzmetal et al., 2005). As mentioned in the introduction, Prinzmetal et al. suggested that attention is driven by both a voluntary process, which affects both RTs and accuracy, and an involuntary process which affects RTs only. At this regard, Prinzmetal et al. (2005) suggested that voluntary attentional processes operate via channel enhancement, whilst involuntary attentional processes operates via channel selection. Accordingly, it can be suggested that the dot perspective task requires both, an involuntary orienting process, and voluntary processes. Participants are first involuntarily oriented towards the location indicated by the directional features of the cue, then, a voluntary decisional process confirms whether the number of targets visible from the given perspective correspond to the prompted one. This decisional process is affected by the social features of the cue. When the social features are isolated, the elicited mentalizing processes on their own have scarce or no power to direct attention; they can only affect the decisional process [5].

[5] It is important to notice that here the voluntary decisional process does not correspond to the definition of "decisional process" advanced by Prinzmetal et al. (2005). Prinzmetal et al. (2005) define as decisional process the involuntary attentional process that directs one's attention towards the location that contains the target, thus answering the question: "Which location contains the target?" (Prinzmetal et al., 2005, p. 74), which correspond to the involuntary orientating process of the advanced interpretation. Here, the decisional process represents the response selection process, modulated by the social features of the cues. This is evident in Prinzmetal et al. (2005, p. 88) when the authors state: *"Channel selection, on the other hand, does not affect the perceptual representation but involves a decision as to which location should be responded to. If there is a conflict as to which location should be responded to, responses are delayed".* In this thesis, the responses are expected to be delayed when the point of view/directional features of the cue are inconsistent with the location of the target discs. In other words, higher reaction times when in inconsistent conditions.

This might explain why mentalizing processes have not been detected by some studies (Cole et al., 2015; Conway et al., 2017; Santiesteban et al., 2015; Wilson et al., 2017 and others). Moreover, it can also explain why some other studies did not detect the interference in the error rate (Cole et al., 2016; Langton, 2018; O'Grady et al., 2020). In these cases, it can be assumed that the involuntary process driven by the directional features of the cue might have overpowered the voluntary process driven by the social features. To sum up, when another is present in the visual scene and we are requested to validate/confirm our point of view, our attention is oriented by the other's directional features while their social features affect our voluntary attentional processes. RTs and error are often employed to measure the same cognitive processes, even in studies employing the dot perspective task. Previous ambiguous results, together with our findings, show that this should not be always assumed. The suggested integrated approach between the mentalizing and domain general accounts is further supported by the results originated from tasks eliciting either the decisional or the orienting process separately. For example, in the Posner's spatial cueing task (Posner & Coehn, 1984), which does not require any decisional process, Hayward & Ristic (2018) showed that a directional cue direct attention regardless of its social features. Conversely, in a task that engages only a decisional process, as in the Room Observer and Mirror Perspective test [ROMP; Bertamini & Soranzo (2018); Soranzo et al. (2021)], in which participants were asked to judge how many targets are visible from a given position indicated by a cue, an advantage emerges for social cues compared to non-social cues.

4.5.3 Conclusions

To summarise, Experiment 2 investigated the role of social and directional features of the other in reflexively orientating attention by developing a cue having only social features (*Social_Only* cue) and comparing its effects with a cue with conjugated social and directional features (*Social+Directional* cue). Results showed that while the *Social+Directional* cue was able to generate interference in both RTs and error rate, the *Social_Only* cue did not generate interference in the RTs but only in the error rate. It can be suggested that in the dot perspective task two processes are involved: an involuntary orientating process - measured by the RTs - and voluntary processes – measured also by the error rate. An integrated approach between the mentalizing and the domain general accounts can be proposed in order to explain the interference effect emerging in the dot perspective task.

4.6 Preliminary experiment

4.6.1 Introduction and Methods

Two preliminary experiments were conducted to assess whether the *Social_Only* and *Social+Directional* cues orient attention. For this purpose, an adapted version of the Posner paradigm (Posner & Coehn, 1984) was used. The experimental sequence of the events was as follow: At the beginning, a fixation cross was presented at the centre of a computer screen for 1000 ms. This was then followed by the onset of a cue (*Social_Only* cue in experiment 1A and *Social+Directional* cue in experiment 1B) in the centre of the screen for 200 ms. A target disc was then presented either to the left or to the right. Participants were asked to press the "LEFT" key on their keyboard when the target appeared on the left and the "RIGHT" key when the target appeared on the right. A total of 128 trials were presented in a random order. As in a typical Posner paradigm, in 75% of the trials the cue faced towards the location of the target (Congruent) and to the opposite direction in the remaining 25% (Incongruent). Reaction times were recorded. After 64 trials, participants were requested to have a break in order to avoid any fatigue effect. Before starting the experiment, participants underwent a short practice. 32 participants in total (16 per experiment, see methods section in the main study for the power analysis) took part in this study (age range 22 to 55 years old) of which 16 females. Participants were naïve to the purpose of the study and received no remuneration for taking part. None of these participants took part in the main study. See main study for recruitment and ethics procedure.

4.6.2 Results

For a description of the statistical tools employed in this preliminary study see the main study results section. Means and standard deviations for RTs are shown in Table 4.9

Table 4.9: Mean and SD for RTs.

Congruency	Group	Mean	sd
RTs			
Incongruent	Social_Only	0.492	0.131
	Social+Directional	0.535	0.225
Congruent	Social_Only	0.477	0.143
	Social+Directional	0.474	0.215

As it can be seen in Table 4.9, participants were faster in the Congruent than in the Incongruent condition for both *Social_Only* and *Social+Directional* cue. However, a meaningful difference is evident between the two cues. Participants were overall slower in the Incongruent condition of the *Social+Directional* cue. Figure 4.10 shows the results of a Bayesian Weibull mixed-effects model with Congruency and Types of cue - together with their interaction - as population-level factors and Subject as group-level factor. Flat priors for the population level effects were used, and weakly informative priors for the intercept [student_t(3, 0.7, 2.5)] and for the group level effects [student_t(3, 0, 2.5)]. For model estimation, four chains with 5000 iterations (2500 warmup) were used. Convergence was checked as for the main study.

Table 4.10: Population level effects of the brms model.

Covariate	Estimate	Est.Error	l-95% CI	u-95% CI
Intercept	-0.76	0.06	-0.89	-0.64
CongruencyCongruent	-0.02	0.02	-0.05	0.01
GroupSocialPDirectional	0.11	0.09	-0.06	0.29
CongruencyCongruent:GroupSocialPDirectional	-0.08	0.02	-0.13	-0.04

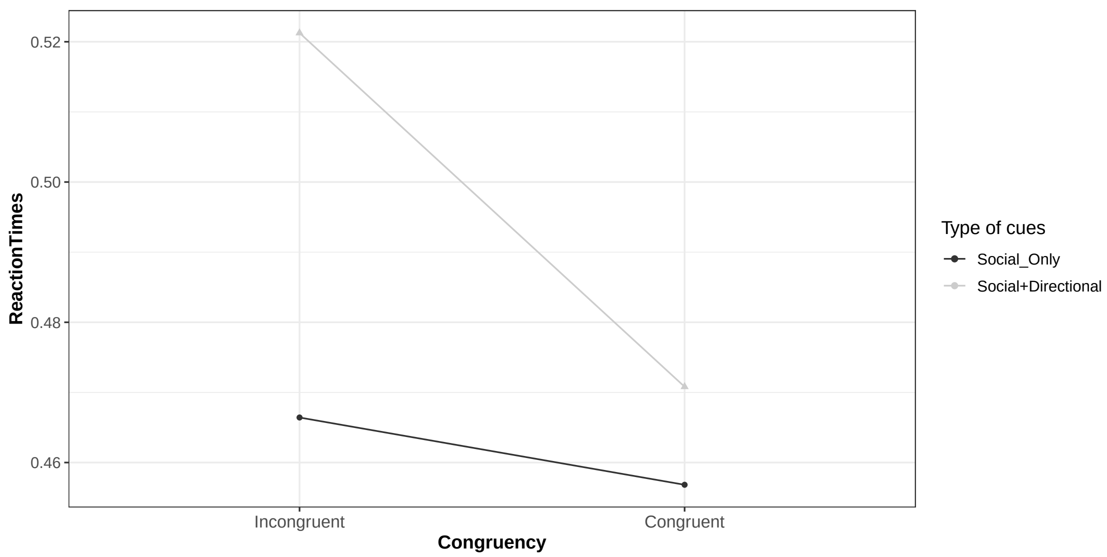


Figure 4.9: Estimated marginal means for each level of Congruency (Incongruent vs Congruent) for each Types of cue (*Social+Directional* cue and *Social_Only* cue).

Figure 4.9 and Table 4.10 show the estimated marginal means of the two different conditions (Congruent vs Incongruent) for the two cues (Social+Directional and Social_Only). A main effect of the interaction between Types of Cue and Congruency emerged, with shorter RTs for the Congruent and Social+Directional trials [-0.08, SE 0.02, 95% CI (-0.13, -0.04)].

4.6.3 Cueing effects of the two cues

Table 4.11 and Figure 4.10 show the cueing effects (intended as the mean difference between the Incongruent and Congruent conditions) generated by the two types of cue. As it can be seen, the Social+Directional cue clearly generates a cueing effect; with the entire HDI falling outside the ROPE. While the Social_Only cue does not with 92.8% of the HDI falling within the ROPE.

Table 4.11: Cueing effect for each types of cue.

Parameter	Mean	89% HDI	89% ROPE	% in ROPE
Incongruent - Congruent, Social_Only	9.68e-03	[0.00, 0.02]	[-0.02, 0.02]	92.78%
Incongruent - Congruent, Social+Directional	0.05	[0.04, 0.06]	[-0.02, 0.02]	0%

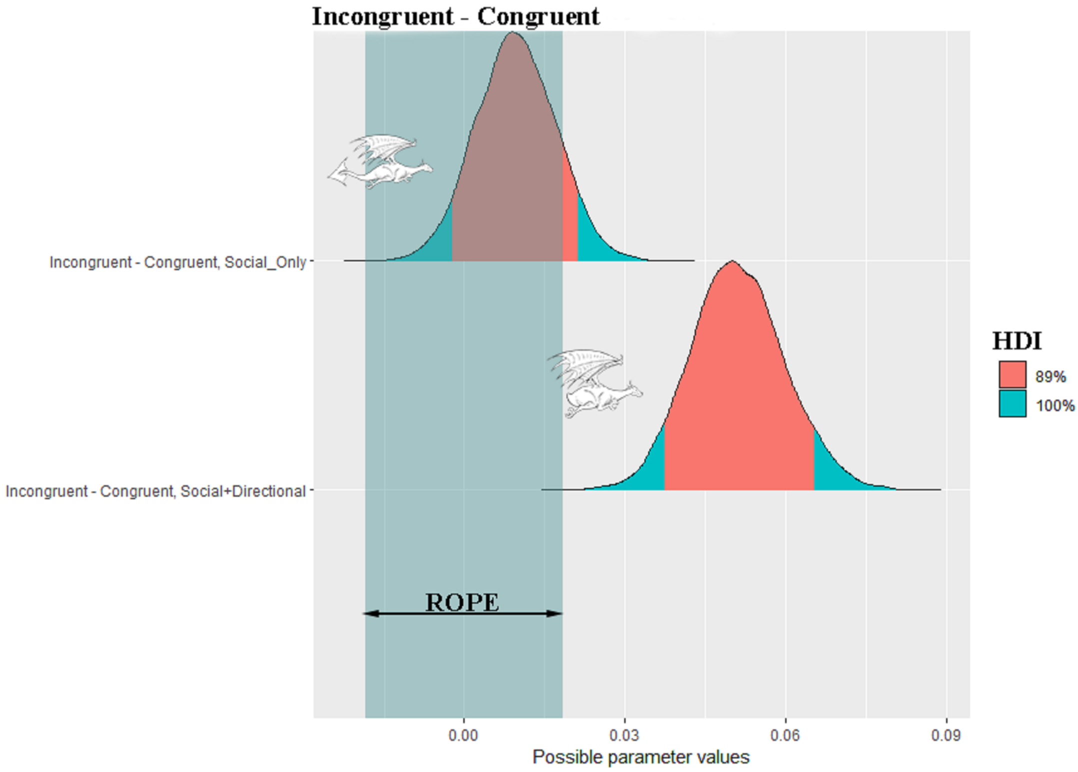


Figure 4.10: ROPE and HDI of the effect for the two types of cue: *Social_Only* and *Social+Directional* cue.

Taken together, these results show that the *Social+Directional* cue orients attention while the *Social_Only* cue does not. This indicates that the arrowed-shaped tail cancels out (or at least attenuates) the directional features of the dragon's posture.

5
Experiment 3

5.1 Introduction

By employing a novel bidirectional cue, experiment 2 evaluated the relative contributions of the mentalizing and domain-general processes in generating interference effect in the Dot Perspective Taking paradigm. As aforementioned, previously employed humans or humans-like cues (including the one employed in experiment 1) presented confounded directional and social features. Since it is challenging, if not impossible, to separate the social from the directional component of the avatar, in experiment 2 it was hypothesised that in a cue presenting conflicting directional features, the orienting effect generated by these features may be cancelled out or attenuated, leaving only the isolated social features to orient participants' attention. Interestingly, the results showed that, although the cue with confounded features induces interference effect in both RTs and error rate, the newly developed cue with isolated social features could only generate interference in the error rate. An integrated approach between the domain-general and mentalizing account was proposed to explain these results. Two processes are engaged in the Dot Perspective Task (DPT): an involuntary orienting process - assessed by the RTs - and a voluntary process - measured also by the error rate. Following the results of experiment 2 and their interpretation, experiment 3 aims to replicate these findings in order to provide further evidence in support of this integrated approach. In particular, by experimentally manipulating the directional features of the cue employed in the task, it aims to investigate the idea that the directional features of a cue should affect only RTs and not error rates. If this is the case, when similar cues with different levels of saliency are employed, the cue with highly salient directional features is expected to cause stronger interference in RTs, but comparable interference in error rates when compared to cues with less salient directional features. Furthermore, this experiment aims to answer one of the possible critiques that may be advanced against the cue employed in experiment 2. As previously acknowledged in the discussion section of experiment 2, two main critiques may be raised. The first is about the cue's social features. It might be argued that a dragon-shaped avatar is distinct from a human avatar since it does not resemble a human figure and it is a fantasy creature; hence, it cannot be said to have any social features. Several studies have shown that non-human animals, mascots, and fantasy creatures orient attention in the same manner as human avatars do (Dujmovi & Valerjev, 2018; MacDorman et al., 2013; Simon et al., 1976). For instance, MacDorman et al. (2013) showed that the eerie nature of others does not prevent individuals from adopting their viewpoint, although this can be influenced by past exposure/familiarity with them. For example, neither the scariest characters such as a Zombie or a fantasy creature nor the most human characters such as the photographs of humans interfered the least or the most with self-perspective judgement in MacDorman et al. (2013). Second, Nielsen et al. (2015) stated that arrows had certain social features and should be regarded as semi-social cues. This would indicate that the cue's arrow-shaped tail should possess social features as well as directional features. This assertion is not supported by empirical evidence and contradicts Massironi & Bruno (2001)'s explanation of the role of arrows. Because the second is not supported by empirical evidence and contradicts Massironi & Bruno (2001)'s explanation, this chapter aims to provide an answer only to the first possible critique. In doing this, this experiment employs a new bi-directional cue. Following MacDorman et al. (2013), which shows that the eeriness of the others does not hinder people from taking their point of view, the new bi-directional cue, the figure of a devil, was chosen due to its body stance closely resembling the stance of a human figure. Because the dragon employed in experiment 2 presents a fusiform body structure, it is interesting if the same results could be replicated by a cue with a more human body structure. Furthermore, due to its fusiform shape, the dragon, when devoided of its tail may be implicitly interpreted as a masked arrow. Previous research such as Reuss et al. (2011) and Ansorge & Neumann (2005) has shown that masked arrowed cues are able to generate a Reflexive Attentional Shift (RAS) in spatial cueing tasks (Posner, 1980; Posner & Coehn, 1984). Similarly, to the dragon employed in experiment 2, the devil's tail follows the body harmoniously, it is not recognized as an additional cue, and attention orientation is not affected by the complexity of a scene with multiple cues. First, a devil with an arrowed-shaped tail pointed in the opposite direction of its point of view was developed. In line with experiment 2, this cue was named *Social_Only*. A second devil with no tail was used as control conditions and was named *Social+Directional*. Lastly, a third cue represented by a devil with the tail pointing towards the same direction as the devil's point of view was developed. This was named *Social+Directional+* as the directional features of the devil's tail point towards the same direction of its viewpoint and stance, providing therefore much stronger directional information (Figure 5.1). The effect generated by the latter cue is of major interest to the aim of this thesis. Whilst the *Social_Only* and *Social+Directional* are expected to replicate experiment 2 results, the possible interference effect generated by the *Social+Directional+* may provide a deeper insight into the relative contribution of directional features in generating the interference effect. The *Social+Directional+* in fact should possess much stronger directional information than the other cues.

In line with experiment 2, the size of the tail was chosen to achieve similar directional effects to those of the posture. The size of the tail and the ability to direct the attention of the three cues were assessed by means of a preliminary experiment using the Posner spatial cueing paradigm (Posner & Coehn, 1984).

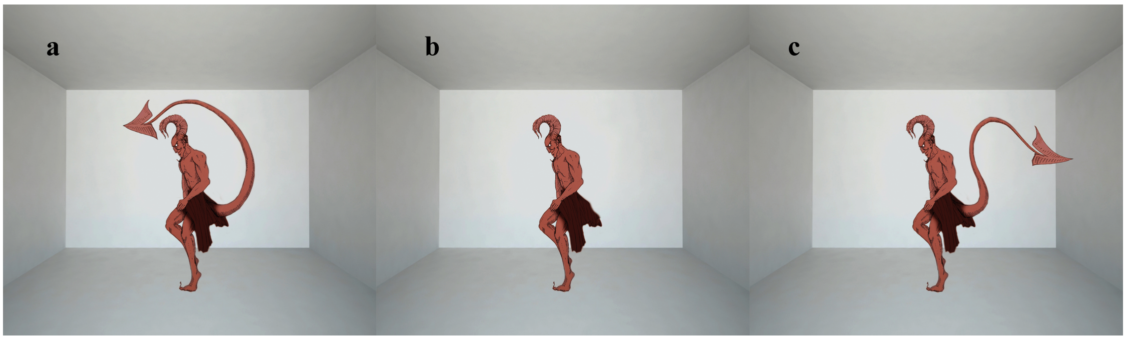


Figure 5.1: Cues used in experiment 3. a) *Social+Directional+* cue: A devil with an arrowed shaped tail pointing towards the same direction faced by the devil. The directional feature of the muzzle is strengthened by the extra directional features of the tail; b) *Social+Directional* cue: The same devil but without the arrowed-shaped tail. The directional feature of the stance is not contrasted by any directional features; c) *Social_Only* cue: the devil with an arrowed-shaped tail pointing to the opposite direction of the stance. The role of the tail is to contrast the directional features of the devil's stance leaving only its social features to orient attention.

5.1.1 Account's predictions

It is hypothesised that both domain-general and the mentalizing account would predict similar outcomes to the ones predicted in experiment 2. However, as an integrated account was presented, in order to explain the results, the predictions of this approach will also be included below:

- The mentalizing account predicts that *Social_Only*, *Social+Directional* and *Social+Directional+* cues generate the same amount of interference for both RTs and Errors. This is because according to this account; the directional features on their own are not sufficient to generate interference, but the social features need also to be present in the cue.

- The domain-general account predicts that the *Social_Only* cue should generate less or no interference for both RTs and Errors because the directional features of the body posture are cancelled out or attenuated by the tail, leaving no directional features to orient attention[1]. Furthermore, it predicts that the *Social+Directional+* should generate a bigger interference than the *Social+Directional*, having the former stronger directional features.

- Lastly, the integrated account would predict that the directional features of the other should affect the involuntary orientating process, but not the decisional process. In other words, the more salient the directional features, the stronger should be the interference in the RTs, whilst no changes in interferences are predicted for the error rates. In particular, for the RTs, the *Social_Only* cue should generate less or no interference, the *Social+Directional* and *Social+Directional+* should both generate interference with the latter generating a bigger one. Whilst the three cues should generate a similar amount of interference for the Error Rates.

[1] The scenario in which the interference generated by the *Social+Directional* cue is smaller than that generated by the *Social_Only* cue is not plausible. It would mean that the arrow-shaped tail orients attention opposite to where it points.

5.2 Methods

5.2.1 Sampling plan and stopping rule

The sampling plan and stopping rule followed the Sequential Bayes Factors (SBF) procedure (Schönbrodt et al., 2017) presented in chapter 2 of this thesis. Thus, data collection continued until the predetermined stopping criterion was reached at the point of checking. Sampling was stopped after collecting 26 participants as one of the BF10 was higher than 10 for one of the cues (specifically, the BF10 of the interference in the RTs for the *Social+Directional+* was BF10 = 19.74).

5.2.2 Participants

In total fifty-four (54) participants, 18 per condition, took part in this study (age range 18 to 22) of which 33 were females. Participants were naïve to the purpose of the study and received no remuneration for taking part. Informed consent was obtained from each participant through the Qualtrics online platform (`https://www.qualtrics.com`) in accordance with the University's ethical procedures.

5.2.3 Design

The variables used in the study were: Consistency (Inconsistent vs Consistent), Perspective (Self vs Other) and Types of cues (*Social_Only* vs *Social+Directional* vs *Social+Directional+*). While the variables Consistency and Perspective were measured within-subjects – as the dot-perspective task requires – the variable Types of cues were measured between subjects. This was to control for the "experimental subordination" phenomenon (Asch, 1956; Gilchrist, 2020). If the same participants would have seen a devil with and without the tail or with the tail pointing towards another direction, they might have adjusted their answers according to what they thought they were expected to respond.

5.2.4 Stimuli and Procedure

Stimuli presentation and procedure were accordingly to the general procedure presented in chapter 2 of this thesis. In this experiment, the pronouns YOU and DEVIL were employed to prompt participants respectively with the "Self" or "Other" perspective. In total, 80 trials were presented to each participant. These comprised 36 YES and 44 NO response trials. 36 were Consistent trials, 36 were Inconsistent trials and 8 were fillers, in which no discs were presented. Furthermore, 40 trials had as prompted perspective YOU while the remaining 40 had DEVIL[2]. Before the start of the experiment, participants took part in a small practice of 12 trials to familiarize themselves with the task. The experiment lasted on average 15 minutes.

5.3 Results

5.3.1 Descriptive Statistic

Means and standard deviations for both RTs and error rate are shown in Table 5.1 and Figure 5.2 and 5.3. Following Whelan (2008), trials in which RTs are faster than 100 ms were deemed to be considered non-genuine. There were no RTs under 100 ms in this experiment. Given the required cut-off of 2000 ms on all trials, no trimming was performed on higher RTs.

[2]Note that Wilson et al. (2017) found that impersonal pronouns generate the same amount of interference as personal pronouns therefore the prompt DEVIL was used (see also MacDorman et al., 2013).

Table 5.1: Mean and SD for RTs (top) and Error Rates (bottom).

Perspective	Consistency	TypeofCue	Mean	sd
Other	Inconsistent	Social+Directional+	0.816	0.344
		Social+Directional	0.745	0.274
		Social_Only	0.704	0.288
	Consistent	Social+Directional+	0.704	0.237
		Social+Directional	0.679	0.283
		Social_Only	0.702	0.310
Self	Inconsistent	Social+Directional+	0.826	0.298
		Social+Directional	0.804	0.325
		Social_Only	0.720	0.328
	Consistent	Social+Directional+	0.732	0.279
		Social+Directional	0.739	0.318
		Social_Only	0.699	0.291

Perspective	Consistency	TypeofCue	Mean	sd
Other	Inconsistent	Social+Directional+	0.214	0.411
		Social+Directional	0.236	0.426
		Social_Only	0.263	0.441
	Consistent	Social+Directional+	0.113	0.318
		Social+Directional	0.106	0.309
		Social_Only	0.135	0.343
Self	Inconsistent	Social+Directional+	0.318	0.467
		Social+Directional	0.275	0.448
		Social_Only	0.309	0.463
	Consistent	Social+Directional+	0.175	0.381
		Social+Directional	0.118	0.324
		Social_Only	0.175	0.381

As it can be seen, for RTs, an interference pattern (intended as the mean difference between the Inconsistent and the Consistent trials) seems to emerge for the *Social+Directional* and *Social+Directional+* cues. On the contrary, the difference between Inconsistent and Consistent trials is much smaller for the *Social_Only* cue.

Similar interference patterns seem to emerge instead between the three cues for the Error rates.

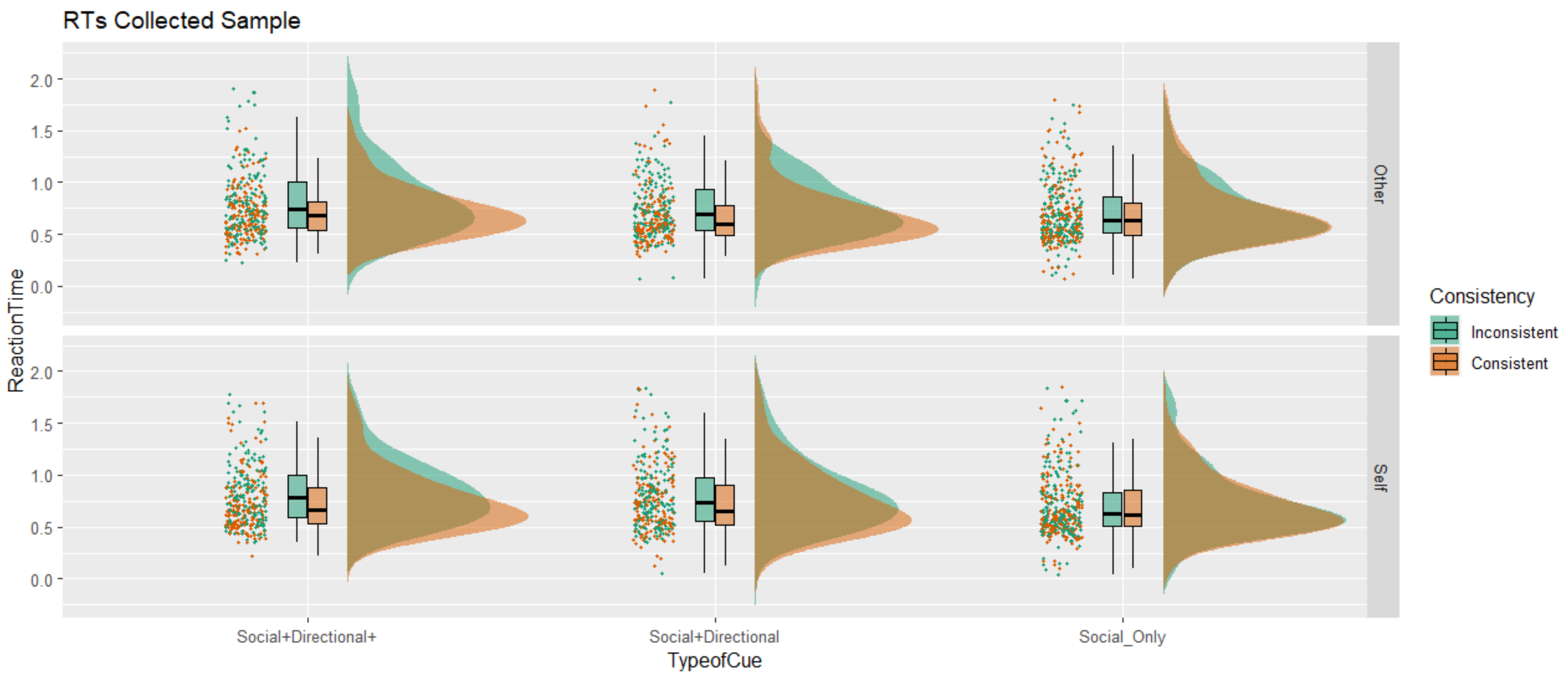


Figure 5.2: Rain plots reporting Mean and SE of distribution for sample's RTs for each combination of stimulus presentation (Consistent vs. Inconsistent) and perspective adopted (Self vs Other) for the three types of cues (*Social+Directional+* vs *Social+Directional* vs *Social_Only*).

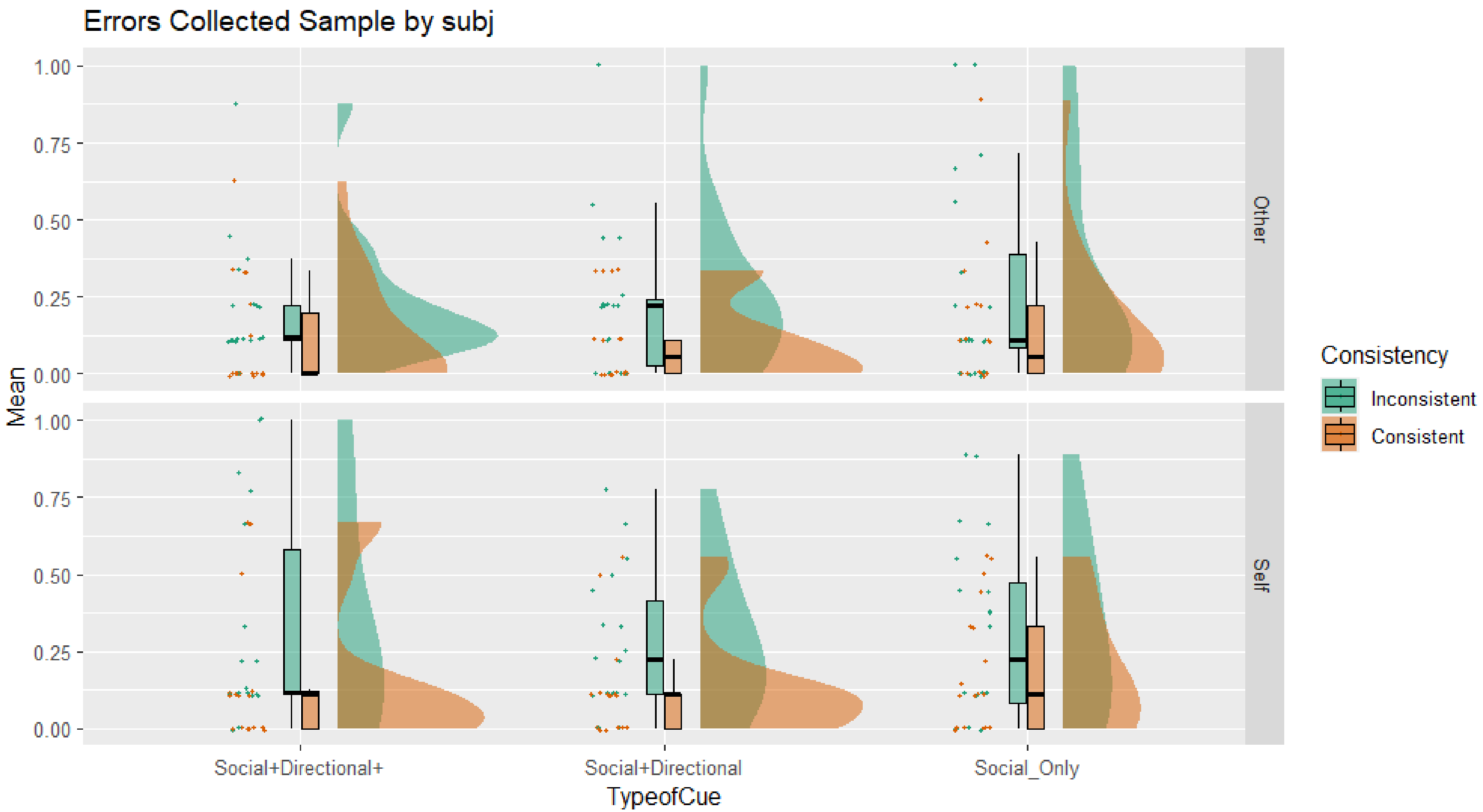


Figure 5.3: Rain plots reporting Mean and SE of distribution for sample's Error rates are averaged also by Subject for each combination of stimulus presentation (Consistent vs. Inconsistent) and perspective adopted (Self vs Other) for the three types of cues (*Social+Directional+* vs *Social+Directional* vs *Social_Only*).

5.3.2 Data Analysis

Similarly to previous experiments, to enable generalization across stimuli and participants, data were analysed with mix-models (Judd et al., 2012); specifically, Bayesian mix-models were created in Stan computational framework (Carpenter et al., 2017) accessed with the high-level interface "brms" package 2.10.0 (Bürkner, 2017, 2018) in R version 3.6.2 (R Core Team, 2020).Whilst the models employed in this experiment were similar to the ones of experiment 2, in an effort to facilitate and ease the description of the task for the reader, the details of the models are specified below. Two individual models were run, one for the RTs and another for the error rate. For both models, the variables Perspective, Consistency and Types of cue - together with their interaction - were inputted as population-level factors and the variable Subject as group-level factor. Moreover, as each combination of the conditions was presented in more than 1 trial, the variable Trials was also inputted in the models as a group-level factor nested within the variable Subject. The two models were therefore similar in their formulae; however, for the RTs it was utilized the Weibull family distribution (Logan, 1992; Palmer et al., 2011; Rouder et al., 2005) and the Bernoulli family distribution for the error rate (Bürkner, 2018). For testing opposite predictions, we set flat priors for the population level effects and weakly informative priors for the intercept [student_t(3, 0.7, 2.5)] and for the group level effects [student_t(3, 0.7, 2.5)]. For model estimation, four chains with 4000 iterations (2500 warmup) were used. Convergence was checked via Gelman & Rubin (1992) convergence statistics (Rhat close or equal to 1.0) and by visual inspection of the posterior distribution of all the coefficients and their chain convergence.

5.3.3 Reaction Time Analysis

Table 5.2 shows the results of the Bayesian linear mixed-effects model. Figure 5.4 shows the estimated marginal means of the interaction between Consistency and Perspective split by the three types of cues.

Table 5.2: Population level effects of the brms model.

Covariate	Estimate	Est.Error	l-95% CI	u-95% CI
Intercept	-0.22	0.07	-0.36	-0.09
PerspectiveSelf	0.01	0.03	-0.05	0.07
ConsistencyConsistent	-0.14	0.03	-0.20	-0.07
TypeofCueSocialPDirectional	-0.11	0.10	-0.30	0.08
TypeofCueSocial_Only	-0.18	0.09	-0.36	0.01
PerspectiveSelf:ConsistencyConsistent	0.01	0.05	-0.08	0.10
PerspectiveSelf:TypeofCueSocialPDirectional	0.09	0.05	0.00	0.18
PerspectiveSelf:TypeofCueSocial_Only	0.01	0.05	-0.08	0.10
ConsistencyConsistent:TypeofCueSocialPDirectional	0.08	0.05	-0.01	0.17
ConsistencyConsistent:TypeofCueSocial_Only	0.13	0.05	0.03	0.22
PerspectiveSelf:ConsistencyConsistent:TypeofCueSocialPDirectional	-0.05	0.07	-0.18	0.08
PerspectiveSelf:ConsistencyConsistent:TypeofCueSocial_Only	-0.02	0.07	-0.15	0.11

It emerged a main effect of Consistency with shorter RTs for the Consistent trials [-0.14, SE 0.03, 95% CI (-0.20, -0.07)]. It emerged also an effect of the interaction between Perspective and Type of Cue with longer RTs in the Self and *Social+Directional* trials [0.09, SE 0.05, 95% CI (0.00, 0.18)] and between Consistency and Type of Cue with longer RTs in the Consistent and *Social_Only* trials [0.13, SE 0.05, 95% CI (0.03, 0.22)].

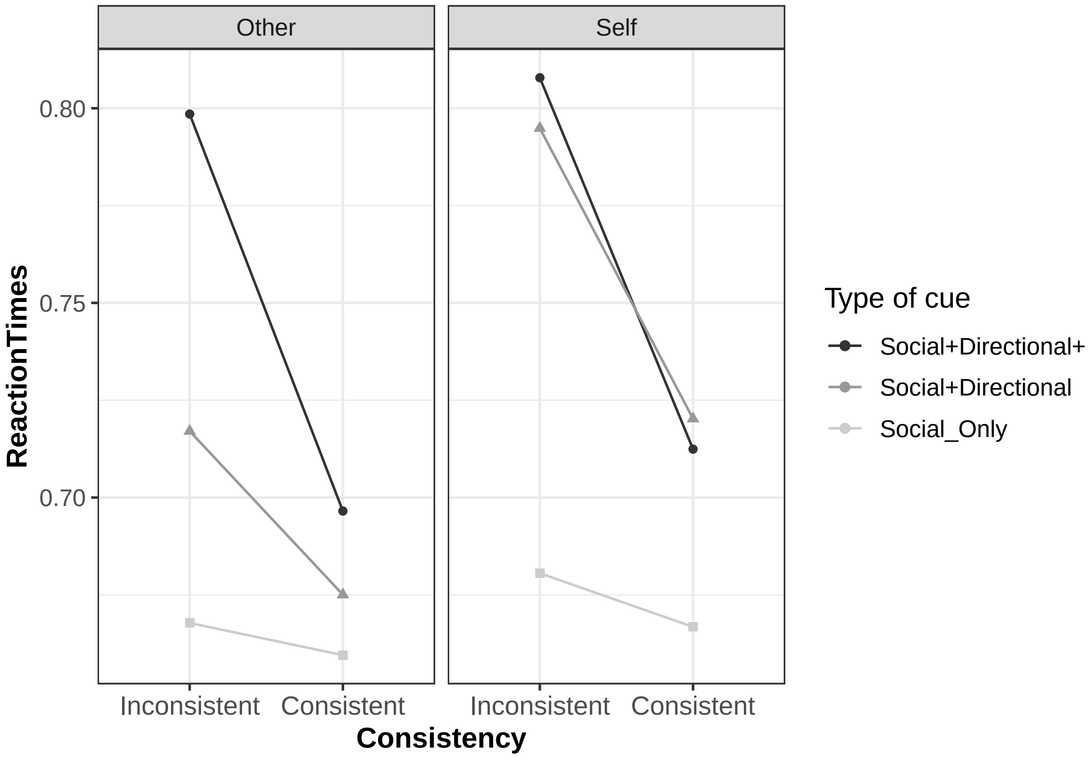


Figure 5.4: Estimated marginal means for RTs for each combination of stimulus presentation (Inconsistent vs Consistent) and Type of cue (*Social+Directional+* vs *Social+Directional* vs *Social_Only*) for perspective adopted (Self vs Other).

5.3.4 Error Rate analysis

Table 5.3 shows the results of the Bayesian mixed-effects model and Figure 5.5 shows the estimated marginal means of the interaction between Consistency and Perspective split by the three types of cue.

Table 5.3: Population level effects of the brms model.

Covariate	Estimate	Est.Error	l-95% CI	u-95% CI
Intercept	-1.70	0.39	-2.47	-0.96
PerspectiveSelf	0.78	0.30	0.18	1.35
ConsistencyConsistent	-1.03	0.37	-1.75	-0.32
TypeofCueSocialPDirectional	0.23	0.54	-0.83	1.30
TypeofCueSocial_Only	0.39	0.52	-0.64	1.42
PerspectiveSelf:ConsistencyConsistent	-0.11	0.48	-1.03	0.84
PerspectiveSelf:TypeofCueSocialPDirectional	-0.53	0.42	-1.33	0.31
PerspectiveSelf:TypeofCueSocial_Only	-0.53	0.40	-1.30	0.27
ConsistencyConsistent:TypeofCueSocialPDirectional	-0.11	0.50	-1.10	0.87
ConsistencyConsistent:TypeofCueSocial_Only	0.01	0.47	-0.91	0.92
PerspectiveSelf:ConsistencyConsistent:TypeofCueSocialPDirectional	0.02	0.68	-1.32	1.34
PerspectiveSelf:ConsistencyConsistent:TypeofCueSocial_Only	0.21	0.63	-1.02	1.46

A main effect of Perspective emerged, with higher error rate for the Self condition [0.78, SE 0.30, 95% CI (0.18, 1.35)]. A main effect of Consistency also emerged, with lower error rate for the Consistent trial [-1.03, SE 0.37, 95% CI (-1.75, -0.32)].

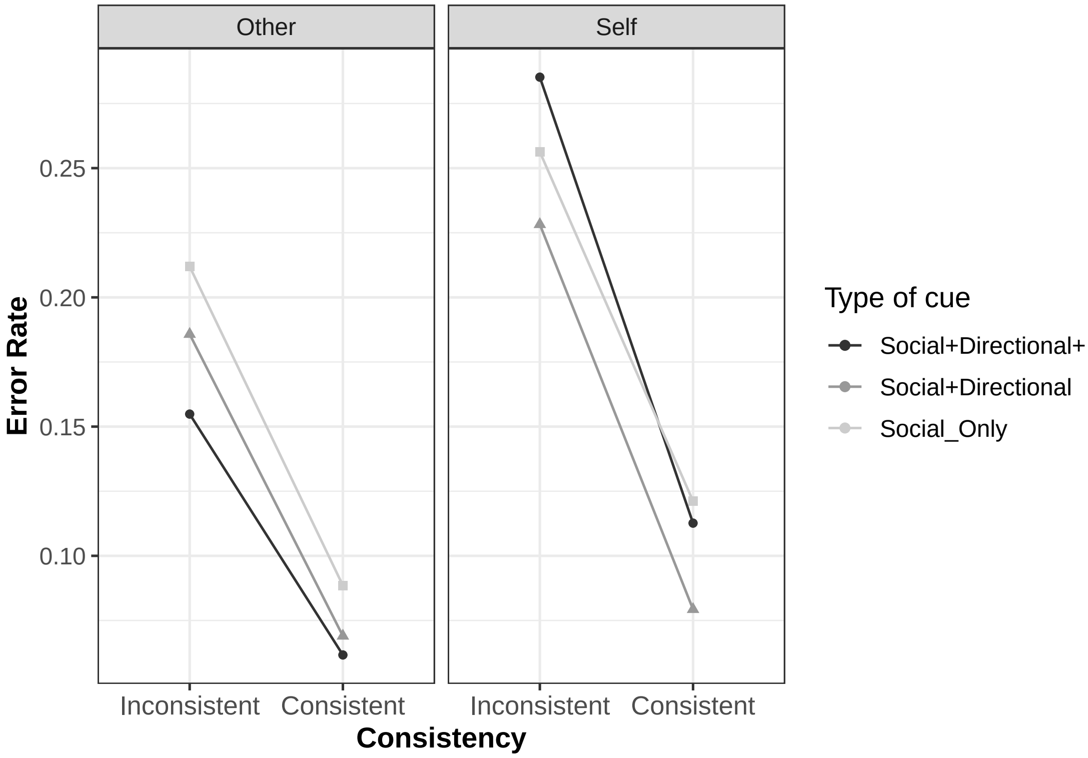


Figure 5.5: Estimated marginal means for error rates for each combination of stimulus presentation (Inconsistent vs Consistent) and Type of cue (*Social+Directional+* vs *Social+Directional* vs *Social_Only*) for perspective adopted (Self vs Other).

5.4 Planned post-hoc comparisons

Because predictors in models are conditional to all other factors with which they interact, they do not provide the desired comparisons. As specified in the introduction, to assess the mentalizing and the domain-general accounts, only the Self level of the Perspective variable is relevant. Within this level of the Perspective variable, the following comparisons were conducted:

- Inconsistent vs Consistent within the *Social+Directional* type of cue;

- Inconsistent vs Consistent within the *Social+Directional+* type of cue;
- Inconsistent vs Consistent within the *Social_Only* type of cue;

Post-hoc comparisons were extracted using the emmeans package version 1.5.4 (Lenth, 2021) and the Easystats package version 0.2.0 (Lüdecke et al., 2020). Decisions on the comparisons were based on the relative positions of the Highest Density Interval (HDI, Box & Tiao, 1992; Chauhan et al., 2017; Hespanhol et al., 2019) and the predefined regions of practical equivalence (ROPE) of 89% (Kruschke & Liddell, 2018a, 2018b; McElreath & Safari, 2020). In agreement with Kruschke & Liddell (2018a) the ROPEs were defined as +/-0.1*SD for the contrasts.

5.4.1 Reaction Time analysis

Table 5.4 and Figure 5.6 show the interference (intended as the RTs difference between the Inconsistent and Consistent levels of Consistency variable) generated by the three cues.

Table 5.4: Interference for the Type of cue variable.

Parameter	Mean	89% HDI	89% ROPE	% in ROPE
Inconsistent - Consistent, Social+Directional+, Self	0.10	[0.06, 0.14]	[-0.03, 0.03]	0%
Inconsistent - Consistent, Social+Directional, Self	0.07	[0.03, 0.12]	[-0.03, 0.03]	0%
Inconsistent - Consistent, Social_Only, Self	0.01	[-0.02, 0.05]	[-0.03, 0.03]	83.22%

As it can be seen, the *Social+Directional+* cue clearly generates an interference, with the entire HDI falling outside of the ROPE. The cue clearly generates an interference; the entire HDI falls outside of the ROPE, indicating that the 89% most credible values of the interference are practically different from the null. Similarly, the full 89% of the *Social+Directional* falls outside of the ROPE. Thus, indicating as well that the most credible values of this interference are practically different from the null. There is instead only a 16% probability that the *Social_Only* cue generates interference; 83.22% of the HDI falls within the ROPE, indicating that 83.22% of the most credible values of the interference are practically equivalent to the null value.

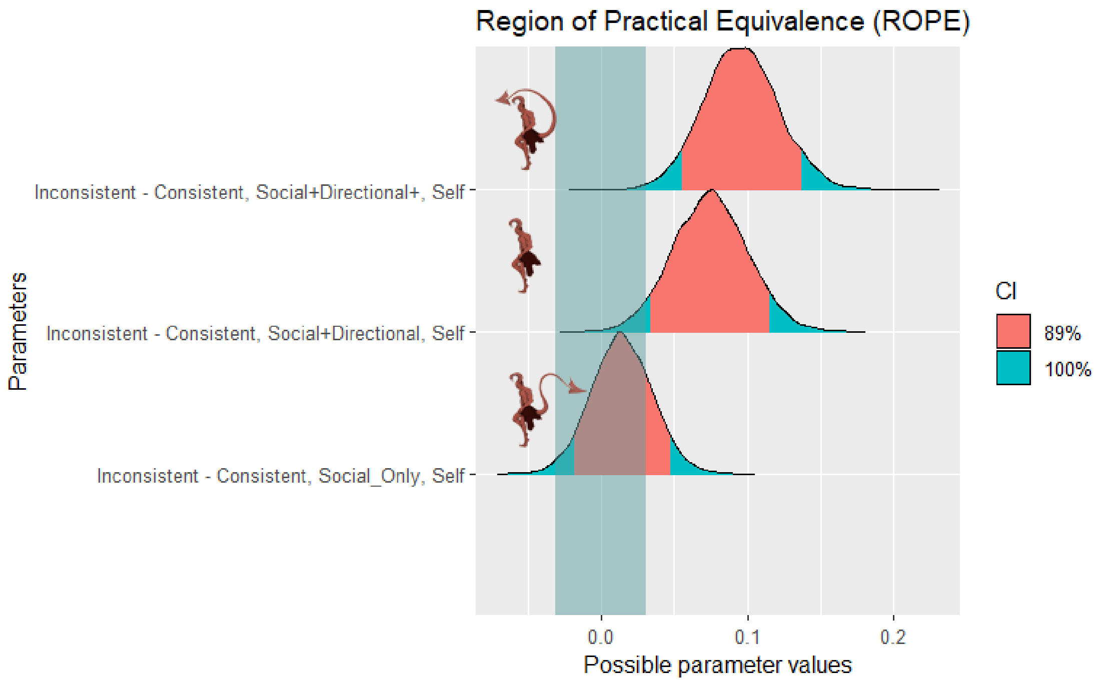


Figure 5.6: ROPE and HDI of the interaction for *Social+Directional+*, *Social+Directional* and *Social_Only* cue for RTs.

The comparison between the interferences generated by the three types of cue is shown in Table 5.5 and Figure 5.7.

As it can be seen, the *Social+Directional+* cue generated a much larger interference than the *Social_Only* cue with only 1% of the most probable values of the contrast that fall within the ROPE. Similarly, the *Social+Directional* cue generated a larger interference than the *Social_Only* cue with 86% of the most probable values of the contrast falling outside of the ROPE and therefore being considered practically different from the null. When considering the contrast between the interferences generated by the *Social+Directional* and *Social+Directional+* cue, nearly 60% of the most probable values of the contrast fall within the ROPE and therefore being considered equally to the null. Thus, showing that the addition of a consistent directional feature to the cue did not generate a bigger interference in 60% of the most probable values.

Table 5.5: Interference difference between the three cues.

Parameter	Mean	89% HDI	89% ROPE	% in ROPE
Inconsistent - Consistent, (Social+Directional+) - (Social+Directional), Self	0.02	[-0.04, 0.08]	[-0.03, 0.03]	60.03%
Inconsistent - Consistent, (Social+Directional+) - Social_Only, Self	0.08	[0.03, 0.14]	[-0.03, 0.03]	0.80%
Inconsistent - Consistent, (Social+Directional) - Social_Only, Self	0.06	[0.01, 0.11]	[-0.03, 0.03]	14.16%

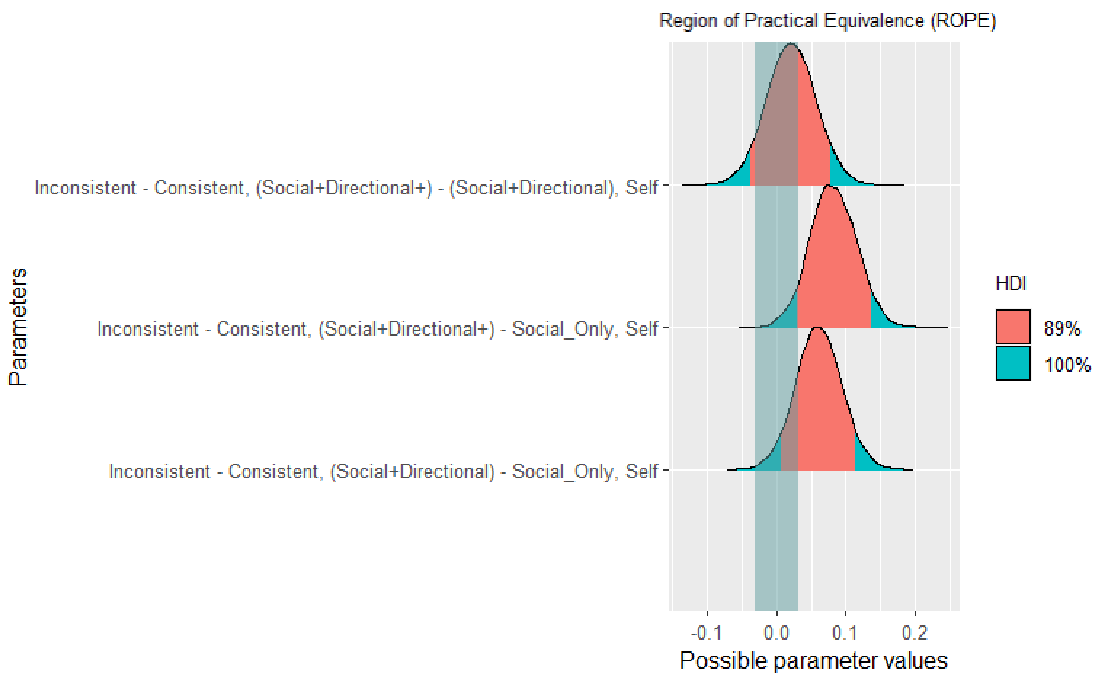


Figure 5.7: ROPE and HDI of the differences between the interference of the *Social+Directional+*, *Social+Directional* and *Social_Only* for RTs.

5.4.2 Error Rates Analysis.

Table 5.6 and Figure 5.8 show the interference generated by the three cues. All the cues show a clear interference pattern. For all the cues, the entire HDI falls outside of the ROPE indicating that 89% of the most credible values of the interference are different from the null value.

Table 5.6: Interference for the Type of cue variable.

Parameter	Mean	89% HDI	89% ROPE	% in ROPE
Inconsistent - Consistent, Social+Directional+, Self	0.17	[0.09, 0.27]	[-0.04, 0.04]	0%
Inconsistent - Consistent, Social+Directional, Self	0.15	[0.07, 0.22]	[-0.04, 0.04]	0%
Inconsistent - Consistent, Social_Only, Self	0.13	[0.06, 0.21]	[-0.04, 0.04]	0%

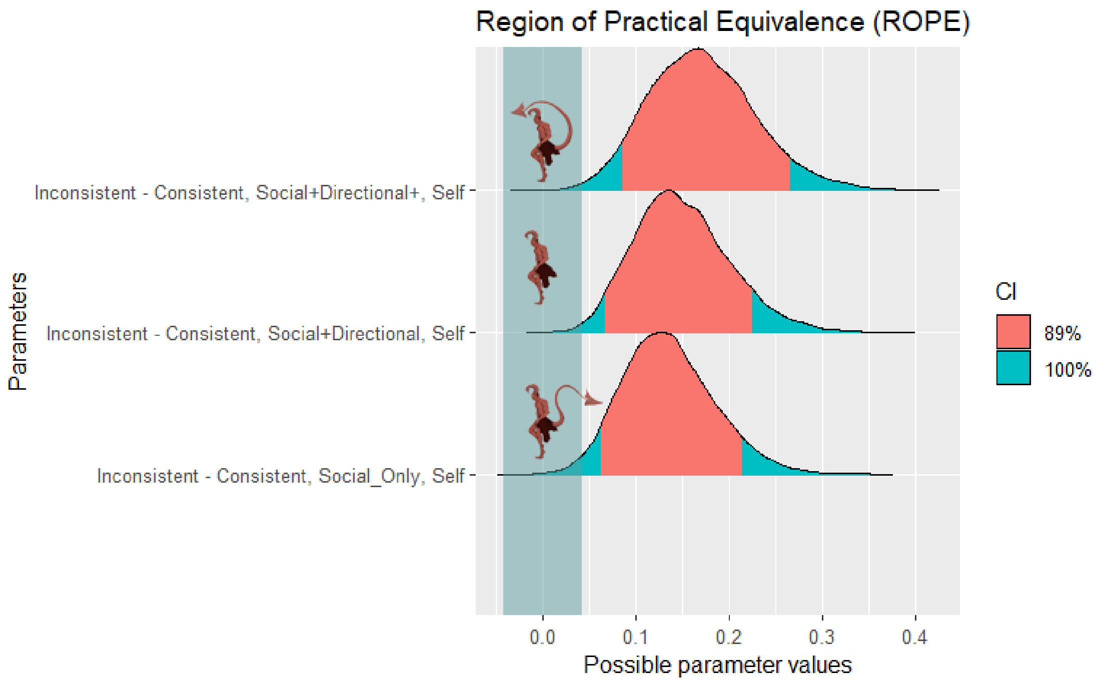


Figure 5.8: ROPE and HDI of the interaction for *Social+Directional+* cue, *Social+Directional* cue and *Social_Only cue* for the error rates.

The comparison between the interferences generated by the three types of cue is shown in Table 5.7 and Figure 5.9. It can be seen that the three types of cue generated a similar amount of interference with no evident difference between them.

Table 5.7: Interference difference between the three cues.

Parameter	Mean	89% HDI	89% ROPE	% in ROPE
Inconsistent - Consistent, (Social+Directional+) - (Social+Directional), Self	0.02	[-0.10, 0.15]	[-0.04, 0.04]	45.28%
Inconsistent - Consistent, (Social+Directional+) - Social_Only, Self	0.04	[-0.08, 0.16]	[-0.04, 0.04]	42.89%
Inconsistent - Consistent, (Social+Directional) - Social_Only, Self	0.01	[-0.10, 0.13]	[-0.04, 0.04]	50.21%

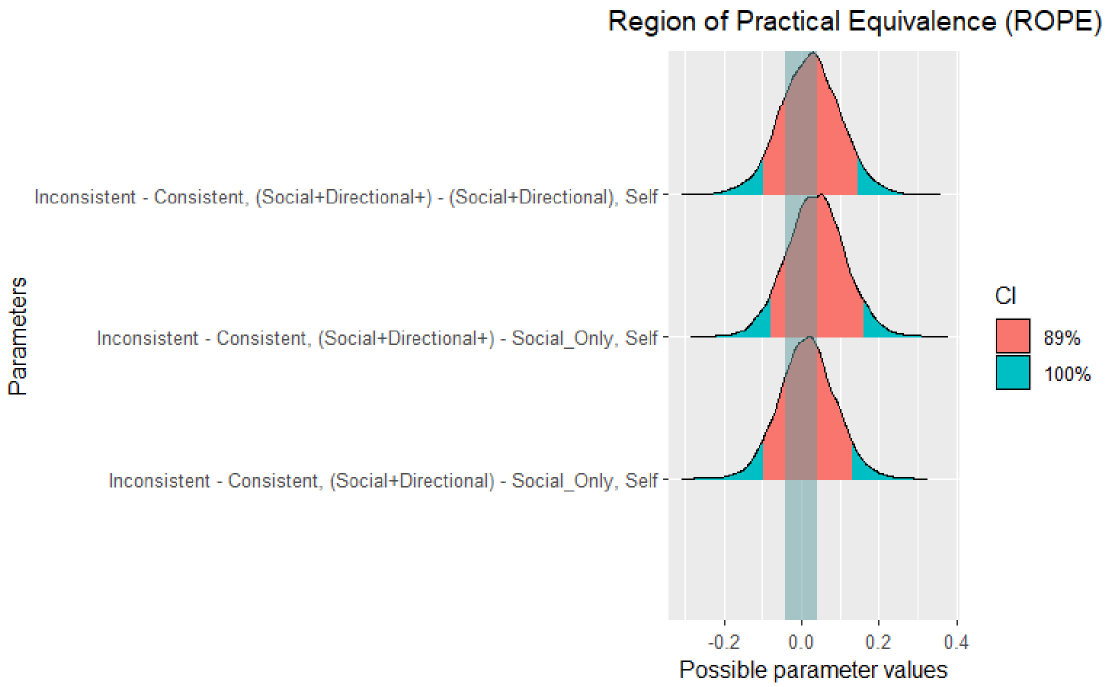


Figure 5.9: ROPE and HDI of the differences between the interference of *Social+Directional+*, *Social+Directional* and *Social_Only* for error rates.

5.5 Discussion

This experiment presented a dual aim. In a first instance, it aimed to replicate experiment 2 results and to provide further evidence in support of the need for an integrated approach in order to explain the interference effect that can be appreciated in the DPT. To this end, it aimed to experimentally manipulate the directional features of the cue employed in the task to investigate the idea the directional features of a cue should affect only the reflexive orientating process measured by RTs and not the voluntary decisional process measured by the error rates. To accomplish this, the saliency of the directional features of the cue was experimentally manipulated. Furthermore, this experiment aimed to provide further evidence in opposition to one of the possible critiques that may be advanced against the cue employed in experiment 2 by employing a more human-like bi-directional cue. As previously stated in the discussion part of experiment 2, two major criticisms may be raised towards the cue employed in that experiment. The first suggests that arrows may have social features. This however has been shown to not be empirically supported. The second regards the social aspects of the cue. It might be claimed that because a dragon-shaped avatar is dissimilar from a human avatar (since it does not resemble a human figure), it may not have social features[3]. To this end, this experiment employs a new bi-directional cue. Following MacDorman et al. (2013), which shows that the eeriness of the others does not hinder people from taking their point of view, the new bi-directional cue was chosen due to its closer resemblance with a human figure. A devil with an arrowed-shaped tail pointed in the opposite direction of its point of view was developed and named, in line with experiment 2, as *Social_Only*. In addition, a devil with the same tail pointing in the same direction and a devil with no tail was used as control conditions. The former was defined as *Social+Directional+*, as the tail was providing an extra directional feature pointing towards the same side faced by the devil's viewpoint. The latter was simply called *Social+Directional*, as both features were still presented within the cue without the addition of extra features. Furthermore, the devil's standing position resembles a human' standing stance due to their similar body structure. The standing stance may represent a major difference from the cue employed in experiment 2. The fusiform structure of the dragon employed in experiment 2 in fact may be viewed as a disguised arrow. Previous research (Ansorge & Neumann, 2005; Reuss et al., 2011) showed that masked arrowed cues can induce a reflexive shift of attention in spatial cueing tasks (Posner, 1980; Posner & Coehn, 1984). The employment of a bi-directional cue with a different and more human-like

[3]It must be noted that previous studies have shown that non-human animals, mascots, and fantasy creatures orient attention in the same way as human avatars do (Dujmovi & Valerjev, 2018; MacDorman et al., 2013; Simon et al., 1976).

stance becomes therefore important to investigate which processes are underlying the interference effect generated in the dot-perspective task. From the analysis of the RTs, it emerged that the *Social+Directional+* and the *Social+Directional* both generated an interference effect, with the *Social+Directional+* generating a larger interference than the *Social+Directional*. The *Social_Only* cue instead did not generate any interference. This result is in line with experiment 2's RTs analysis and the domain-general account because the cue with stronger directional features did generate the larger interference, whilst the cue presenting only social features was not capable of generating it. The analysis of the Error rates however did not reflect the RTs analysis, showing that the interference in the error rates persisted even when the social features of the cue were isolated. Individually, this result would support the mentalizing account. Taken together, the RTs and Error rates analysis are in line with experiment 2 findings and therefore support the idea that an integrated approach between the two accounts is needed and that the two behavioural measures reflect different processes (Khalifa-Gueta, 2018; Prinzmetal et al., 2005). These findings strengthen up the hypothesis advanced in experiment 2 which is that two different processes are required in the DPT, a voluntary and an involuntary process: an involuntary orienting process which affects RTs only and a voluntary decisional process which affects both RTs and errors. Participants are first involuntarily oriented towards the location indicated by the directional features of the cue; then the voluntary decisional process provides an answer to the task confirming whether the targets visible from a given perspective are equal to the prompted number.

5.5.1 Conclusions

To summarise, experiment 3 aimed to further investigate the role of directional and social features in generating interference effect and to answer one of the possible critiques advanced to experiment 2, whilst replicating its findings. Results confirmed experiment 2 findings by showing that cues with conjugated social and directional features (*Social+Directional* and *Social+Directional+*) generate interference in both RTs and errors whilst a cue with isolated social features (*Social_Only*) did not generate interference in RTs but only in the error rates. More interestingly, the *Social+Directional+* cue, which possessed stronger directional features but identical social features, generated the larger interference in the RTs, whilst generating the same amount of interference as the other cues in the error rates. Thus, supporting the idea that the saliency of a cue's directional feature may directly affect the amount of interference effect measured in the RTs, whilst it does not affect the error rates.

These results further support the hypothesis that two processes are engaged in the DPT: an involuntary orienting process - assessed by the RTs only - and a voluntary decisional process - measured also by the error rate. Thus, providing further evidence in favour of the need for an integrated approach between the domain-general and mentalizing account in order to explain the interference effect emerging in the DPT.

5.6 Preliminary experiment

5.6.1 Introduction and Methods

Three preliminary experiments were conducted to assess whether the *Social_Only*, *Social+Directional* and *Social+Directional+* cues orient attention. For this purpose, similarly to experiment 2, an adapted version of the Posner paradigm (Posner & Coehn, 1984) was used. The experimental sequence of the events was as follow: At the beginning, a fixation cross was presented at the centre of a computer screen for 1000 ms. This was then followed by the onset of a cue (*Social_Only* cue in experiment 3A, *Social+Directional* cue in experiment 3B and *Social+Directional* in experiment 3C) in the centre of the screen for 200 ms. A target disc was then presented either to the left or to the right. Participants were asked to press the "LEFT" key on their keyboard when the target appeared on the left and the "RIGHT" key when the target appeared on the right. A total of 128 trials were presented in a random order. As in a typical Posner paradigm, in 75% of the trials the cue faced towards the location of the target (Congruent) and to the opposite direction in the remaining 25% (Incongruent). Reaction times were recorded. After 64 trials participants were requested to have a break in order to avoid any fatigue effect. Before starting the experiment, participants underwent a short practice. 48 participants in total (16 per experiment, see methods section in the main study for the power analysis) took part in this study (age range 22 to 52) of which 24 females. Participants were naïve to the purpose of the study and received no remuneration for taking part. None of these participants took part in the main study (See main study for recruitment and ethics procedure).

For a description of the statistical tools employed in this preliminary study, see the main study results section. Means and standard deviations for RTs are shown in Table 5.8

5.6.2 Results

As it can be seen in Table 5.8, participants were faster in the Congruent than in the Incongruent condition for all the three types of cues. However, a meaningful difference is evident between them with participants being much slower in the Congruent condition when the *Social_Only* cue was employed. Furthermore, interestingly, participants were faster in the Incongruent condition when the *Social+Directional+* cue was employed than then the cue was the *Social+Directional*.

Table 5.8: Mean and SD for RTs.

TypeofCue	Congruency	Mean	sd
Social+Directional+	Incongruent	0.446	0.099
	Congruent	0.418	0.108
Social+Directional	Incongruent	0.458	0.128
	Congruent	0.412	0.123
Social_Only	Incongruent	0.449	0.141
	Congruent	0.440	0.153

Figure 5.9 shows the results of a Bayesian Weibull mixed-effects model with Congruency and Types of cue - together with their interaction - as population-level factors and Subject as group-level factor. Flat priors for the population level effects were used and weakly informative priors for the intercept [student_t(3, 0.7, 2.5)] and for the group level effects [student_t(3, 0, 2.5)]. For model estimation, four chains with 5000 iterations (2500 warmup) were used. Convergence was checked as for the main study.

Table 5.9: Population level effects of the brms model.

Covariate	Estimate	Est.Error	l-95% CI	u-95% CI
Intercept	-0.86	0.05	-0.95	-0.77
CongruencyCongruent	-0.04	0.01	-0.07	-0.01
TypeofCueNoTail	0.06	0.07	-0.07	0.19
TypeofCueTailInconsistent	0.00	0.06	-0.12	0.13
CongruencyCongruent:TypeofCueNoTail	-0.05	0.02	-0.09	-0.01
CongruencyCongruent:TypeofCueTailInconsistent	0.06	0.02	0.02	0.10

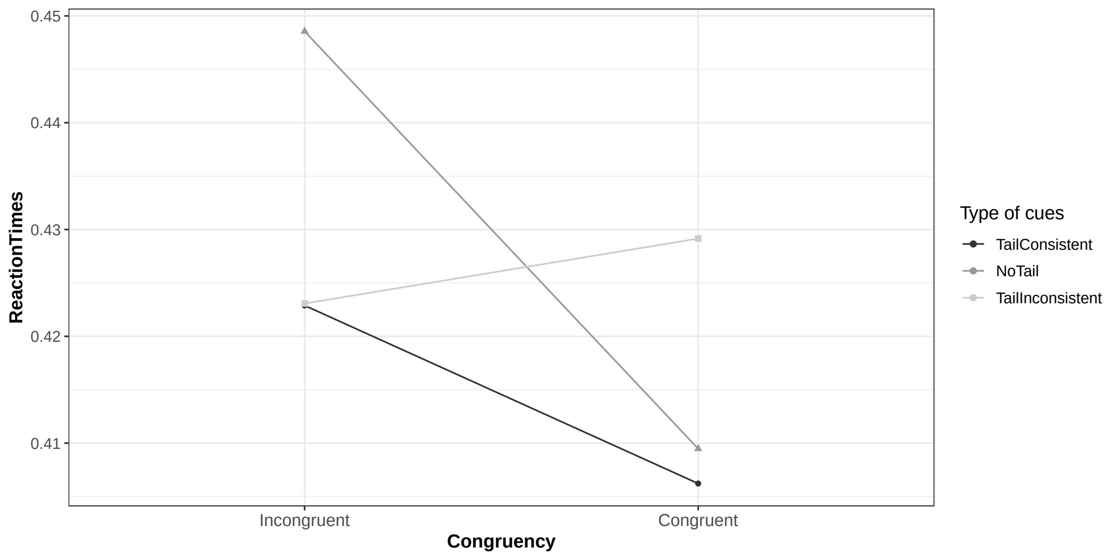


Figure 5.10: Estimated marginal means for each level of Congruency (Incongruent vs Congruent) for each Type of cue (*Social+Directional+* vs *Social+Directional+* vs *Social_Only*).

Figure 5.10 and Table 5.9 show the estimated marginal means of the two different conditions (Congruent vs Incongruent) for the three cues (*Social+Directional*, *Social+Directional+* and *Social_Only*). A main effect of the interaction between Types of Cue and Congruency emerged, with shorter RTs for the Congruent and Social+Directional trials [-0.05, SE 0.02, 95% CI (-0.09, -0.01)] and longer RTs for the Congruent and *Social_Only* trails [0.06, SE 0.02, 95% CI (0.02, 0.10)].

5.6.3 Cueing effects of the three cues

Table 5.10 and Figure 5.11 show the cueing effects (intended as the mean difference between the Incongruent and Congruent conditions) generated by the three types of cue. As it can be seen, the *Social+Directional* cue clearly generates a cueing effect; with the entire HDI falling outside the ROPE. Interestingly, the *Social+Directional+* cue generates a smaller cueing effect than the *Social+Directional* cue with 21.25% of the HDI falling within the ROPE. As expected, *Social_Only* cue does generate any cueing effect with 91.17% of the HDI falling within the ROPE.

Table 5.10: Cueing effect for each type of cue.

Parameter	Mean	89% HDI	89% ROPE	% in ROPE
Incongruent - Congruent, TailConsistent	0.02	[0.01, 0.03]	[-0.01, 0.01]	21.25%
Incongruent - Congruent, NoTail	0.04	[0.03, 0.05]	[-0.01, 0.01]	0%
Incongruent - Congruent, TailInconsistent	-6.11e-03	[-0.02, 0.00]	[-0.01, 0.01]	91.17%

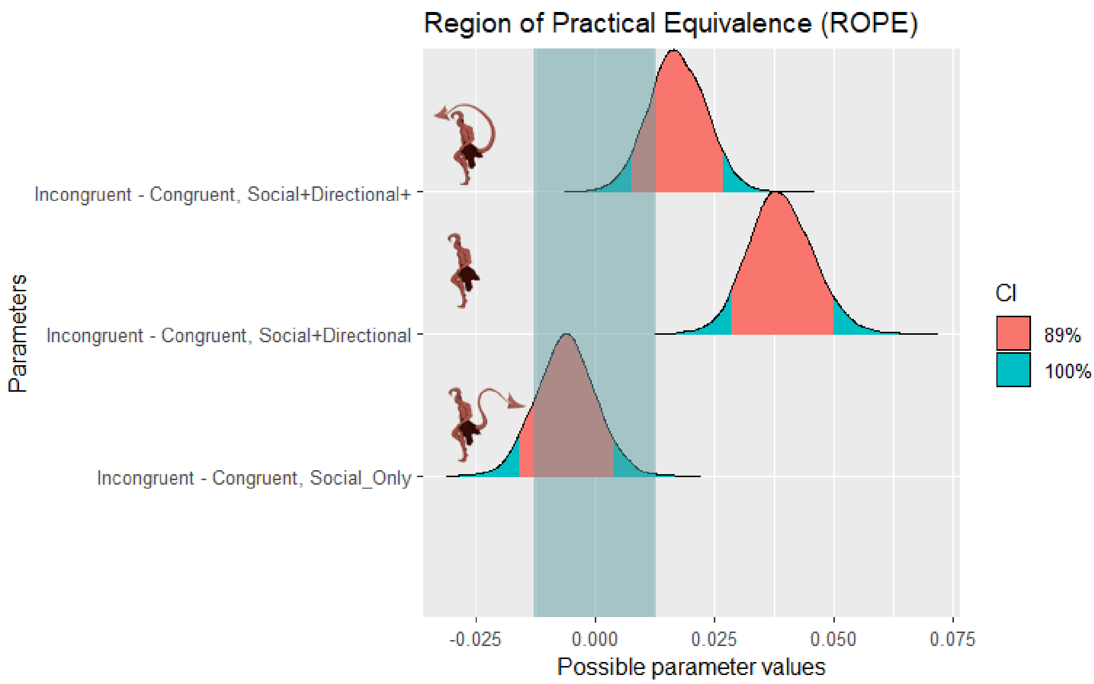


Figure 5.11: ROPE and HDI of the interaction for the three types of cues *Social+Directional+*, *Social+Directional* and *Social_Only* cue.

Taken together, these results show that the *Social+Directional* and the *So-*

cial+Directional+ cues orient attention, while the *Social_Only* cue does not. This indicates that the arrowed-shaped tail cancels out (or at least attenuates) the directional features of the devil's posture.

6
Experiment 4

6.1 Introduction

Experiments 2 and 3 provided further support to the hypothesis that two processes - a reflexive orientating and a voluntary decisional process - are involved in generating the attentional interference recorded in the Dot Perspective Task. The former is influenced by the saliency of the directional features of the cue present in the visual scene, while the latter is influenced by its social features. Furthermore, both experiments suggested that behavioural measures such as Reaction Times and error rates may be not equally sensitive to the two processes. Whilst the involuntary orientating process appears to be measured by the RTs only, the voluntary decisional process is measured also by the error rate. Whilst experiment 3 focused on experimentally manipulating the directional features of the cue, increasing, or contrasting their saliency, this experiment will focus on experimentally manipulating also its social features. To accomplish this, the attribution of intentionality to the cue by the participants was modulated. As previously mentioned in the introductory chapters of this thesis, Wiese et al. (2012) and Langton (2018) suggested that the reason for the Dot-Perspective task's inconsistent outcomes whilst employing similar manipulation of the cue's social features (e.g., goggles vs blindfolded cues) may have been due to participants' different stance towards the cue's intentions. Before mentalizing processes may emerge and humans depict the other's behaviour or perspective, people must take an active attitude toward a cue (Wiese et al., 2012). The way we allocate resources is thus influenced by our perception that other people are intentional systems. We can engage in collaborative activities by sharing our goals, intentions, information, and beliefs with others by paying attention to where they are attending (Tomasello, 2008; Wiese et al., 2012). This helps to establish shared intentionality. Moreover, if this is the case, manipulating the social features of the cue could provide further evidence in support of the idea that two different processes are involved in generating the interference effect and that those two are differently affected in a different manner by the social and the directional features of the cues. To experimentally manipulate both the directional and social features of the cue, a similar process of thoughts to the one employed to generate the previous cues was used. The two cues employed in this experiment can be seen in Figure 6.1.

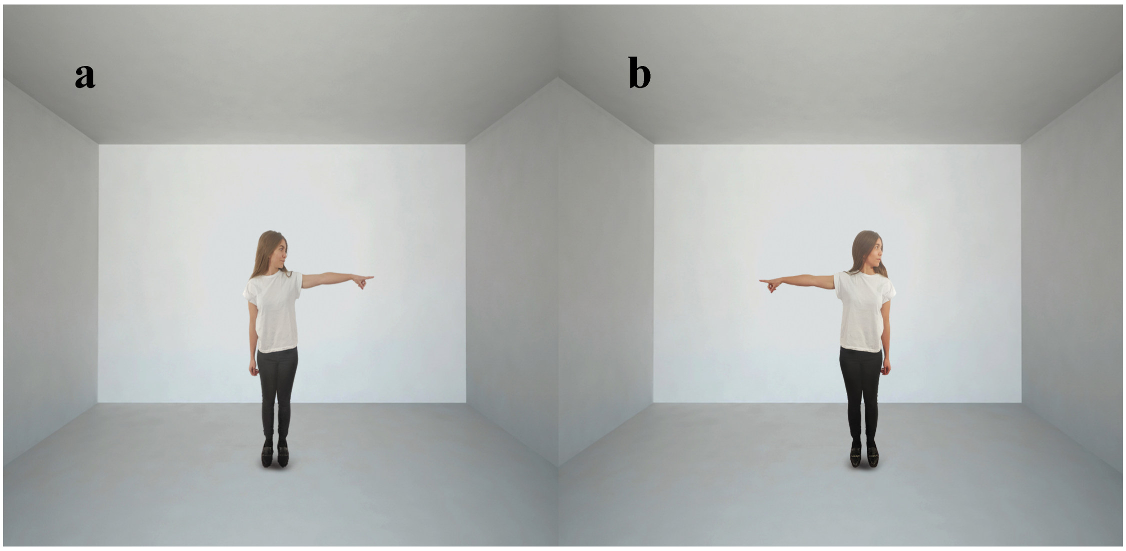


Figure 6.1: Cues used in experiment 4. a) *Clear_Intentionality*: the human avatar presents coherent and confounded social and directional features, which show a clear intentionality. b) *Ambiguous_Intentionality*: the human avatar presents contrasting social and directional features, which make its intentionality to point participant's attention towards a specific direction ambiguous.

Analogously to previous experiments, the body features of a cue were manipulated in order to obtain a cue in which social and directional features could be manipulated to obtain the desirable features. To this end, a female human avatar was employed as starting point. The human avatar presented neutral clothes and it presented a neutral body stance. In other words, the human avatar was facing the participants and only its head was turned either left or right to face a specific direction[1]. By using this avatar as a starting point, a first cue presenting clear intentionality was developed. This cue consisted of the same female human avatar, however, instead of having her arm along the body, this cue presented one of her arms extended and pointing towards the same location of her head. Despite being similar to the *Social+Directional+*, for ease of understanding and due to the aim of this experiment to investigate the attribution of intentionality

[1]The effectiveness of this avatar to generate attentional interference and therefore a Reflexive Attention Shift in the Dot Perspective Task was shown in a preliminary experiment (see preliminary experiment section for the results)

to the cue, this cue is named *Clear_Intentionality*. The straight arm, together with the girl's viewpoint, shows a clear intention by the avatar to direct the participants' attention towards a specific direction. Pointing with the index finger is a ubiquitous human behaviour that can be found in all cultures across the world (Povinelli & Davis, 1994). Since an early age, humans have used pointing to communicate and indicate intentionality with others without the use of verbal skills (Crais et al., 2004). Furthermore, visual perspective taking, among other cognitive abilities, has been linked with the onset of pointing in infancy (Povinelli & Davis, 1994). Likewise, a second cue having contrasted directional features and ambiguous intentionality was developed. Similarly, to the dragon and the devil previously employed, the added directional feature (the arm) points towards the opposite direction of the girl's viewpoint. However, whilst the previous cues were named *Social_Only* as the contrasting directional features did not have any social relevance and therefore it left only the social features to orient attention; the same name cannot be used here. As aforementioned, the extended arm presents social relevance rendering the cue's intentionality ambiguous. This cue was therefore named *Ambiguous_Intentionality*.

6.1.1 Account's prediction

Since both previous experiments consistently provided evidence in favour of the need for an integrated approach account, this section will present the prediction advanced by this integrated approach when similar cues to the ones presented in Fig 6.1 are employed.

Because according to the integrated approach Reaction Times and error rates may measure distinct cognitive processes [2], different results are predicted for the

[2]Comprehensively, RTs may measure involuntarily orientating processes elicited by the direc-

two measures.

- For the *Clear Intentionality* cue, the integrated approach account would predict that the avatar would generate interference for both RTs and error rates. On one hand, the attentional interference measured by the RTs would be due to the directional features of the cue eliciting an orientating process, on the other hand, the interference measured by the error rates would be due to the decisional process affected by the social features of the cues.

- Conversely, the integrated account would predict that the *Ambiguous Intentionality* cue would not generate any interference for both RTs and error rates. The absence of interference in the RTs would be due to the contrasting directional features of the arm and the cue's face, whilst the absence of interference in the error rates would be due to the contrasting social information provided by the cue's viewpoint and its intentionality expressed by the straight pointing arm. It must be noted that both the mentalizing and domain-general account would make a similar prediction to the one advanced by the integrated account. However, whilst the two accounts would predict similar outcomes, their interpretations, which rely on a single process, would still not be able to explain previous findings resulting from cues having only one set of features left to orient attention (e.g., the dragon and the devil employed in previous experiments). In other words, when similar cues to the ones employed in this experiment are present in the visual scene, the domain-general and mentalizing account fail to recognize that even if the effects produce the same behavioural data, they may be caused by different processes (Cole & Millett, 2019).

tional features of the cue whilst error rates may measure voluntarily decisional processes elicited and affected by its social features.

6.2 Methods

6.2.1 Sampling plan and stopping rule

Sampling plan and stopping rule followed the Sequential Bayes Factors (SBF) procedure (Schönbrodt et al., 2017) presented in the General Methods section of this thesis. Thus, data collection continued until the predetermined stopping criterion at the point of checking was reached. Sampling was stopped after collecting 18 participants as one of the BF10 was higher than 10 (specifically, the BF10 of the interference for the *Clear_Intentionality* cue was equal to 38.617).

6.2.2 Participants

Eighteen (18) participants took part in this study (age range 20 to 37) of which 12 females. Participants were naïve to the purpose of the study and received no remuneration for taking part. Informed consent was obtained from each participant through the Qualtrics online platform (`https://www.qualtrics.com`) in accordance with the University's ethical procedures.

6.2.3 Design

The variables used in the study were: Consistency (Inconsistent vs Consistent), Perspective (Self vs Other) and Types of cue (*Clear_Intentionality* vs *Ambiguous_Intentionality*). Contrary to previous experiments, all the variables were measured by employing a within-participant design.

Due to the type of cue employed and its manipulation, it was hypothesized that it would not generate the "experimental subordination" phenomenon (Asch, 1956; Gilchrist, 2020), and therefore they would not adapt their answers according to what they thought they were expected to respond.

6.2.4 Stimuli and Procedure

Stimuli presentation and procedure were accordingly to the general procedure presented in chapter 2 of this thesis. In this experiment, the pronouns YOU and SHE were employed to prompt participants respectively with the "Self" or "Other" perspective. In total, 120 trials were presented to each participant. These comprised 54 YES and 66 NO response trials. In 60 trials the *Clear_Intentionality* cue was presented, whilst the *Ambiguous_Intentionality* cues was presented in 60 trials. Furthermore 60 trials had as prompted perspective YOU while the remaining 60 had SHE. Before the start of the experiment, participants took part in a small practice of 12 trials to familiarize with the task. The experiment lasted on average 15 minutes.

6.3 Results

Means and standard deviations for both RTs and error rate are shown in Table 6.1 and Figure 6.2. As per Whelan (2008), trials in which RTs are faster than 100 ms should be considered non-genuine. No RTs lower than 100 ms were present in this study. No trimming was conducted on higher reaction times, given the imposed cut-off of 2000 ms on all trials.

Table 6.1: Mean and SD for RTs (top) and Error Rates (bottom).

Perspective	Consistency	TypeofCue	Mean	sd
Other	Inconsistent	Clear_Intentionality	0.829	0.319
	Consistent	Ambiguous Intentionality	0.837	0.347
		Clear_Intentionality	0.788	0.311
Self	Inconsistent	Ambiguous Intentionality	0.733	0.271
		Clear_Intentionality	0.757	0.292
	Consistent	Ambiguous Intentionality	0.735	0.278
		Clear_Intentionality	0.679	0.251

Perspective	Consistency	TypeofCue	Mean	sd
Other	Inconsistent	Clear_Intentionality	0.171	0.378
	Consistent	Ambiguous Intentionality	0.125	0.334
		Clear_Intentionality	0.053	0.225
Self	Inconsistent	Ambiguous Intentionality	0.044	0.207
		Clear_Intentionality	0.137	0.344
	Consistent	Ambiguous Intentionality	0.045	0.207
		Clear_Intentionality	0.061	0.241

As it can be seen, for both RTs and error rates, an interference (intended as the mean difference between the Inconsistent and the Consistent trials) seems to emerge for the "*Clear_Intentionality* cue while no interference appears to be present for the *Ambiguous_Intentionality* cue.

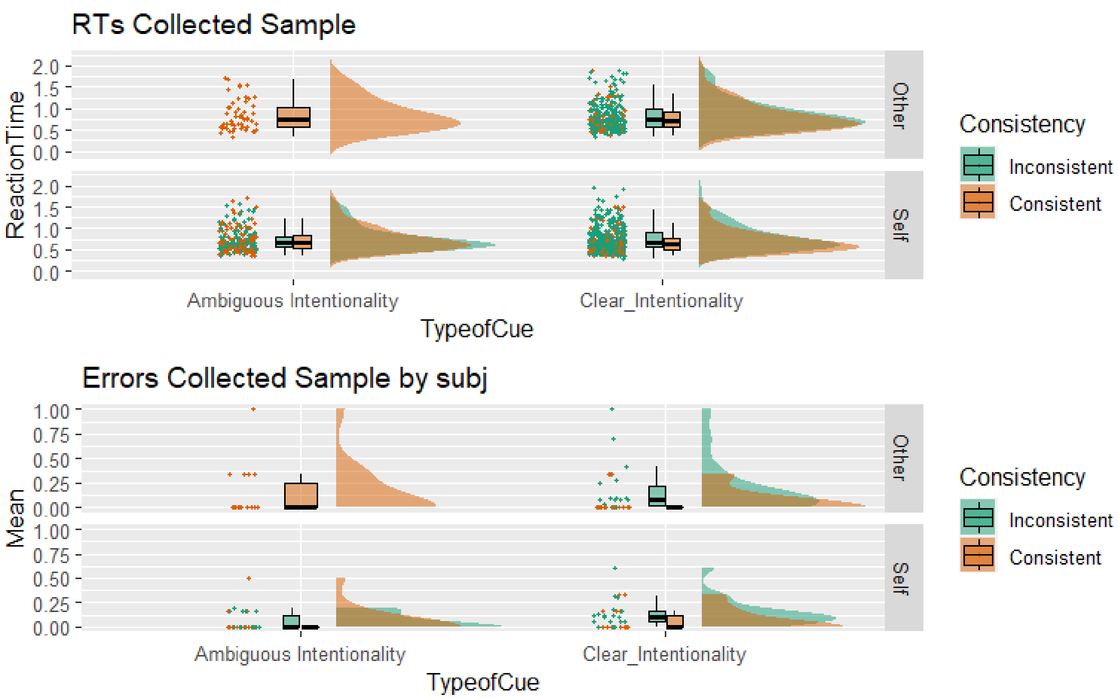


Figure 6.2: Rain plots reporting Mean and SE of distribution for sample's RTs on the top and Error Rates on the bottom for each combination of stimulus presentation (Consistent vs. Inconsistent) and perspective adopted (Self vs Other) for the two types of cues (*Ambiguous_Intentionality* vs *Clear_Intentionality*).

6.3.1 Data Analysis

Similarly to previous experiments, to enable generalization across stimuli and participants, data were analysed with mix-models (Judd et al., 2012); specifically, Bayesian mix-models were created in Stan computational framework (Carpenter et al., 2017) accessed with the high-level interface "brms" package 2.10.0 (Bürkner, 2017, 2018) in R version 3.6.2 (R Core Team, 2020). Like in experiment 3, in an effort to facilitate and ease the description of the task for the reader, the details of the models are specified below. Two individual models were run, one for the RTs and another for the error rate. For both models, the variables Perspective, Consistency and Types of cues - together with their interaction - were initially inputted as population-level factors and the variable Subject as a group-level factor. Moreover, as each combination of the conditions was presented in more than 1 trial, the variable Trials was also inputted in the models as a group-level factor nested within the variable Subject. The two models were therefore similar in their formulae; however, for the RTs it was utilized the Weibull family distribution (Logan, 1992; Palmer et al., 2011; Rouder et al., 2005) and the Bernoulli family distribution for the error rate (Bürkner, 2018). For testing opposite predictions, we set flat priors for the population level effects and weakly informative priors for the intercept [student_t(3, 0.7, 2.5)] and for the group level effects [student_t(3, 0.7, 2.5)]. For model estimation, four chains with 4000 iterations (2500 warmups) were used. Convergence was checked via Gelman & Rubin (1992) convergence statistics (Rhat close or equal to 1.0) and by visual inspection of the posterior distribution of all the coefficients and their chain convergence. The inspection of the Bayesian mix-model for RTs showed an issue with convergence. Rhat convergence diagnostic is employed in order to compare the between- and within-chain estimates for model parameters and other interesting univariate values. The Rhat for this model were in fact equal or above to RHat 2.26 rendering the predicted values not reliable. A second set of models was run for both RTs and error rates. Because the level Other of the variable perspective was not of interest for this study, these new models did not include Perspective as a variable. Thus only the trials with Perspective Self were investigated. The remaining variables and set-up of the model remained unvaried. For both RTs and error rates, the new model converged, with an Rhat close to or equal to 1.0.

6.3.2 Reaction Time Analysis

Table 6.2 shows the results of the Bayesian linear mixed-effects model. Figure 6.3 shows the estimated marginal means for Inconsistent and Consistent trials for the two types of cues.

Table 6.2: Population level effects of the brms model.

Covariate	Estimate	Est.Error	l-95% CI	u-95% CI
Intercept	-0.36	0.07	-0.49	-0.23
ConsistencyConsistent	-0.01	0.03	-0.08	0.06
TypeofCueClear_Intentionality	0.07	0.03	0.01	0.13
ConsistencyConsistent:TypeofCueClear_Intentionality	-0.14	0.05	-0.23	-0.06

It emerged a main effect of TypeofCue with longer RTs for the *Clear_Intentionality* Trials [0.07, SE 0.03, 95% CI (0.01, 0.13)]. It emerged also an effect of the interaction between Consistency and Type of Cue with shorter RTs in the Consistent and *Clear_Intentionality* trials [-0.14, SE 0.05, 95% CI (-0.23, -0.06)].

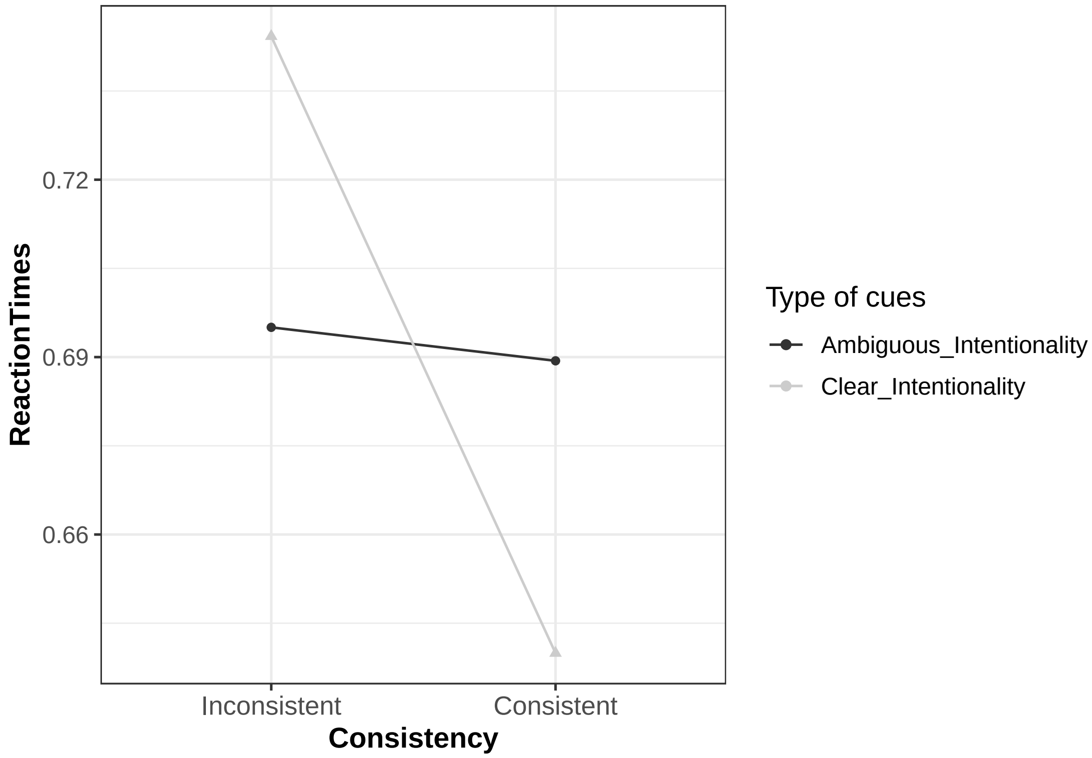


Figure 6.3: Estimated marginal means for each combination of stimulus presentation (Inconsistent vs Consistent) and Type of cue (*Ambiguous_Intentionality* vs *Clear_Intentionality*) for RTs.

6.3.3 Error Rate analysis

Table 6.3 shows the results of the Bayesian mixed-effects model and Figure 6.4 shows the estimated marginal means for the Inconsistent and Consistency trials for the two types of cue.

Table 6.3: Population level effects of the brms model.

Covariate	Estimate	Est.Error	l-95% CI	u-95% CI
Intercept	-3.79	0.64	-5.17	-2.66
ConsistencyConsistent	0.00	0.71	-1.41	1.39
TypeofCueClear_Intentionality	1.50	0.54	0.55	2.61
ConsistencyConsistent:TypeofCueClear_Intentionality	-1.10	0.85	-2.80	0.56

For the error rates, it only emerged a main effect of TypeofCue with more errors in the *Clear_Intentionality* Trials [1.50, SE 0.54, 95% CI (0.55, 2.61)]. No other effects emerged for the error rates.

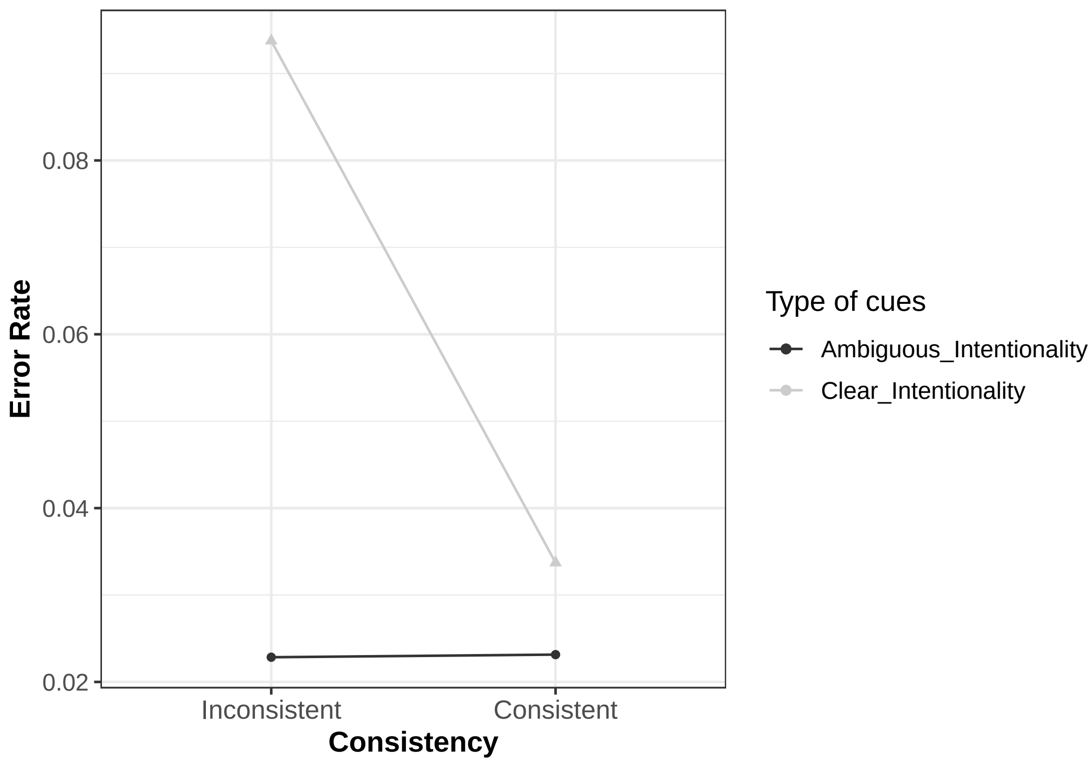


Figure 6.4: Estimated marginal means for each combination of stimulus presentation (Inconsistent vs Consistent) and type of cues (*Clear_Intentionality* vs *Ambiguous_Intentionality*) for error rates.

6.4 Planned post-hoc comparisons

Because predictors in models are conditional to all other factors with which they interact, they do not provide the desired comparisons. As specified in the introduction, to assess the prediction of the integrated approach account, planned comparisons were conducted between:

- Inconsistent vs Consistent within the *Ambiguous_Intentionality* type of cue;
- Inconsistent vs Consistent within the *Clear_Intentionality* type of cue;
- Between the interferences of the two cues (Inconsistent - Consistent in the *Ambiguous_Intentionality* vs Inconsistent - Consistent in the *Clear_Intentionality* cue).

Post-hoc comparisons were extracted using the emmeans package version 1.5.4 (Lenth, 2021) and the Easystats package version 0.2.0 (Lüdecke et al., 2020). Decisions on the comparisons were based on the relative positions of the Highest Density Interval (HDI, Box & Tiao, 1992; Chauhan et al., 2017; Hespanhol et al., 2019) and the predefined regions of practical equivalence (ROPE) of 89% (Kruschke & Liddell, 2018a, 2018b; McElreath & Safari, 2020). In agreement with Kruschke & Liddell (2018a) the ROPEs were defined as +/-0.1*SD for the contrasts.

6.4.1 Reaction Time analysis

Table 6.4 and Figure 6.5 show the interference (intended as the RTs difference between the Inconsistent and Consistent levels of Consistency variable) generated by the two cues. The *Clear_Intentionality* cue clearly generates an interference; the entire HDI falls outside of the ROPE indicating that 89% of the most credible values of the interference are different from the null value. There is instead only a 14% probability that the *Ambiguous_Intentionality* cue generates interference; 86% of the HDI falls within the ROPE, indicating that 86% of the most credible values of the interference are practically equivalent to the null value.

Table 6.4: Interference for the two types of cue.

Parameter	Mean	89% HDI	89% ROPE	% in ROPE
Inconsistent - Consistent, Ambiguous_Intentionality	5.62e-03	[-0.03, 0.04]	[-0.03, 0.03]	86.83%
Inconsistent - Consistent, Clear_Intentionality	0.10	[0.07, 0.14]	[-0.03, 0.03]	0%

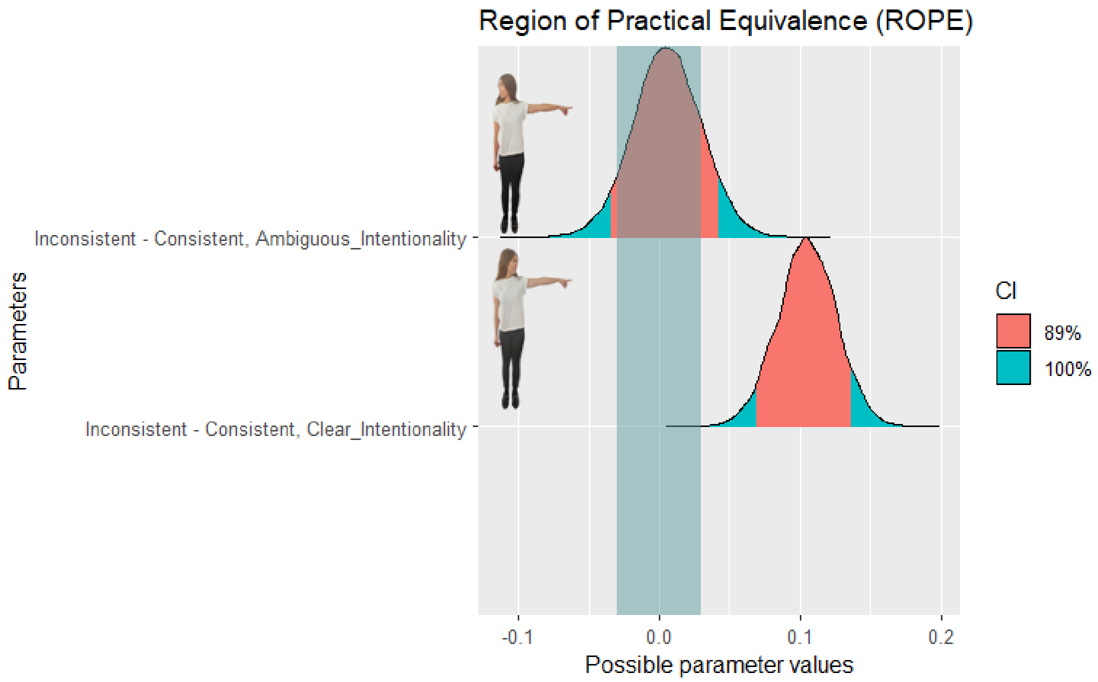


Figure 6.5: ROPE and HDI of the interference for *Ambiguous_Intentionality* and *Clear_Intentionality* cue for RTs.

The comparison between the two interferences (i.e., the interferences generated by the two types of cue) is shown in Table 6.5 and Figure 6.6. It can be seen that the *Clear_Intentionality* cue generated much more interference than the *Ambiguos_Intentionality* cue. The entire HDI falls outside of the ROPE indicating that 89% of the most credible values of the difference between the interferences are different from the null value.

Table 6.5: Interference difference between the two cues.

Parameter	Mean	89% HDI	89% ROPE	% in ROPE
Inconsistent - Consistent, Ambiguous_Intentionality - Clear_Intentionality	-0.10	[-0.15, -0.05]	[-0.03, 0.03]	0%

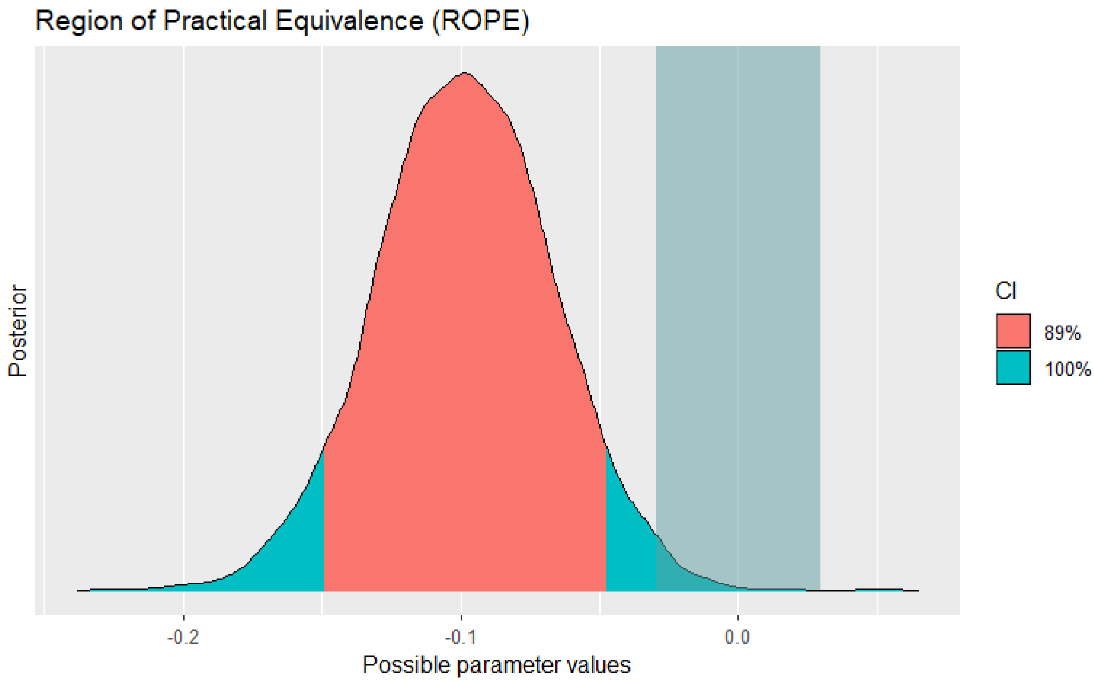


Figure 6.6: ROPE and HDI of the differences between the interference for *Ambiguous_Intentionality* and *Clear_Intentionality* cue for RTs.

6.4.2 Error Rates Analysis.

Table 6.6 and Figure 6.7 show the interference generated by the two cues. The *Ambiguous_Intentionality* cue generates no interference, with 100% of the HDI falling within the ROPE. On the contrary, an interference is present for the *Clear_Intentionality* cue with only 7% of the HDI falling within the ROPE, thus meaning that 99% of the most credible values of this contrast are different from the null value.

Table 6.6: Interference for the two types of cue.

Parameter	Mean	89% HDI	89% ROPE	% in ROPE
Inconsistent - Consistent, Ambiguous_Intentionality	-3.30e-04	[-0.03, 0.03]	[-0.03, 0.03]	99.79%
Inconsistent - Consistent, Clear_Intentionality	0.06	[0.02, 0.10]	[-0.03, 0.03]	7.13%

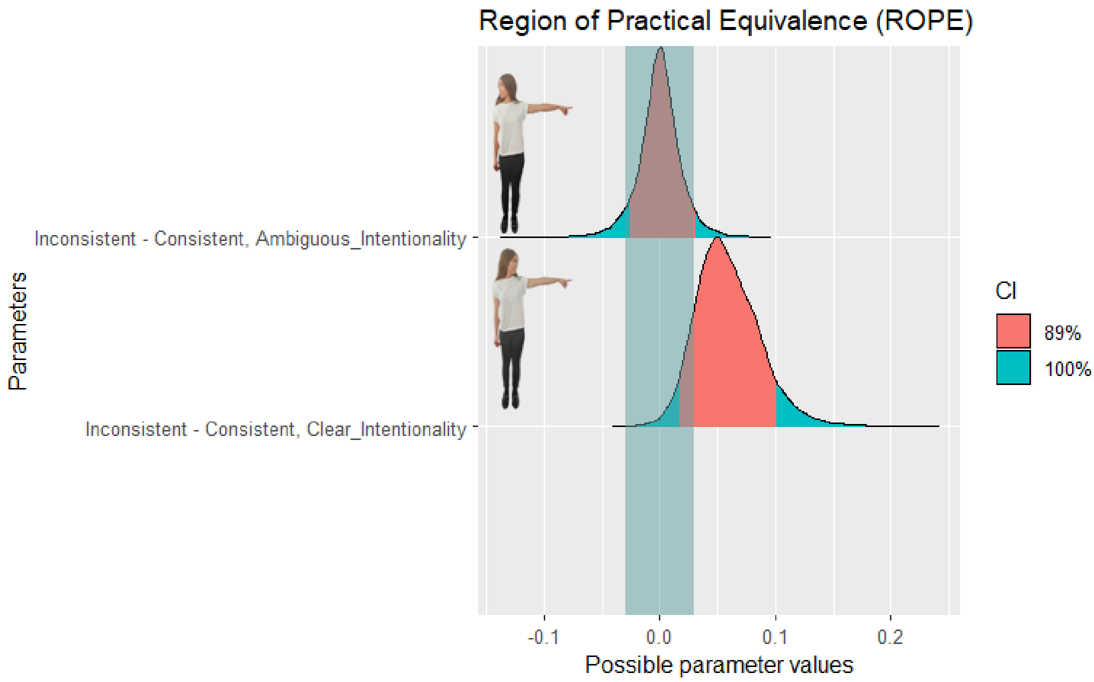


Figure 6.7: ROPE and HDI of the interference for *Ambiguous_Intentionality* and *Clear_Intentionality* cue for error rates.

The comparison between the interferences generated by the two types of cue is shown in Table 6.7 and Figure 6.8. It can be seen that 88% of the 89% most probable values for this comparison fall outside of the ROPE, clearly indicating that the two cues generate a different amount of interference.

Table 6.7: Interference difference between the two cues.

Parameter	Mean	89% HDI	89% ROPE	% in ROPE
Inconsistent - Consistent, Ambiguous_Intentionality - Clear_Intentionality	-0.06	[-0.11, -0.01]	[-0.03, 0.03]	12.47%

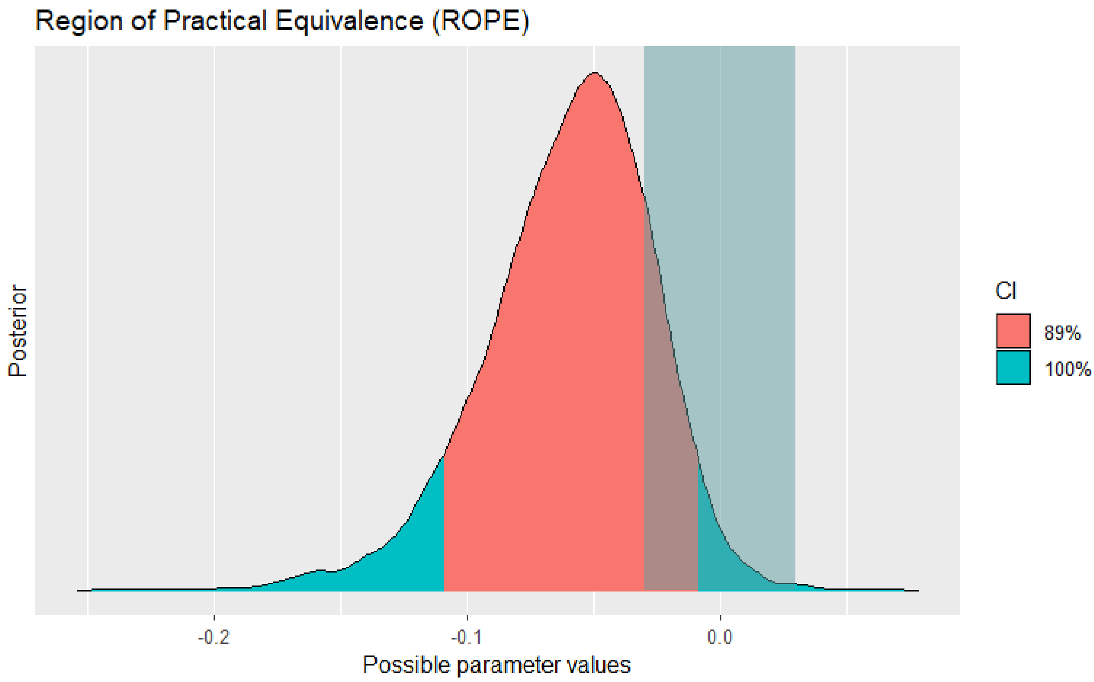


Figure 6.8: ROPE and HDI of the differences between the interference of *Ambiguous_Intentionality* and *Clear_Intentionality* cue for error rates.

6.5 Discussion

This experiment aimed to further investigate the role of domain-general and mentalizing processes in generating attentional interference. The findings from Experiments 2 and 3 provided support to the hypothesis that the attentional interference observed in the Dot Perspective Task is the result of two processes: a reflexive orienting process and a voluntary decisional process. The saliency of the cue's directional features affects the former, while the cue's social features affect the latter. Therefore, an integrated approach between mentalizing and domain-general accounts seems to be needed to explain this phenomenon.

Moreover, this experiment aimed to provide further evidence in support of the idea that RTs and error rates may not be equally sensible to different cognitive processes, as suggested by the results of previous experiments. While the involuntary orientating process is measured only by RTs, the voluntary decision-making process appears to be measured also by the error rates.

To accomplish this, a set of cues with experimentally manipulated social features were employed. This was achieved by experimentally manipulating the attribution of intentionality by the participants to the cues presented in the visual scene. Wiese et al. (2012) and Langton (2018) hypothesised that participants' diverse attitudes toward the cue's intentions may have contributed to the Dot-Perspective task's conflicting results. People must adopt an active attitude toward a cue before mentalizing processes may arise and humans can describe the behaviour or the perspective of the other (Tomasello, 2008; Wiese et al., 2012). If this is the case, then manipulating the social features of the cue may offer additional evidence that the attentional interference is produced by two distinct processes, each of which is influenced differently by its social and directional features. To this end, two cues were developed: a cue with *Clear_Intentionality* and a second cue with *Ambiguos_Intentionality*. The intentionality of the cue was expressed by its head and viewpoint position in relation to its body and by a straight pointing arm. On one hand, the head and viewpoint positions were chosen because it has been shown that cues in which body stances where the head and torso orientation are not aligned have a stronger effect in directing attention in spatial cueing tasks. This would be because this combination more accurately signals a person's active attentional behaviour than the more passive gaze-maintained combination (Gardner, Bileviciute, et al., 2018; Hietanen, 2002; Pomianowska et al., 2012). On the other hand, the pointing arm was chosen because humans have utilised pointing to communicate and denote intent with others without the need for language (Crais et al., 2004). Additionally, the development of pointing in infancy has been connected to the ability to take a visual viewpoint (Povinelli & Davis, 1994).

Results showed that the *Clear_Intentionality* cue was able to generate interference in both RTs and error rates, whilst the *Ambiguous_Intentionality* cue did not generate any interference in any of the two behavioural measures. These results provide further evidence in favour of the integrated approach and of the idea that the two measures are sensitive to different cognitive processes, with the saliency of the directional features of the cue affecting only the RTs, while its social features also affect the error rates. In experiments 2 and 3, cues with only contrasting directional features (named *Social_Only*) did generate attentional interference in the error rates only, whilst cues with confounding social and directional features did generate it in both measures. Differently from previous experiments, where the position of the contrasting directional features was unintentional, in this experiment, the contrasting directional features - the pointing arm - were attributed a social relevance, providing therefore at the same time contrasting directional and social features. Thus, cancelling out the effects of the viewpoint in addition to one of the cue's body stances. These results are consistent with the previous experiments included in this thesis. Furthermore, these results are in line with Marotta et al. (2012), which show that whilst studies may often report similar attentional effects for social and directional cues, a qualitative dissociation is present as different attentional mechanisms are involved in their processing. To this end, the effect generated by the social features of the cue seems to be due to participants attributing to the cue the intention to look in a specific direction (goal-oriented) (Marotta et al., 2012; Vuilleumier, 2002). When the cue has only directional features (e.g., an arrow), the interference would be generated by a low-level stimulus-driven system; consequently, these social dynamics would not be in play (as shown by experiments 2 and 3).

6.6 Preliminary experiment

6.6.1 Introduction

As mentioned above, experiment 4's cue's features were manipulated similarly to previous experiments, in order to develop a cue that would allow the manipulation of social and directional features. A female human avatar was used as the main basis for this. The human avatar had neutral attire and a neutral body stance with an incongruent head's position (Figure 6.9). In other words, just the head of the human avatar, which was facing the participants, was rotated to the left or right to face a certain direction. In this pilot study, it was investigated how well this avatar could induce the interference effect seen in the Dot Perspective Task [3].

Figure 6.9: The cue employed in this preliminary experiment.

[3] It must be noted that contrary to previous experiments, where pilot experiments were run in order to provide evidence about the ability of the contrasting directional features (e.g., the dragon's and devil's tail) of orienting attention and eventually manipulating their size, the size of the arm and its natural position when pointing towards somewhere cannot be physically manipulated. For this reason, this was not piloted.

Sampling plan and stopping rule

Sampling plan and stopping rule followed the Sequential Bayes Factors (SBF) procedure (Schönbrodt et al., 2017) presented in chapter 2 of this thesis. Thus, data collection continued until the predetermined stopping criterion at the point of checking was reached. Sampling was stopped after collecting 16 participants as one of the BF10 was higher than 10 (specifically, the BF10 of the interference was equal to 20.551).

Participants

Sixteen (16) participants took part in this study (age range 20 to 37) of which 11 females. Participants were naïve to the purpose of the study and received no remuneration for taking part. Informed consent was obtained from each participant through the Qualtrics online platform (`https://www.qualtrics.com`) in accordance with the University's ethical procedures.

6.6.2 Design

The variables used in the study were: Consistency (Inconsistent vs Consistent) and Perspective (Self vs Other). Both Consistency and Perspective were measured within-subjects, as the dot-perspective task requires.

6.6.3 Stimuli and Procedure

Stimuli presentation and procedure were accordingly to the general procedure presented in chapter 2 of this thesis. In this experiment, the pronouns YOU and SHE were employed to prompt participants respectively with the "Self" or "Other" perspective. In total, 124 trials were presented to each participant. These comprised 60 YES and 64 NO response trials. 60 were Consistent trials, 60 were

Inconsistent trials and 4 were fillers, in which no discs were presented. Furthermore 62 trials had as prompted perspective YOU while the remaining 62 had SHE. Before the start of the experiment, participants took part in a small practice of 14 trials to familiarize with the task. The experiment lasted on average 20 minutes.

6.6.4 Results

Descriptive Statistic

Means and standard deviations for both RTs and error rate are shown in Table 6.8 and Figure 6.10.As per Whelan (2008), trials in which RTs are faster than 100 ms should be considered non-genuine. No RTs lower than 100 ms were present in this study. No trimming was conducted on higher reaction times, given the imposed cut-off of 2000 ms on all trials.

Table 6.8: Mean and SD for RTs and Error Rates.

Perspective	Consistency	Mean	sd
RTs			
Other	Inconsistent	0.867	0.268
	Consistent	0.789	0.267
Self	Inconsistent	0.927	0.291
	Consistent	0.811	0.278
Errors			
Other	Inconsistent	0.290	0.455
	Consistent	0.094	0.292
Self	Inconsistent	0.184	0.388
	Consistent	0.082	0.275

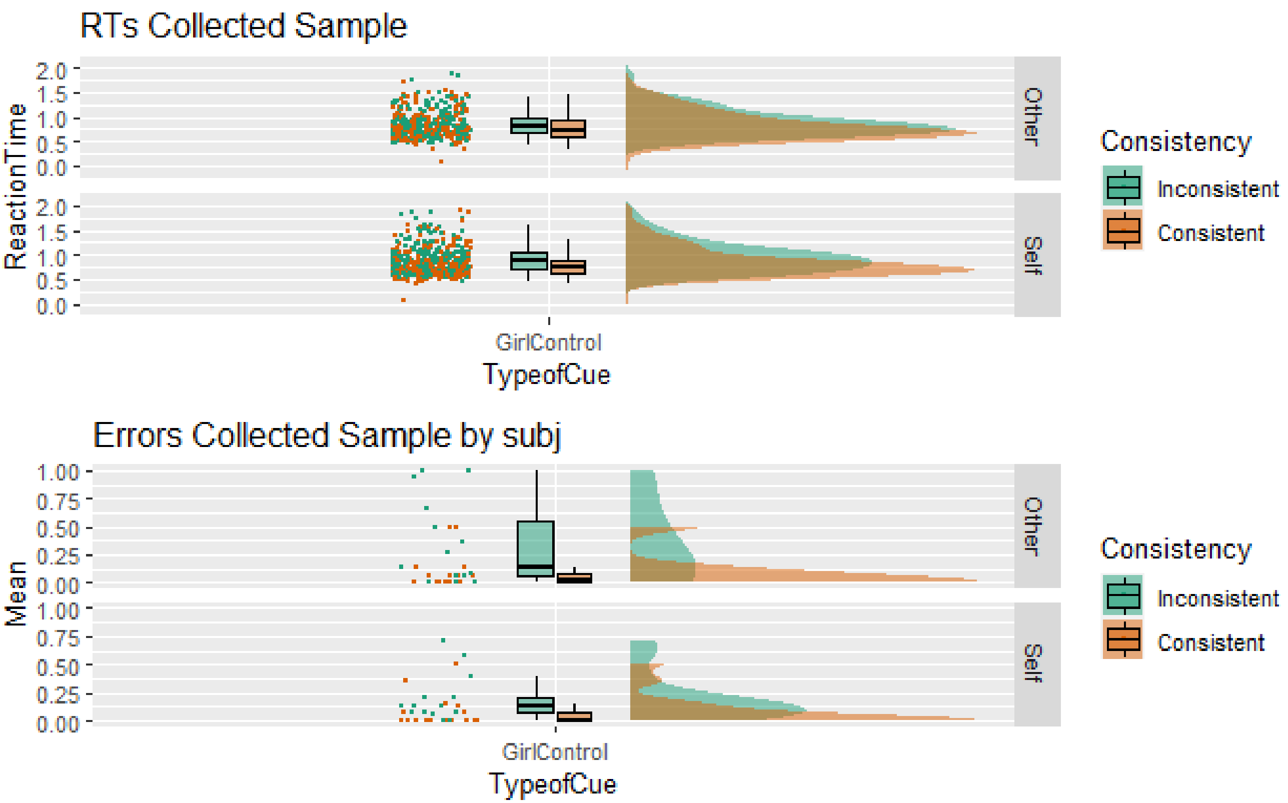


Figure 6.10: Rain plots reporting Mean and SE of distribution for sample's RTs on the top and Error Rates on the bottom for each combination of stimulus presentation (Consistent vs. Inconsistent) and perspective adopted (Self vs Other).

Data Analysis

Reaction Time Analysis Figure 6.11 and Table 6.9 show the estimated marginal means of the two different conditions (Inconsistent vs Consistent) for RTs.

Table 6.9: Population level effects of the brms model.

Covariate	Estimate	Est.Error	l-95% CI	u-95% CI
Intercept	-0.18	0.06	-0.29	-0.07
PerspectiveSelf	0.06	0.02	0.02	0.11
ConsistencyConsistent	-0.09	0.02	-0.13	-0.05
PerspectiveSelf:ConsistencyConsistent	-0.05	0.03	-0.11	0.01

It emerged a main effect of Perspective, with slower RTs in the Self trials [0.06, SE 0.02, 95% CI (0.02, 0.11)]. It also emerged a main effect of Consistency with faster RTs in the Consistent trials [-0.09, SE 0.02, 95% CI (-0.13, -0.05)].

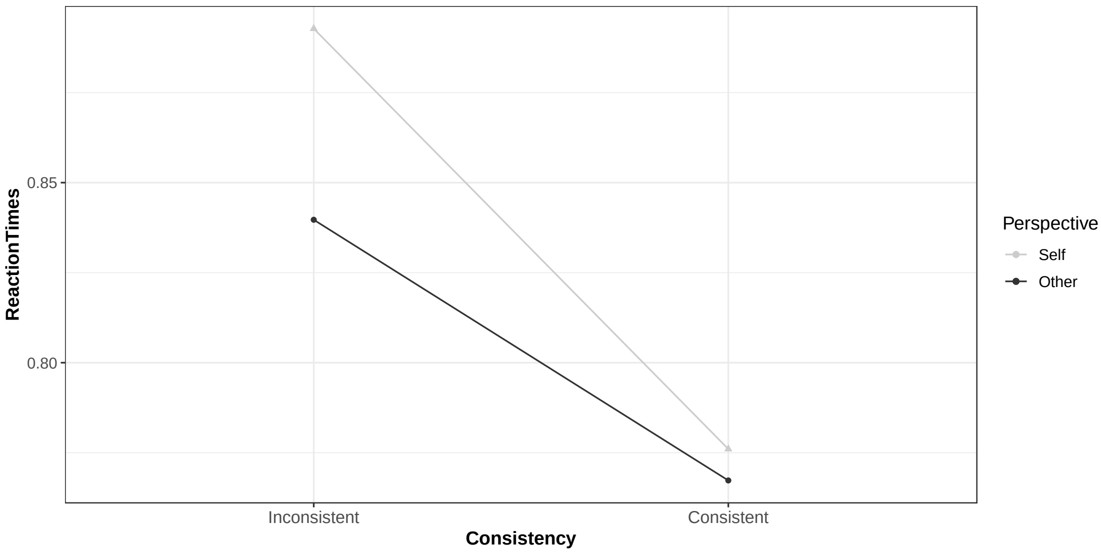


Figure 6.11: Estimated marginal means for each combination of stimulus presentation (Inconsistent vs Consistent) for Perspective adopted (Self vs Other).

Error Rate analysis

Figure 6.12 and Table 6.10 show the estimated marginal means of the two different conditions (Inconsistent vs Consistent) for the error rates.

Table 6.10: Population level effects of the brms model.

Covariate	Estimate	Est.Error	l-95% CI	u-95% CI
Intercept	-1.04	0.46	-1.96	-0.13
PerspectiveSelf	-0.85	0.27	-1.38	-0.32
ConsistencyConsistent	-1.92	0.33	-2.58	-1.26
PerspectiveSelf:ConsistencyConsistent	0.63	0.47	-0.28	1.56

It emerged a main effect of Perspective, with less error rates in the Self trials [-0.85, SE 0.27, 95% CI (-1.38, -0.32)]. It also emerged a main effect of Consistency with less errors in the Consistent trials [-1.92, SE 0.33, 95% CI (-2.58, -1.26)].

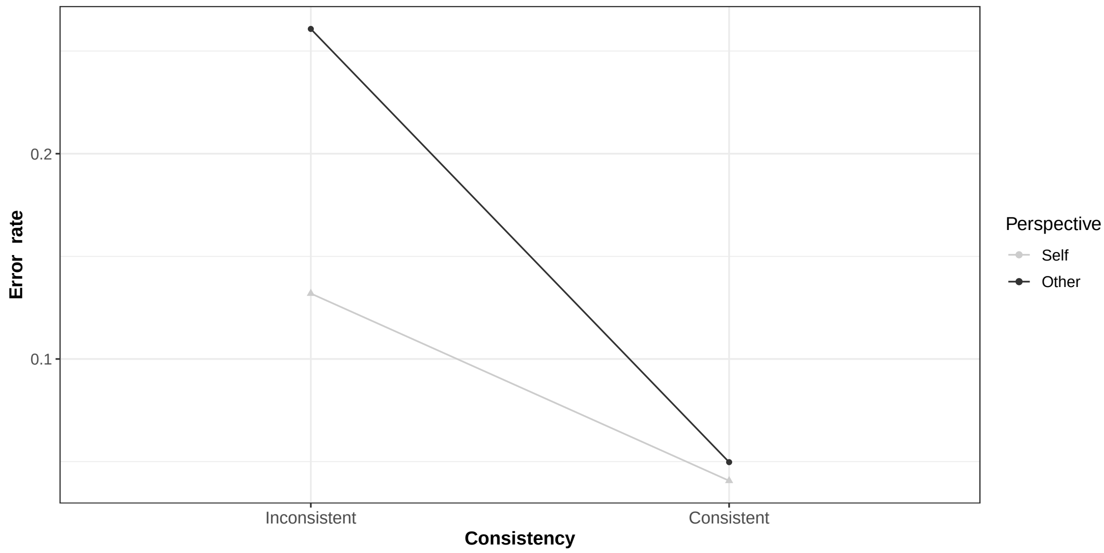


Figure 6.12: Estimated marginal means for each combination of stimulus presentation (Inconsistent vs Consistent) and Perspective (Self vs Other).

Planned post-hoc comparisons

Because predictors in models are conditional to all other factors with which they interact, they do not provide the desired comparisons. As specified in the introduction, to assess the mentalizing and the domain-general accounts only the Self level of the Perspective variable is relevant. Within this level of the Perspective variable, the comparison between Inconsistent and Consistent trials for both RTs and Errors was conducted.

Post-hoc comparisons were extracted using the emmeans package version 1.5.4 (Lenth, 2021) and the Easystats package version 0.2.0 (Lüdecke et al., 2020). Decisions on the comparisons were based on the relative positions of the Highest Density Interval (HDI, Box & Tiao, 1992; Chauhan et al., 2017; Hespanhol et al., 2019) and the predefined regions of practical equivalence (ROPE) of 89% (Kruschke & Liddell, 2018a, 2018b; McElreath & Safari, 2020). In agreement with Kruschke & Liddell (2018a) the ROPEs were defined as +/-0.1*SD for the contrasts.

Reaction Time analysis

Table 6.11 and Figure 6.13 show the interference generated by the cue for the RTs. As it can be seen, 100% of the most probable value of the contrast between Inconsistent and Consistent trials fall outside of the ROPE, indicating that the totality of the most probable values is practically different from the null.

Table 6.11: Interference generated by the cue.

Parameter	Mean	89% HDI	89% ROPE	% in ROPE
Inconsistent - Consistent, Self	0.12	[0.09, 0.15]	[-0.03, 0.03]	0%

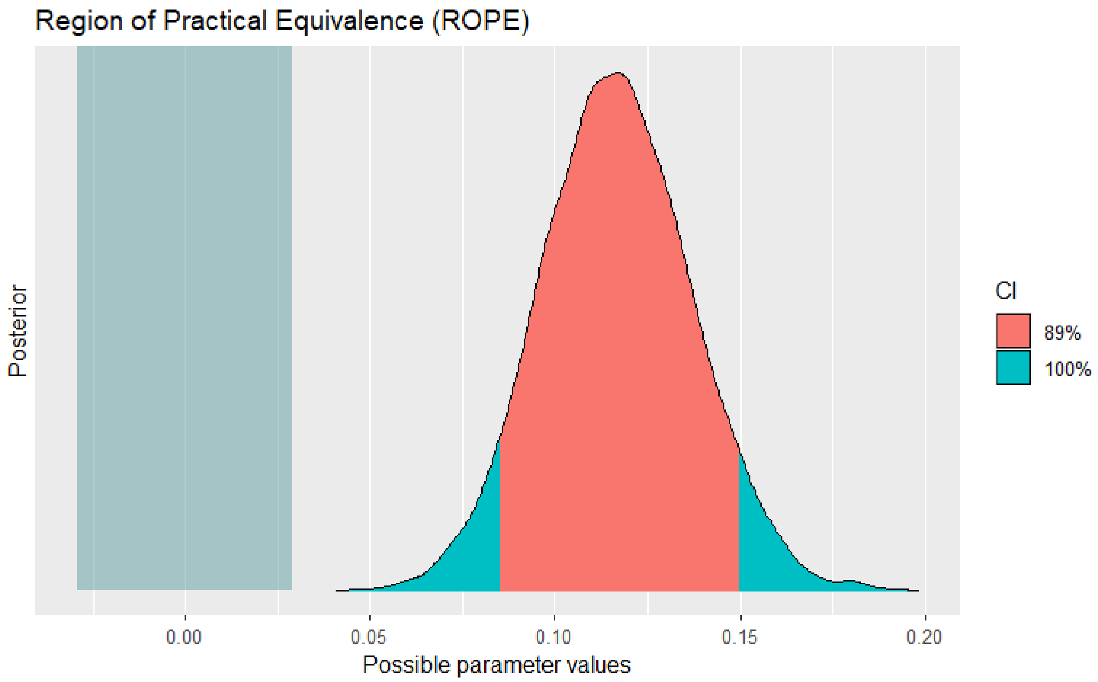


Figure 6.13: ROPE and HDI of the contrast between Inconsistent and Consistent trials for the cue employed in this preliminary experiment.

Error Rates Analysis.

Table 6.12 and Figure 6.14 show the interference generated by the cue. The entire HDI falls outside of the ROPE indicating that 100% of the 89% most credible values of the interference are different from the null value.

Table 6.12: Interference generated by the cue.

Parameter	Mean	89% HDI	89% ROPE	% in ROPE
Inconsistent - Consistent, Self	0.10	[0.03, 0.16]	[-0.03, 0.03]	0%

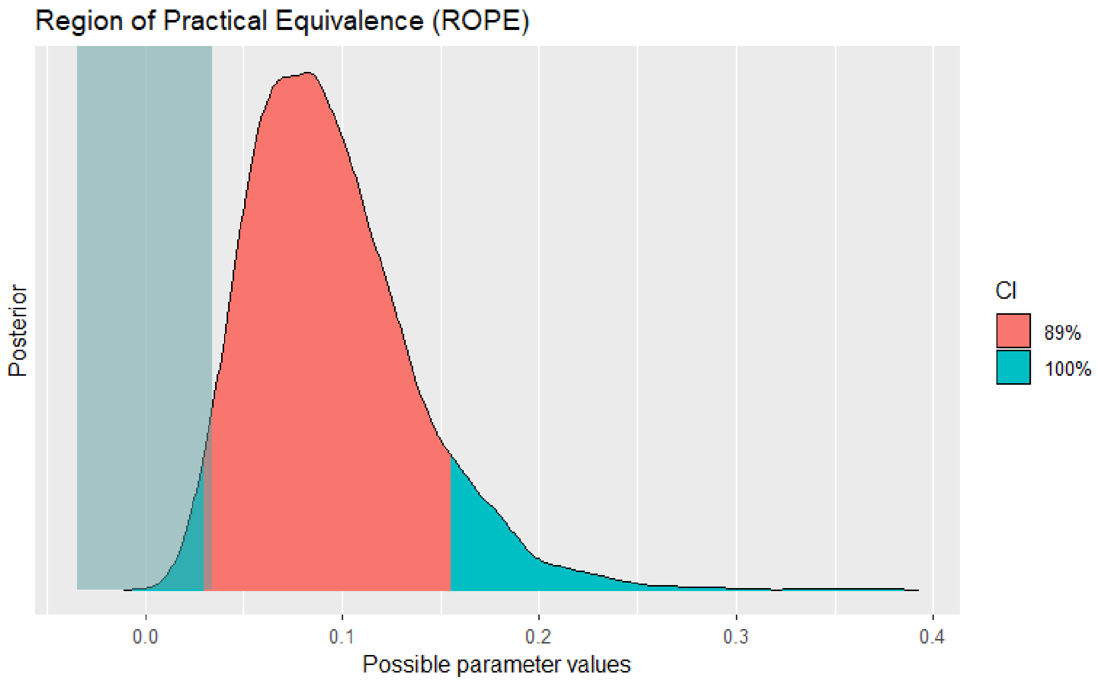


Figure 6.14: ROPE and HDI of the contrast between Inconsistent and Consistent trials for the cue employed in this preliminary experiment.

6.6.5 Conclusions

These results show that the base cue employed to develop the *Ambiguous_Intentionality* and *Clear_Intentionality* cues used in the main experiment is able to generate an interference effect in the DPT.

7
General Discussion

This chapter provides a discussion and interpretation of the findings highlighted in the experimental chapters of this thesis as well as recommendations for future research. It will then present a general discussion which will bring together the individual findings of each experiment and finally present a model which aims to explain the processes involved in the interference effect generated by the presence of others in the visual scene and observed in the Dot Perspective Task (DPT).

People cannot help being affected by what others see. Even when we are focused on our own actions and goals, our attention is profoundly affected by the presence of others regardless of what we are thinking or feeling. This has been shown in several studies (Kampis & Southgate, 2020). The mere presence of another person in a visual scene can trigger people to spontaneously consider how another person's perspective may affect their behaviour, even if that perspective is unrelated to their own. An interference effect may result from the presence of a person facing a different direction. As a result of this shift, individuals are able to process information more efficiently by directing their cognitive resources towards certain information or locations (Pesimena et al., 2019). While there is general agreement about the mechanisms driving this interference effect when this elicited by directional cues, a fascinating case is that of cues that have social relevance (e.g., another person). It has been suggested that VPT may be responsible for it. In order to investigate VPT-1 and the attentional interference generated by the presence of an other in the visual scene, Samson et al. (2010) developed the Dot Perspective Task. They aimed to design a task similar to those successfully performed by newborns and chimps, such as Hare et al. (2000) and Sodian et al. (2007). The authors posited that the particular conditions under which different subjects were tested may explain why inhibiting one's own perspective would be so difficult in some circumstances (so that adults display an egocentric bias) and so easy in others (so that infants and non-human animals with scarce cognitive resources seem to effortlessly override the bias). Participants in Samson et al. (2010)'s Dot Perspective Task are asked to confirm if the number of target discs present in a visual scene and observable from a certain perspective is equal to a previously given number. Employing this paradigm, an "interference" pattern is shown in inconsistent trials. Participants show longer RTs and commit more errors than in consistent trials. This interference emerges when participants adopt the avatar's perspective as well as when they adopt their own. Whilst the egocentric intrusion that occurs while taking the other perspective is universally interpreted in terms of the Theory of Mind (Premack & Woodruff, 1978) (from the Latin ego "I"). There is no consensus on the cause of the interference when participants report what they perceive.

To explain the interference that emerged in the DPT, Samson et al. (2010) advanced the idea that this interference was caused by *Spontaneous Visual Perspective Taking*, asserting that when participants judge their own perspective, they reflexively consider the perspective of others (the cues). In other words, because of the social nature of perception and action, individuals can't help but envision what others are seeing.

According to the authors, this implicit process appears to be analogous to the attentional cueing effects produced by human gazes in a variety of visual activities (Frischen et al., 2007). In their account, the authors stressed, however, that this phenomenon would not be attributable to the cue providing directional information (as established before in the spatial cueing paradigms), but rather to the cue being able to see the targets (Samson et al., 2010). The ability of the cue to see thus plays a major role in Samson's interpretation, according to which participants were able to quickly compute and incorporate the avatar's line of sight, and hence what the avatar could see, into their assessment. Samson et al. (2010)'s interpretation has been during the years supported by a range of research (e.g., Capozzi et al., 2014; Furlanetto et al., 2016; Nielsen et al., 2015), and became known as the "mentalizing account". Concurrently with the mentalizing account, a second account, which provide a different interpretation of this interference, was advanced by an equally large body of research. In opposition to the mentalizing account, this second body of research suggests that this interference is caused by the other's directional features, such as posture and face position (e.g., Cole et al., 2015; Cole & Millett, 2019; Heyes, 2014; Langton, 2018). This account is known as the "domain-general account" as the interference is generated by low-level directional features that elicit domain-general cognitive processes. These processes do not entail thinking about mental states but can result in similar behaviours in social situations (Heyes, 2014; Michael & D'Ausilio, 2015). Moreover, in recent years, a restricted group of authors advanced the idea that an integrated approach may be needed to explain the processes behind this interference effect. In particular, Capozzi & Ristic (2020) suggested that the interference might be influenced by both domain-general and mentalizing processes. While the directional features of the cues may elicit the interference, a perspective taking process may modulate its magnitude. With different results and interpretations arising from similar versions of the dot-perspective task, and in an effort to understand which processes are at play in generating the interference, different authors started to look into whether the findings were related to the dot-perspective task's unique characteristics, such as task relevance (Bukowski et al., 2015), stimulus onset asynchrony (Bukowski et al., 2015; Gardner, Bileviciute, et al., 2018) and the attribution of knowledge and intentionality to the other person present in the visual scene (Langton, 2018; Wiese et al., 2012). These additional challenges and the search for a new methodology that would allow the measurement of the relative contribution of the different processes underlying this interference have been the focus of this thesis.

7.1 Isolating the social features of the others

An innovative set of cues employed in the DPT, and a Bayesian statistical approach was employed with the purpose of measuring and quantifying the relative contribution of mentalizing and domain-general processes in generating this interference effect. Contrary to previous cues employed as "the others" in literature in which social and directional features are always conjugated, the characteristics of these novel cues allowed their manipulation. Thus, making possible to isolate the social from the directional features. This was achieved by integrating to the cue a new contrasting directional feature which would cancel out or attenuate the existing directional features of the others. For this reason, these cues were named *Social_Only* cues. The *Social_Only* cues were employed in experiment 2

(Ch.4), 3 (Ch.5) and 4 (Ch.6) of this thesis. It must be noted however that the *Social_Only* cue employed in experiment 4 (Ch.6) represented a peculiar case. In this cue, the contrasting features (an extended pointing arm) presented both social and directional features. This cue was named as *Ambiguous_Intentionality* cue. Experiment 1 (Ch.3) instead consisted of a replication of the classic DPT as it was developed by Samson et al. (2010), however results were analysed by employing a Bayesian statistical approach. A Bayesian approach not only distinguish between "absence of evidence" and "evidence of absence", providing evidence in favour of the null hypothesis, but also permits to identify the most credible values of a factor. In experiment 1 (Ch.3), the cue presented at the centre of the room was a girl. The results clearly showed that the presence of the cue in the room generated an interference effect. This is in line with previous studies that employed a human avatar as a cue. This was however expected, as both the mentalizing and domain-general accounts have provided evidence of the presence of an attentional interference when participants judge their own perspective, and the cue is a human without any components that blocks or impede their line of sight. It is noteworthy that despite the general agreement on the presence of this interference pattern, the two accounts' interpretations of which processes are involved in generating this interference widely differ.

The subsequent experiments focussed on the features of the cue to isolate and measure the relative role of the mentalising and domain-general processes in generating attentional interference. Looking back at the cues employed in previous experiments (e.g., Cole et al., 2016; Furlanetto et al., 2016; Samson et al., 2010; Santiesteban et al., 2014), as well as the cue employed in experiment 1 (Ch.3) of this thesis, the directional and social features that elicited domain-general and mentalising processes were always conjugated. In other words, considering the avatar in Figure 1.4, the directional features, signified by its posture -and the social features -signified by its viewpoint- both indicate the same direction. It is clear how this represents an obstacle for any study that aims to investigate the relative contribution of the two processes in generating attentional interference by means of behavioural tasks such as the DPT. It is in fact, difficult, if not impossible, to disentangle the social feature of the cue from its directional feature. On one side, walls (Langton, 2018), glasses (Nielsen et al., 2015) or bandages (Wilson et al., 2017) have been used in the past to remove the cue's viewpoint and to manipulate the participant's beliefs about the ability to see of the cues. According to the authors supporting the mentalizing account, by manipulating the cue's viewpoint by these means, the interference would have disappeared. However, while an avatar believed to be unable of seeing did not generate interference in Furlanetto et al. (2016), it did in Cole et al. (2015) and Wilson et al. (2017). On the other side, as pointed out by Cole & Millett (2019), showing that a *Directional_Only* cue generates interference does not rule out the mentalising account because different processes may give rise to a similar effect. In order to overcome the limitation of the previously employed cues, the experiments included in this thesis employed a series of bidirectional cues.

In experiment 2 (Ch.4), a bidirectional cue represented by a dragon with an arrow-shaped tail pointing oppositely to its posture was employed. This cue was named the *Social_Only* cue and its effects were compared with the effects of a similar dragon but devoid of the tail. The directional features of this latter cue were not contrasted, resulting therefore in a *Social+Directional* cue. Experiment 2 (Ch.4) results revealed a distinct pattern of interference between RTs and error rate. RTs analysis showed that whereas the *Social+Directional* cue generated considerable interference, the *Social_Only* cue did not. Because the social features of the cue alone were not capable of creating the interference in the RTs, this result clearly supports the domain-general account. It should also be noted that the arrow-shaped tail had a very powerful effect in cancelling out the interference, even though the tail was irrelevant to the task and participants in the *Social_Only* cue were never prompted to pay attention to it. The analysis of the errors, on the other hand, did not reflect that of the RTs. Participants in the inconsistent trials made more errors than in the consistent trials with both cues. This shows that the interference persisted even when the directional features were cancelled out, leaving only the social features to possibly orient attention. This result, unlike the RT analysis, supports the mentalising account. The occurrence of interference in errors but not in RTs supports the hypothesis that the two metrics reflect distinct processes (Kahana & Loftus, 1999; Prinzmetal et al., 2005; van Ede et al., 2012). As previously stated, Prinzmetal et al. (2005) proposed that attention is influenced by both a voluntary and involuntary process. The voluntary process affects both RTs and error rates, while the involuntary process just RTs. Thus, the DPT may necessitates an orienting (involuntary) and decision-making (voluntary) process. Participants' attention is first involuntarily directed towards the location indicated by the cue's directional features. The number of targets visible from the given perspective is then compared to the prompted one by means of a voluntary decision-making process. The social characteristics of the cue influence this decision-making process. When the social features are isolated, the evoked mentalising processes have little or no power to direct attention on their own; they can only influence the decision-making process. This could explain why other research (Conway et al., 2017; Santiesteban et al., 2015; Wilson et al., 2017 and others) have not been able to detect mentalising processes. It may also explain why several other investigations (Cole et al., 2016; Langton, 2018; O'Grady et al., 2020) failed to find the interference in the error rate. In these circumstances, it's possible that the automatic process triggered by the cue's directional aspects outweighed the voluntary process triggered by the social features. It is worth noting that whilst this is the first time that the idea that RTs and error rates reflect distinct processes is advanced in the context of VPT and DPT, similar findings were previously reported by Bonato et al. (2018) while investigating voluntary orienting of spatial attention. The authors reported a similar dissociable effect for RTs and error rates. They suggested that the effect on RTs may be due to an automatic process that modulates attention orienting based on spatial and temporal factors in the environment, which may act outside awareness and without explicit strategies. Simultaneously they suggested that the effect on error rates was more strongly linked to voluntarily internal cognitive strategies. Furthermore, if the results from tasks eliciting either the decisional or the orienting process are taken into consideration, the idea that both processes are involved in the DPT is further supported. Hayward & Ristic (2018) demonstrated that a directional cue directs attention regardless of its social aspects in a Posner's spatial cueing test (Posner & Coehn, 1984), which does not need any decisional process. In contrast, in a task that only involves a decision-making process, such as the Room Observer and Mirror Perspective test (ROMP, Bertamini & Soranzo, 2018; Soranzo et al., 2021), where participants are asked to judge how many targets are visible from a given position indicated by a cue, an advantage emerges for social cues. Consequently, results from experiment 2 (Ch.4) suggested an integrated approach between the two accounts present in the literature.

To further investigate the integrated approach proposed in experiment 2 (Ch.4), experiment 3 (Ch.5) employed a second bidirectional cue comprised of a devil, which similarly to the dragon, presented an arrow-shaped tail. However, in addition to the *Social_Only* and *Social+Directional* cues, this experiment presented a third cue, comprised of a devil whose tail pointed coherently towards the same direction as the devil's existing directional features. This cue was named *Social+Directional+* because the arrowed-shape tail in this condition provides an extra set of directional features cueing towards the same location. Moreover, in contrast with the dragon, the devil's body resembled the shape of a standard human avatar. Interestingly, experiment 3 (Ch.5) results were in line with experiment 2 (Ch.4) findings. Similarly to the previous experiment, RTs analysis showed the presence of interference for the *Social+Directional* cue but not for the *Social_Only* cue. Furthermore, as expected, a more prominent interference was recorded in the *Social+Directional+* cue, where the tail was pointing towards the same direction as the devil's body. Remarkably, just like in experiment 2 (Ch.4), the error rates analysis showed a similar amount of interference in each of the three types of cues. These results provide further support to the hypothesis that both social and directional features of a cue are involved in generating the attentional interference shown in the DPT; with the directional features of the cue affecting only the involuntary orienting process and the social features affecting also the voluntary decisional process.

To further establish the idea that both processes play a role in the DPT, experiment 4 (Ch.6) investigated the role of the attribution of intentionality to the cues employed in the DPT. As mentioned in the introduction, people must take an active attitude toward a cue before mentalizing processes can occur and the other's behaviour or perspective can be inferred. (Wiese et al., 2012). In the DPT, it is possible to manipulate the attribution of intentionality to the cue by employing bi-directional cues. Similarly to experiment 2 (Ch.4) and experiment 3 (Ch.5), where the cues presented either ambiguous contrasting or coherent extra-directional features, a cue with ambiguous intentionality was developed and employed in experiment 4 (Ch.6). The cue consisted of a human figure with her arm extended and pointing either to the same location or the opposite location of her head. These cues were named respectively *Clear_Intentionality* and *Ambiguous_Intentionality*. Pointing with the index finger is a ubiquitous human behaviour that can be found in all cultures across the world (Povinelli & Davis, 1994). Since an early age, humans use pointing to communicate and indicate intentionality with others without the use of verbal skills (Crais et al., 2004) and perspective taking, among other cognitive abilities has been linked with the onset of pointing in infancy (Povinelli & Davis, 1994). Coherently with experiments 2 (Ch.4) and 3 (Ch.5), the results of experiment 4 (Ch.6) showed that the *Clear_Intentionality* cue generates an attentional interference in the DPT. Interestingly instead, when the cue, did not only present contrasting directional features but also ambiguous intentionality (the *Ambiguous_Intentionality* cue), the cue did not generate interference in RTs nor in the error rates. The results of these experiments are in agreement with those from previous experiments included in this thesis. Furthermore, these findings are consistent with Marotta et al. (2012), who found that while studies generally show identical attentional effects for social and directional cues, a qualitative dissociation exists because distinct attentional mechanisms are engaged in their processing. The effect produced by the cue's social features appears to be due to participants attributing to the cue the intention to look and/or pointing in a specific direction (goal-oriented) (Marotta et al., 2012; Vuilleumier, 2002) This qualitative dissociation can be appreciated in RTs and error rates in the DPT when either social or directional features are isolated. These results further support the idea that both social and directional features of a cue are involved in generating the interference effect shown in the DPT. Whilst the directional features affect the involuntary orientating process, the attribution of intentionality, being a social feature, affects the voluntary processes, inhibiting the interference when intentionality is ambiguous.

7.2 A dual-processes model of the interference effect

This section outlines an interpretative model of the interference effect generated by the presence of others. However, before introducing a novel model that explains this phenomenon, a short preamble is needed. In the introduction section of this thesis, the ability of humans to effortlessly detect and recognize objects around them by means of a selective process known as visual attention was discussed. A lack of these attentional processes would result in humans becoming overwhelmed by the amount of information perceived since there is substantially more perceptual information that is presented to the brain than can be efficiently processed at a given moment in time. These attentional processes are often encompassed under the term *attention*, which is seen as a unitary single mechanism that governs stimuli inputs and selection (see Chun et al., 2011). A growing body of evidence however suggests that these attentional selection processes are practically involved in every level of processing, from sensory processing to decision-making and awareness (Chun et al., 2011; Oberauer, 2019) [1]. Thus, attention should be viewed as a characteristic of a variety of perceptual and cognitive mechanisms and processes and not as a generic unitary model. These processes are in constant communication with one another, and executive control processes aid in the system's overall prioritisation (Chun et al., 2011; Lavie et al., 2004; Pashler, 1998). The results of the experimental

[1] Behavioural investigations and cognitive neuroscience methodologies, such as brain imaging and neuropsychology, that indicate some degree of modularity in the brain, provide evidence against unitary models of attention (Chun et al., 2011).

chapters of this thesis provide further evidence in favour of this hypothesis.

Whilst a large number of classifications of attention have been discussed in the literature (and also mentioned in the introduction of this thesis), such as covert/overt attention, exogenous/endogenous or bottom-up/top-down, these do not provide a comprehensive organising concept, instead, they focus on differentiating specific properties of attention, whilst ignoring their shared objectives and targets, which can be achieved only by encompassing the different attentional processes. To this end, Chun et al. (2011) underlined how the fundamental properties of attention are shared across various systems which have the common goal of selecting and modulating the most relevant information in order to drive our behaviour. Accordingly, they proposed a taxonomy based on the categories of information that are targeted by attention. Specifically, they proposed a clear distinction between selecting a) information acquired through the senses (External Attention) and b) information already stored in the mind (Internal Attention) - whether recovered from long-term memory or preserved in working memory (WM). As a matter of fact, there is a broad consensus that working memory and attention share a close relationship (Oberauer, 2019). During information processing, cognitive control is limited to prioritizing relevant information over irrelevant information (Konstantinou et al., 2014; Lavie, 2010). The WM actively maintains these processing priorities, allocating capacity with a higher priority to relevant information. A greater working memory capacity might facilitate the process of calculating perspectives and retaining them in mind (Qureshi et al., 2010; Qureshi & Monk, 2018). Additionally, non-social cues (such as arrows) held in WM failed to elicit attentional orienting effects showing a qualitative difference between social and directional features of a cue and their different interaction with different cognitive processes.

A taxonomy of attention such as the one advanced by Chun et al. (2011) provides good foundations to build a comprehensive model which is able to explain the different results of the experiments of this thesis and the findings present in the literature.

In a task like the dot-perspective task, where a cue is presented in the centre of the visual scene, external attention is firstly involuntarily directed towards a specific location. This is achieved by a spatial cueing effect elicited by the directional features of the cue, with cueing improving target detection and discrimination (Corbetta & Shulman, 2002; Klein, 2000; Yantis et al., 2002). Subsequently, internal attention, which includes cognitive control processes and operates over representations in working memory (Chun et al., 2011; Konstantinou et al., 2014; Oberauer, 2019), is involved in response selection in order to verify that the number of targets visible from a specific perspective is equal to a previously prompted number. These processes appear to be affected by the social features of the cue. Ji et al. (2022) showed that social relevant cues were able to orient attention in a WM task. Additionally, non-social cues (such as arrows) held in WM failed to elicit attentional-orienting effects. As a result, these findings, together with the results of this thesis demonstrate a qualitative difference between social and directional features of a cue and their different interaction with different cognitive processes underlying the interference effect.

Based on the findings of this thesis, Chun et al. (2011)'s taxonomy of attention, previous results showing the close relation between WM and attention (Lavie, 2010; Oberauer, 2019) and Prinzmetal et al. (2005)'s suggestion that different behavioural measures can measure different attentional processes, a dual-process model of the interference is advanced to address the following:

1) Explain previous inconsistencies in the literature;
2) Integrate previous opposite and contrasting interpretations;
3) Provide a framework to further investigate this interference effect.

The dual-process model of the interference effect accounts for previous inconsistencies in research employing the DPT by suggesting that two concurrent parallel processes are involved in generating the interference (Figure 7.1).

For clearness and for the ease of read, the dual-processes model of the interference effect is hereby presented in two different figures (Figure 7.1 and Figure 7.2). Figure 7.1 presents the distinct processes involved in generating the interference effect, whilst Figure 7.2, building on top of the previous figure, identifies an important distinction between automatic and spontaneous involuntary processes involved in the interference effect.

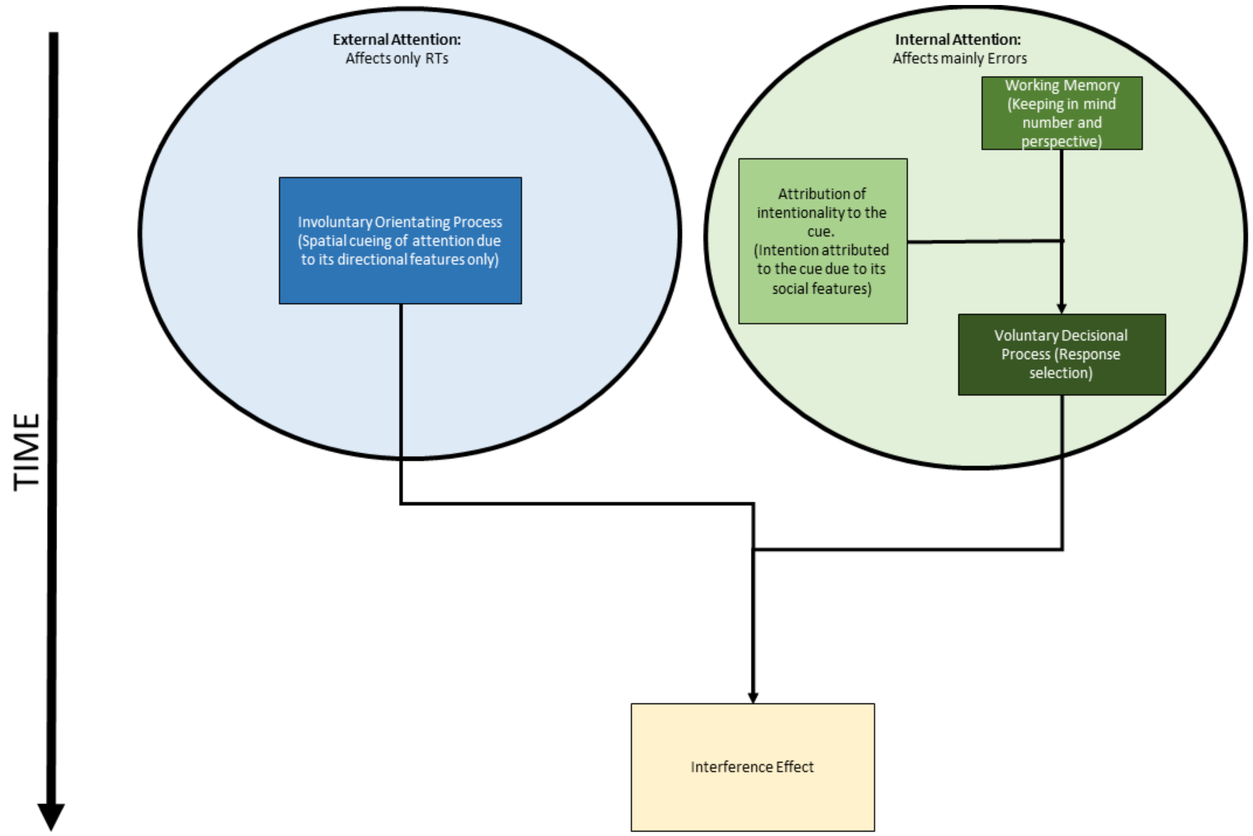


Figure 7.1: The dual-processes model of the interference effect. Two distinct processes are involved in generating the interference effect. These can be identified as external and internal attention. The external attention encompasses the involuntary bottom-up orientating processes elicited by the directional features of the cue. This affects only RTs. The internal attention instead, encompasses two different top-down processes which inform a voluntary decisional processes that affects mostly the error rates. These are, the attribution of intentionality to the cue, which is modulated by its social features and the involvement of working memory.

As can be seen in Figure 7.1, two parallel attentional processes contribute to generating the interference in the dot-perspective task, external and internal attention. Our attention is firstly involuntarily oriented by the directional characteristics of the cue, such as its stance and faced direction, then a voluntary decisional process is involved in order to provide an answer to the question posed by the task. Whilst external attention is an involuntary process affected only by the saliency of the different directional features of the cue, internal attention encompasses different mechanisms that affect the voluntary decisional process.

First of all, working memory allows for the keeping and manipulation of information that became unavailable by keeping an internal representation (Chun et al., 2011; D'Esposito et al., 1995; Smith & Jonides, 1999). In the case of the Dot Perspective Task, participants, which have to verify how many discs are visible from a given perspective, must internally represent the given perspective and prompted number of targets while they are presented with the visual scene. Secondly, the attribution of intentionality to the cues employed in the DPT affects the voluntary response selection process. It must be noted that, despite affecting the voluntary process, the attribution of intentionality to the cue is not itself a voluntary process. Participants in fact are never asked or primed to attribute intentionality to any social features of the cue; consequently, participants seem to implicitly attribute an intention to cues presenting clear social features.

An important distinction must be made here. The terms reflexive, involuntary, implicitly, automatic, and spontaneous have often been used interchangeably in literature employing the DPT. These have been in fact used to describe solely stimulus-driven processes (Bukowski et al., 2015; Cole et al., 2016; Gardner, Hull, et al., 2018; Langton, 2018; O'Grady et al., 2020). Other researchers, outside of the DPT literature, have proposed that automaticity should be seen as a matter of degree, with characteristics such as goal-directedness, intentionality, control, and solely stimulus-driven reaction all playing a factor in determining whether a process is automatic (Moors & De Houwer, 2006; O'Grady et al., 2020). In agreement, this dual-processes model supports the idea, advanced by O'Grady et al. (2020), that a distinction must be made between automatic (reflexive) and spontaneous cognitive processes. "Automatic processes" are those that are involuntary and cannot be inhibited, whilst should be defined as "spontaneous processes" those processes that are still involuntary and rapid but are determined by intentionality or other types of top-down processes. Specifically, in the dual-processes model, the involuntary shift of attention generated by the directional features of the cue is defined as an automatic process, whilst the attribution of intentionality is defined as a spontaneous process (Figure 7.2).

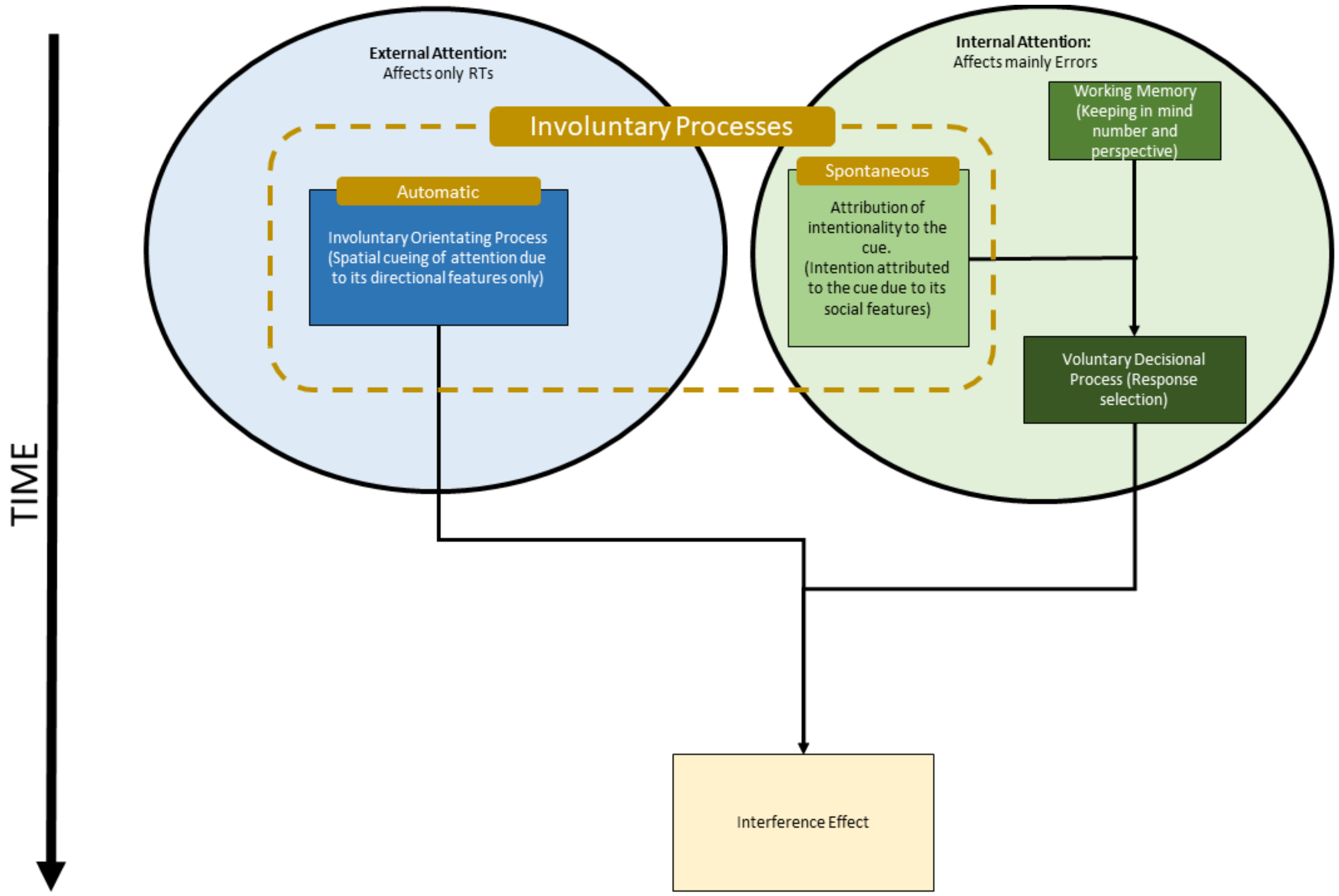


Figure 7.2: The dual-processes model of the interference effect. The dual-processes model of the interference effect identify involuntary processes in both external and internal attention. An important distinction is clear between automatic and spontaneous involuntary processes. Automatic processes are those that occur involuntarily and cannot be stopped. While those processes that are still involuntary and rapid but are determined by intentionality or other sorts of top-down processes should be described as spontaneous processes.

This dual-processes model of the interference effect is in line with previous research such as Prinzmetal et al. (2005), Kahana & Loftus (1999) and Bonato et al. (2018) which suggested that different behavioural measures may measure different mental processes. In particular, Prinzmetal et al. (2005) showed that in attention research, RTs and accuracy experiments may not yield the same results and that whenever the two measures do not yield similar outcomes, the coexistence of different processes underlying these results should be further explored [2]. The results of the experiments included in this thesis can all be interpreted in light of this dual-processes model of the interference effect. The next paragraph will provide a short summary of how each cue employed in the different experiments of this thesis orient attention in agreement to the model.

7.3 Model evaluation

This short paragraph will bring together the results of each experiment, by presenting how each individual cue should orient attention in accordance to the dual-processes model of the interference effect. Among the different cues employed in the different experiments of this thesis, it is possible to identify two main features of the cue in accordance to the aforementioned model: the directional features and the cue's intentionality.

When an other presented coherent directional features and unambiguous intentionality, it affected both the external and internal attention. The interference persisted in both RTs and error rates, because both set of features were clearly

[2] It must be noted that Prinzmetal et al. (2005) taxonomy of voluntary and involuntary processes differs from the one employed in this thesis. As previously mentioned, different types and taxonomies of attention have been advanced over the years. The taxonomy employed in this thesis follows Chun et al. (2011)' taxonomy and it aims to categorize the different processes involved in the dot-perspective task according to the types of information that attention operates over.

directing external and internal towards a specific location (Figure 7.3).

Figure 7.3: Some of the cues employed in Experiment 1 (Ch.3),2 (Ch.4) and 3 (Ch.5). The cues present clear and confounded social and directional features.

Coincidentally, this effect was modulated by the salience and strength of the directional features of the other when it exuded unambiguous intentionality and presented more salient directional features (Figure 7.4).

Figure 7.4: Some of the cues employed in Experiment 4 (Ch.6) and 3 (Ch.5). The two cues present clear and confounded social and directional features which saliency is increased by the addition of an extra feature. In experiment 4 (Ch.6), this feature is represented by the straight pointing arm, which possesses both, directional and social relevance. In experiment 3 (Ch.5), it is instead represented by the overarching tail. This extra feature conveys only directional information.

When the other instead had contrasting directional features, but unambiguous, such that directional features did not provide any cueing information, the presence of the other did not affect external attention whilst it did affect internal attention. No interference was recorded in the RTs, whilst it persisted in the error rates (Figure 7.5).

Figure 7.5: Some of the cues employed in Experiment 2 (Ch.4). The cues present contrasting directional features. In both cues the arrowed-shaped tail contrasts the directional effect generated by the directional information conveyed by their body stance.

Lastly, when also the intentionality was ambiguous, the presence of the other in the visual scene did not affect external nor internal attention. In other words, it did not shift participants' attention. The interference disappeared in both behavioural measures as neither directional features or social features could provide clear information in order to elicit either external or internal attentional processes (Figure 7.6).

Figure 7.6: One of the cues employed in Experiment 4 (Ch.6). The cue presents contrasting directional features and ambiguous intentionality. The straight pointing arm contrast both, the directional and social information conveyed by the body stance and viewpoint.

It should be mentioned that the dual-process model of the interference effect advanced in this thesis suggests that internal attention and the encompassed decisional process affect both RTs and errors. This however was not reflected in the results of the different experiments. While developing the DPT, Samson et al. (2010) aimed to create a similar type of task to the ones which infants and chimpanzees can perform successfully, thus implying that one of the main characteristics of the task must have been its simplicity. It can be speculated that the absence of an effect of internal attention on RTs may be due to these specific characteristics of the DPT; with internal attention having overall a small effect on both behaviour measures that can however mainly be appreciated in the error rates. Together with the short time that participants have to answer each trial (2000ms), this may explain why different studies failed to find an effect of the social features of the cues that underline internal attention even on error rates, with results often showing a ceiling effect in the error rates and interference only in RTs (Langton, 2018; O'Grady et al., 2020). Future research could further investigate this by employing more complex versions of the DPT or other perspective taking tasks such as Keysar et al. (2003)'s director task. However, whether or not this latter interpretation of the reason why the effect of internal attention could not be appreciated in RTs is right or not, the experiments included on this thesis show that in attention research, it should not be assumed that RT and accuracy experiments produce the same results.

7.4 Future Directions

In this section, possible future research will be discussed in order to expand our understanding of the interference effect, taking into account the dual-process model of the interference effect. First of all, future experiments should investigate to what extent participants assume the perspective of the other present in the visual scene in the DPT. In studies employing the DPT, participants have always been placed in an omniscient position in which they were "able to see" the totality of the visual scene, thus making the participants not implicitly aware of what the avatar or cue can and cannot see. It is hypothesised that this experiment may provide further evidence in support of the dual-process model of the interference effect by outlining further processes of internal attention that may play a role in this phenomenon. It is expected that the embodiment of the alternative visual perspective will affect participants' RTs and Error rates similar to the attribution of intentionality. Secondly, the relationship between internal attention, cognitive control processes and working memory should be further investigated. Multiple studies showed how different types of working memory load can affect the perceptual processing and detection of stimuli and distractors (Konstantinou et al., 2014; Konstantinou & Lavie, 2013, 2020; Yang et al., 2015). An adapted version of the DPT may be developed in order to manipulate participants' working memory load in order to investigate its role in the interference effect.

Furthermore, future research should investigate whether visual perspective processes rely on graphical representations of mental models or the processing of previous experiences and assumed knowledge about the scene. To this end, researchers could manipulate the visual scenes presented to the participants and present the participants with the point of view of the cues. In this way, participants will be aware of the cue's knowledge of the scenes and of the target and how this differs from their own. Lastly, Cole et al. (2015) argued that the effect seen in the DPT is due to the establishment of a gaze-cueing schema that is facilitated by the repetition of observed gaze direction, with the major effect of the schema being the quick orienting of spatial attention to the gaze-at place. Because the effect is generated by cues with clear directional features, this can be applied to most of the cues such as arrows, or non-humans stimuli. Whilst this does not strictly apply to the cues employed in this thesis (which presented contrasting directional and social features), it would still be interesting to investigate participants' potential strategies. This could be accomplished by incorporating within the dot-perspective tasks visual and/or auditory distractors. This schema theory of VPT would be supported if the proposed VPT-like data trends would be disrupted by the presence of the distractors.

7.5 Conclusions

The current work investigated the role of domain-general and mentalizing processes in generating the interference effect generated by the presence of others in the visual scene. An innovative set of stimuli was used within the DPT, a well known task often used to assess VPT-1 and the interference effect. Furthermore, for the first time, a Bayesian statistical approach was employed to analyse the data. By using these, it was possible to measure the relative contribution of domain-general and mentalizing processes in generating the interference effect. Thus, bridging the gap presents in literature. Moreover, a model of the interference effect was advanced, this is a first in literature. Whilst others have suggested the need of an integrated approach between the two processes (e.g., Capozzi & Ristic, 2020), no previous experimental work advanced a model of the interference effect that can encompass and explain the contrasting interpretations presented in the literature. The results showed that both directional and social features of the others present in the visual scenes play a role in orientating people's attention. Yet, they elicit different sets of voluntary and involuntary processes. A dual-processes model of the interference effect could be employed to explain this phenomenon. When an other is present in the visual scene and we are asked to judge our own perspective, our attention is firstly reflexively orientated towards where the other is looking and secondly a voluntary decisional process is engaged in order to provide a response. The former orientating process is purely stimulus-driven and can be labelled as automatic (reflexive) and defined as external attention; whilst the voluntary decisional process interacts with working memory and other spontaneous top-down processes such as the attribution of intentionality to the cue and are defined as internal attention. Taking into account the dual-processes model of the interference effect, it becomes apparent that both the mentalizing and domain-general accounts are simplistic, and that the interference effect, which underlies what is commonly referred to as spontaneous VPT, emerges as a result of a more complex interplay of automatic bottom-up processes, spontaneous top-down processes, and voluntary top-down processes.

References

Abubshait, A., Momen, A., & Wiese, E. (2020). Pre-exposure to Ambiguous Faces Modulates Top-Down Control of Attentional Orienting to Counterpredictive Gaze Cues. *Frontiers in Psychology*, *11*, 2234. https://doi.org/10.3389/fpsyg.2020.02234

Allison, T., Puce, A., & McCarthy, G. (2000). Social perception from visual cues: Role of the STS region. *Trends in Cognitive Sciences*, *4*(7), 267–278. https://doi.org/10.1016/S1364-6613(00)01501-1

Ansorge, U., & Neumann, O. (2005). Intentions Determine the Effect of Invisible Metacontrast-Masked Primes: Evidence for Top-Down Contingencies in a Peripheral Cuing Task. *Journal of Experimental Psychology: Human Perception and Performance*, *31*(4), 762–777. https://doi.org/10.1037/0096-1523.31.4.762

Apperly, I. A. (2012). What is "theory of mind"? Concepts, cognitive processes and individual differences. *Quarterly Journal of Experimental Psychology*, *65*(5), 825–839. https://doi.org/10.1080/17470218.2012.676055

Apperly, I. A., & Butterfill, S. A. (2009). Do humans have two systems to track beliefs and belief-like states? *Psychological Review*, *116*(4), 953–970. https://doi.org/10.1037/a0016923

ASA. (2022). *Ethical Guidelines for Statistical Practice*. American Statistical Association. https://www.amstat.org/your-career/ethical-guidelines-for-statistical-practice

Asch, S. E. (1956). Studies of independence and conformity: I. A minority of one against a unanimous majority. *Psychological Monographs: General and Applied*, *70*(9), 1–70. https://doi.org/10.1037/h0093718

Baker, M. (2016). 1,500 scientists lift the lid on reproducibility. *Nature*, *533*(7604), 452–454. https://doi.org/10.1038/533452a

Baron-Cohen, S. (1997a). How to build a baby that can read minds: Cognitive mechanisms in mindreading. *The Maladapted Mind: Classic Readings in Evolutionary Psychopathology*, 207–239.

Baron-Cohen, S. (1997b). *Mindblindness: An essay on autism and theory of mind*

(First MIT Press paperback edition). MIT Press.

Baron-Cohen, S., Leslie, A. M., & Frith, U. (1985). Does the autistic child have a “theory of mind” ? *Cognition*, *21*(1), 37–46. https://doi.org/10.1016/0010-0277(85)90022-8

Baron-Cohen, S., Wheelwright, S., & Jolliffe, and T. (1997). Is There a "Language of the Eyes"? Evidence from Normal Adults, and Adults with Autism or Asperger Syndrome. *Visual Cognition*, *4*(3), 311–331. https://doi.org/10.1080/713756761

Beck, D. M., & Kastner, S. (2009). Top-down and bottom-up mechanisms in biasing competition in the human brain. *Vision Research*, *49*(10), 1154–1165. https://doi.org/10.1016/j.visres.2008.07.012

Beck, D. M., & Kastner, S. (2005). Stimulus context modulates competition in human extrastriate cortex. *Nature Neuroscience*, *8*(8), 1110–1116. https://doi.org/10.1038/nn1501

Berecz, H., Tényi, T., & Herold, R. (2016). Theory of Mind in Depressive Disorders: A Review of the Literature. *Psychopathology*, *49*(3), 125–134. https://doi.org/10.1159/000446707

Berkson, J. (1938). Some Difficulties of Interpretation Encountered in the Application of the Chi-Square Test. *Journal of the American Statistical Association*, *33*(203), 526–536. https://doi.org/10.1080/01621459.1938.10502329

Bertamini, M., & Soranzo, A. (2018). Reasoning About Visibility in Mirrors: A Comparison Between a Human Observer and a Camera. *Perception*, *47*(8), 821–832. https://doi.org/10.1177/0301006618781088

Birch, S. A. J., & Bloom, P. (2004). Understanding children’s and adults’ limitations in mental state reasoning. *Trends in Cognitive Sciences*, *8*(6), 255–260. https://doi.org/10.1016/j.tics.2004.04.011

Blust, R. (2000). The origin of dragons. *Anthropos*, *95*(2), 519–536. https://www.jstor.org/stable/40465957

Bonato, M., Lisi, M., Pegoraro, S., & Pourtois, G. (2018). Cue-target contingencies modulate voluntary orienting of spatial attention: Dissociable effects for speed and accuracy. *Psychological Research*, *82*(2), 272–283. https://doi.org/10.1007/s00426-016-0818-6

Box, G. E. P., & Tiao, G. C. (1992). *Bayesian inference in statistical analysis* (Wiley classics library ed). Wiley.

Briand, K. A., & Klein, R. M. (1987). Is Posner’s" beam" the same as Treisman’s" glue"?: On the relation between visual orienting and feature integration theory. *Journal of Experimental Psychology: Human Perception and Performance*, *13*(2), 228.

Bridges, D., Pitiot, A., MacAskill, M. R., & Peirce, J. W. (2020). The timing mega-study: Comparing a range of experiment generators, both lab-based and online. *PeerJ*, *8*, e9414. https://doi.org/10.7717/peerj.9414

Bukowski, H., Hietanen, J. K., & Samson, D. (2015). From gaze cueing to perspective taking: Revisiting the claim that we automatically compute where or what other people are looking at. *Visual Cognition*, *23*(8), 1020–1042. https://doi.org/10.1080/13506285.2015.1132804

Bürkner, P.-C. (2017). Brms : An r package for bayesian multilevel models using stan. *Journal of Statistical Software*, *80*(1). https://doi.org/10.18637/jss.v080.i01

Bürkner, P.-C. (2018). Advanced bayesian multilevel modeling with the r package brms. *The R Journal*, *10*(1), 395. https://doi.org/10.32614/RJ-2018-017

Cacioppo, J. T., Kaplan, R. M., Krosnick, J. A., Olds, J. L., & Dean, H. (2015). Social, behavioral, and economic sciences perspectives on robust and reliable science. *Report of the Subcommittee on Replicability in Science Advisory Committee to the National Science Foundation Directorate for Social, Behavioral, and Economic Sciences*, *1*.

Calder, A. J., Lawrence, A. D., Keane, J., Scott, S. K., Owen, A. M., Christoffels, I., & Young, A. W. (2002). Reading the mind from eye gaze. *Neuropsychologia*, *40*(8), 1129–1138. https://doi.org/10.1016/S0028-3932(02)00008-8

Capozzi, F., Cavallo, A., Furlanetto, T., & Becchio, C. (2014). Altercentric intrusions from multiple perspectives: Beyond dyads. *PLoS ONE*, *9*(12), e114210. https://doi.org/10.1371/journal.pone.0114210

Capozzi, F., & Ristic, J. (2020). Attention AND mentalizing? Reframing a debate on social orienting of attention. *Visual Cognition*, *28*(2), 97–105. https://doi.org/10.1080/13506285.2020.1725206

Carpenter, B., Gelman, A., Hoffman, M. D., Lee, D., Goodrich, B., Betancourt, M., Brubaker, M., Guo, J., Li, P., & Riddell, A. (2017). Stan: A probabilistic programming language. *Journal of Statistical Software*, *76*(1, 1), 1–32. https://doi.org/10.18637/jss.v076.i01

Carrasco, M. (2011). Visual attention: The past 25 years. *Vision Research*, *51*(13), 1484–1525. https://doi.org/10.1016/j.visres.2011.04.012

Carrasco, M. (2018). How visual spatial attention alters perception. *Cognitive Processing*, *19*(S1), 77–88. https://doi.org/10.1007/s10339-018-0883-4

Carrasco, M., Fuller, S., & Ling, S. (2008). Transient attention does increase perceived contrast of suprathreshold stimuli: A reply to Prinzmetal, Long, and

Leonhardt (2008). *Perception & Psychophysics*, *70*(7), 1151–1164. https://doi.org/10.3758/pp.70.7.1151

Chartrand, T. L., & Bargh, J. A. (1999). The chameleon effect: The perception–behavior link and social interaction. *Journal of Personality and Social Psychology*, *76*(6), 893–910. https://doi.org/10.1037/0022-3514.76.6.893

Chauhan, V., Visconti di Oleggio Castello, M., Soltani, A., & Gobbini, M. I. (2017). Social Saliency of the Cue Slows Attention Shifts. *Frontiers in Psychology*, *8*, 738. https://doi.org/10.3389/fpsyg.2017.00738

Cheal, M., Lyon, D. R., & Hubbard, D. C. (1991). Does Attention Have Different Effects on Line Orientation and Line Arrangement Discrimination? *The Quarterly Journal of Experimental Psychology Section A*, *43*(4), 825–857. https://doi.org/10.1080/14640749108400959

Chen, Z. (2012). Object-based attention: A tutorial review. *Attention, Perception, & Psychophysics*, *74*(5), 784–802. https://doi.org/10.3758/s13414-012-0322-z

Chun, M. M., Golomb, J. D., & Turk-Browne, N. B. (2011). A Taxonomy of External and Internal Attention. *Annual Review of Psychology*, *62*(1), 73–101. https://doi.org/10.1146/annurev.psych.093008.100427

Chun, M. M., & Wolfe, J. M. (2001). Visual attention. In *Blackwell handbook of perception.* (pp. 272–310). Blackwell Publishing.

Clements, W. A., & Perner, J. (1994). Implicit understanding of belief. *Cognitive Development*, *9*(4), 377–395. https://doi.org/10.1016/0885-2014(94)90012-4

Cohen, J. (1994). The earth is round (p < .05). *American Psychologist*, *49*(12), 997–1003. https://doi.org/10.1037/0003-066X.49.12.997

Cole, G., Atkinson, M., D'Souza, A., & Smith, D. (2017). Spontaneous Perspective Taking in Humans? *Vision*, *1*(2), 17. https://doi.org/10.3390/vision1020017

Cole, G., Atkinson, M., Le, A. T. D., & Smith, D. T. (2016). Do humans spontaneously take the perspective of others? *Acta Psychologica*, *164*, 165–168. https://doi.org/10.1016/j.actpsy.2016.01.007

Cole, G., & Millett, A. C. (2019). The closing of the theory of mind: A critique of perspective-taking. *Psychonomic Bulletin & Review*, *26*(6), 1787–1802. https://doi.org/10.3758/s13423-019-01657-y

Cole, G., Millett, A. C., Samuel, S., & Eacott, M. J. (2020). Perspective-Taking: In Search of a Theory. *Vision*, *4*(2), 30. https://doi.org/10.3390/vision4020030

Cole, G., Smith, D. T., & Atkinson, M. A. (2015). Mental state attribution and the gaze cueing effect. *Attention, Perception, & Psychophysics*, *77*(4), 1105–1115. https://doi.org/10.3758/s13414-014-0780-6

Conway, J. R., Lee, D., Ojaghi, M., Catmur, C., & Bird, G. (2017). Submentalizing or Mentalizing in a Level 1 Perspective-Taking Task: A Cloak and Goggles Test. *Journal of Experimental Psychology. Human Perception and Performance*, *43*(3), 454–465. https://doi.org/10.1037/xhp0000319

Corbetta, M., & Shulman, G. L. (2002). Control of goal-directed and stimulus-driven attention in the brain. *Nature Reviews Neuroscience*, *3*(3), 201–215. https://doi.org/10.1038/nrn755

Crais, E., Douglas, D. D., & Campbell, C. C. (2004). The Intersection of the Development of Gestures and Intentionality. *Journal of Speech, Language, and Hearing Research*, *47*(3), 678–694. https://doi.org/10.1044/1092-4388(2004/052)

Cumming, G. (2014). The New Statistics: Why and How. *Psychological Science*, *25*(1), 7–29. https://doi.org/10.1177/0956797613504966

Cumming, G. (2008). Replication and *p* Intervals: *p* Values Predict the Future Only Vaguely, but Confidence Intervals Do Much Better. *Perspectives on Psychological Science*, *3*(4), 286–300. https://doi.org/10.1111/j.1745-6924.2008.00079.x

D'Esposito, M., Detre, J. A., Alsop, D. C., Shin, R. K., Atlas, S., & Grossman, M. (1995). The neural basis of the central executive system of working memory. *Nature*, *378*(6554), 279–281. https://doi.org/10.1038/378279a0

de Haan, B., Morgan, P. S., & Rorden, C. (2008). Covert orienting of attention and overt eye movements activate identical brain regions. *Brain Research*, *1204*, 102–111. https://doi.org/10.1016/j.brainres.2008.01.105

Dennett, D. C. (1981). *True believers: The intentional strategy and why it works.*

Dienes, Z. (2016). How Bayes factors change scientific practice. *Journal of Mathematical Psychology*, *72*, 78–89. https://doi.org/10.1016/j.jmp.2015.10.003

Dienes, Z. (2014). Using bayes to get the most out of non-significant results. *Frontiers in Psychology*, *5*. https://doi.org/10.3389/fpsyg.2014.00781

Dienes, Z., & Mclatchie, N. (2018). Four reasons to prefer Bayesian analyses over significance testing. *Psychonomic Bulletin & Review*, *25*(1), 207–218. https://doi.org/10.3758/s13423-017-1266-z

Dimberg, U., Thunberg, M., & Elmehed, K. (2000). Unconscious Facial Reactions to Emotional Facial Expressions. *Psychological Science*, *11*(1), 86–89. https:

//doi.org/10.1111/1467-9280.00221

Downing, C. J. (1985). The spatial structure of visual attention. *Mechanisms of Attention: Attention and Performance XI*, 171–187.

Driver, J., Davis, G., Ricciardelli, P., Kidd, P., Maxwell, E., & Baron-Cohen, S. (1999). Gaze Perception Triggers Reflexive Visuospatial Orienting. *Visual Cognition*, *6*(5), 509–540. https://doi.org/10.1080/135062899394920

Dujmovi, M., & Valerjev, P. (2018). A person, a dog, and a vase: The effect of avatar type in a perspective-taking task. *Proceedings of the 24th Scientific Conference Empirical Studies In Psychology*, 89. https://www.bib.irb.hr/964471

Duncan, J. (1996). *Cooperating brain systems in selective perception and action.*

Edgeworth, F. Y. (1885). Methods of Statistics. *Journal of the Statistical Society of London*, 181–217. https://www.jstor.org/stable/25163974

Edwards, W., Lindman, H., & Savage, L. J. (1963). Bayesian statistical inference for psychological research. *Psychological Review*, *70*(3), 193–242. https://doi.org/10.1037/h0044139

Egeth, H. E., & Yantis, S. (1997). VISUAL ATTENTION: Control, Representation, and Time Course. *Annual Review of Psychology*, *48*(1), 269–297. https://doi.org/10.1146/annurev.psych.48.1.269

Egly, R., Driver, J., & Rafal, R. D. (1994). Shifting visual attention between objects and locations: Evidence from normal and parietal lesion subjects. *Journal of Experimental Psychology: General*, *123*(2), 161–177. https://doi.org/10.1037/0096-3445.123.2.161

Epley, N., Keysar, B., Van Boven, L., & Gilovich, T. (2004). Perspective taking as egocentric anchoring and adjustment. *Journal of Personality and Social Psychology*, *87*(3), 327–339. https://doi.org/10.1037/0022-3514.87.3.327

Eriksen, C. W., & Yeh, Y.-Y. (1985). Allocation of attention in the visual field. *Journal of Experimental Psychology: Human Perception and Performance*, *11*(5), 583–597. https://doi.org/10.1037/0096-1523.11.5.583

Etz, A., & Vandekerckhove, J. (2018). Introduction to Bayesian Inference for Psychology. *Psychonomic Bulletin & Review*, *25*(1), 5–34. https://doi.org/10.3758/s13423-017-1262-3

Etz, A., & Vandekerckhove, J. (2016). A Bayesian Perspective on the Reproducibility Project: Psychology. *PLOS ONE*, *11*(2), e0149794. https://doi.org/10.1371/journal.pone.0149794

Fan, L., Yu, H., Zhang, X., Feng, Q., Sun, M., & Xu, M. (2018). Conflict Tasks of Different Types Divergently Affect the Attentional Processing of Gaze and Arrow. *I-Perception*, *9*(3), 204166951877171. https://doi.org/10.1177/2041669518771713

Farroni, T., Johnson, M. H., Brockbank, M., & Simion, F. (2000). Infants' use of gaze direction to cue attention: The importance of perceived motion. *Visual Cognition*, *7*(6), 705–718. https://doi.org/10.1080/13506280050144399

Farroni, T., Mansfield, E. M., Lai, C., & Johnson, M. H. (2003). Infants perceiving and acting on the eyes: Tests of an evolutionary hypothesis. *Journal of Experimental Child Psychology*, *85*(3), 199–212. https://doi.org/10.1016/S0022-0965(03)00022-5

Fisher, R. A. (1992). Statistical Methods for Research Workers. In S. Kotz & N. L. Johnson (Eds.), *Breakthroughs in Statistics* (pp. 66–70). Springer New York. https://doi.org/10.1007/978-1-4612-4380-9_6

Flavell, J. H. (1977). The development of knowledge about visual perception. *Nebraska Symposium on Motivation. Nebraska Symposium on Motivation*, *25*, 43–76.

Flavell, J. H. (1999). Cognitive development: Children's knowledge about the mind. *Annual Review of Psychology*, *50*, 21–45. https://doi.org/10.1146/annurev.psych.50.1.21

Flavell, J. H., Green, F. L., Flavell, E. R., Watson, M. W., & Campione, J. C. (1986). Development of Knowledge about the Appearance-Reality Distinction. *Monographs of the Society for Research in Child Development*, *51*(1), i–87. https://doi.org/10.2307/1165866

Folk, C. L., Remington, R. W., & Johnston, J. C. (1992). Involuntary covert orienting is contingent on attentional control settings. *Journal of Experimental Psychology: Human Perception and Performance*, *18*(4), 1030–1044. https://doi.org/10.1037/0096-1523.18.4.1030

Frick, A., Mohring, W., & Newcombe, N. S. (2014). Picturing perspectives: Development of perspective-taking abilities in 4- to 8-year-olds. *Frontiers in Psychology*, *5*. https://doi.org/10.3389/fpsyg.2014.00386

Friesen, C. K., & Kingstone, A. (1998). The eyes have it! Reflexive orienting is triggered by nonpredictive gaze. *Psychonomic Bulletin & Review*, *5*(3), 490–495. https://doi.org/10.3758/BF03208827

Frischen, A., Bayliss, A. P., & Tipper, S. P. (2007). Gaze cueing of attention: Visual attention, social cognition, and individual differences. *Psychological Bulletin*, *133*(4), 694–724. https://doi.org/10.1037/0033-2909.133.4.694

Frith, C. D. (Ed.). (2005). *The neuroscience of social interaction: Decoding,* *imitating, and influencing the actions of others* (Repr). Oxford Univ. Press.

Furlanetto, T., Becchio, C., Samson, D., & Apperly, I. (2016). Altercentric interference in level 1 visual perspective taking reflects the ascription of mental states, not submentalizing. *Journal of Experimental Psychology: Human Perception and Performance*, *42*(2), 158–163. https://doi.org/10.1037/xhp0000138

Gabay, S., Avni, D., & Henik, A. (2012). Reflexive orienting by central arrows: Evidence from the inattentional blindness task. *Psychonomic Bulletin & Review*, *19*(4), 625–630. https://doi.org/10.3758/s13423-012-0252-8

Galashan, D., & Siemann, J. (2017). Differences and Similarities for Spatial and Feature-Based Selective Attentional Orienting. *Frontiers in Neuroscience*, *11*, 283. https://doi.org/10.3389/fnins.2017.00283

Galfano, G., Dalmaso, M., Marzoli, D., Pavan, G., Coricelli, C., & Castelli, L. (2012). Eye gaze cannot be ignored (but neither can arrows). *Quarterly Journal of Experimental Psychology*, *65*(10), 1895–1910. https://doi.org/10.1080/17470218.2012.663765

Gardner, M., Bileviciute, A., & Edmonds, C. (2018). Implicit Mentalising during Level-1 Visual Perspective-Taking Indicated by Dissociation with Attention Orienting. *Vision*, *2*(1), 3. https://doi.org/10.3390/vision2010003

Gardner, M., Hull, Z., Taylor, D., & Edmonds, C. J. (2018). “Spontaneous” visual perspective-taking mediated by attention orienting that is voluntary and not reflexive. *Quarterly Journal of Experimental Psychology*, *71*(4), 1020–1029. https://doi.org/10.1080/17470218.2017.1307868

Gelman, A., & Rubin, D. B. (1992). Inference from iterative simulation using multiple sequences. *Statistical Science*, *7*(4), 457–472. https://www.jstor.org/stable/2246093

Gigerenzer, G. (2004). Mindless statistics. *The Journal of Socio-Economics*, *33*(5), 587–606. https://doi.org/10.1016/j.socec.2004.09.033

Gigerenzer, G., & Marewski, J. N. (2015). Surrogate Science: The Idol of a Universal Method for Scientific Inference. *Journal of Management*, *41*(2), 421–440. https://doi.org/10.1177/0149206314547522

Gilchrist, A. (2020). The integrity of vision. *Perception*, *49*(10), 999–1004. https://doi.org/10.1177/0301006620958372

Hamilton, A. F. de C., Brindley, R., & Frith, U. (2009). Visual perspective taking impairment in children with autistic spectrum disorder. *Cognition*, *113*(1), 37–44. https://doi.org/10.1016/j.cognition.2009.07.007

Happé, F., & Frith, U. (1995). Theory of Mind in Autism. In E. Schopler & G. B. Mesibov (Eds.), *Learning and Cognition in Autism* (pp. 177–197). Springer

US. https://doi.org/10.1007/978-1-4899-1286-2_10

Hare, B., Call, J., Agnetta, B., & Tomasello, M. (2000). Chimpanzees know what conspecifics do and do not see. *Animal Behaviour*, *59*(4), 771–785. https://doi.org/10.1006/anbe.1999.1377

Hayward, D. A., & Ristic, J. (2018). Changes in Tonic Alertness but Not Voluntary Temporal Preparation Modulate the Attention Elicited by Task-Relevant Gaze and Arrow Cues. *Vision*, *2*(2). https://doi.org/10.3390/vision2020018

He, Z., Bolz, M., & Baillargeon, R. (2012). 2.5-year-olds succeed at a verbal anticipatory-looking false-belief task: False-belief understanding in 2.5-year-olds. *British Journal of Developmental Psychology*, *30*(1), 14–29. https://doi.org/10.1111/j.2044-835X.2011.02070.x

Hespanhol, L., Vallio, C. S., Costa, L. M., & Saragiotto, B. T. (2019). Understanding and interpreting confidence and credible intervals around effect estimates. *Brazilian Journal of Physical Therapy*, *23*(4), 290–301. https://doi.org/10.1016/j.bjpt.2018.12.006

Heyes, C. (2014). Submentalizing: I Am Not Really Reading Your Mind. *Perspectives on Psychological Science*, *9*(2), 131–143. https://doi.org/10.1177/1745691613518076

Hietanen, J. (2002). Social attention orienting integrates visual information from head and body orientation. *Psychological Research*, *66*(3), 174–179. https://doi.org/10.1007/s00426-002-0091-8

Hietanen, J., Leppänen, J. M., Nummenmaa, L., & Astikainen, P. (2008). Visuospatial attention shifts by gaze and arrow cues: An ERP study. *Brain Research*, *1215*, 123–136. https://doi.org/10.1016/j.brainres.2008.03.091

Horowitz, A. (2011). Theory of mind in dogs? Examining method and concept. *Learning & Behavior*, *39*(4), 314–317. https://doi.org/10.3758/s13420-011-0041-7

Hubbard, R. (2019). Will the ASA's Efforts to Improve Statistical Practice be Successful? Some Evidence to the Contrary. *The American Statistician*, *73*, 31–35. https://doi.org/10.1080/00031305.2018.1497540

Ioannidis, J. P. A., Fanelli, D., Dunne, D. D., & Goodman, S. N. (2015). Meta-research: Evaluation and Improvement of Research Methods and Practices. *PLOS Biology*, *13*(10), e1002264. https://doi.org/10.1371/journal.pbio.1002264

James, W., Burkhardt, F., Bowers, F., & Skrupskelis, I. K. (1890). *The principles of psychology* (Vol. 1). Macmillan London.

Jeffreys, H. (1961). *The Theory of Probability*. Oxford University Press.

Ji, H., Yuan, T., Yu, Y., Wang, L., & Jiang, Y. (2022). Internal Social Attention: Gaze Cues Stored in Working Memory Trigger Involuntary Attentional Orienting. *Psychological Science*, 095679762210946. https://doi.org/10.1177/09567976221094628

Jonides, J. (1981). Voluntary versus automatic control over the mind's eye's movements. *Attention and Performance*.

Judd, C. M., Westfall, J., & Kenny, D. A. (2012). Treating stimuli as a random factor in social psychology: A new and comprehensive solution to a pervasive but largely ignored problem. *Journal of Personality and Social Psychology*, *103*(1), 54–69. https://doi.org/10.1037/a0028347

Kahana, M., & Loftus, G. (1999). Response Time versus Accuracy in Human Memory. In *The nature of cognition*. MIT Press.

Kampis, D., & Southgate, V. (2020). Altercentric Cognition: How Others Influence Our Cognitive Processing. *Trends in Cognitive Sciences*, *24*(11), 945–959. https://doi.org/10.1016/j.tics.2020.09.003

Kanwisher, N., & Wojciulik, E. (2000). Visual attention: Insights from brain imaging. *Nature Reviews Neuroscience*, *1*(2), 91–100. https://doi.org/10.1038/35039043

Kastner, S., De Weerd, P., Desimone, R., & Ungerleider, L. G. (1998). Mechanisms of Directed Attention in the Human Extrastriate Cortex as Revealed by Functional MRI. *Science*, *282*(5386), 108–111. https://doi.org/10.1126/science.282.5386.108

Kastner, S., De Weerd, P., Pinsk, M. A., Elizondo, M. I., Desimone, R., & Ungerleider, L. G. (2001). Modulation of Sensory Suppression: Implications for Receptive Field Sizes in the Human Visual Cortex. *Journal of Neurophysiology*, *86*(3), 1398–1411. https://doi.org/10.1152/jn.2001.86.3.1398

Katsyri, J., Forger, K., Makarainen, M., & Takala, T. (2015). A review of empirical evidence on different uncanny valley hypotheses: Support for perceptual mismatch as one road to the valley of eeriness. *Frontiers in Psychology*, *6*. https://doi.org/10.3389/fpsyg.2015.00390

Kessler, K. (2010). The two forms of visuo-spatial perspective taking are differently embodied and subserve different spatial prepositions. *Frontiers in Psychology*, *1*. https://doi.org/10.3389/fpsyg.2010.00213

Keysar, B., Lin, S., & Barr, D. J. (2003). Limits on theory of mind use in adults. *Cognition*, *89*(1), 25–41. https://doi.org/10.1016/S0010-0277(03)00064-7

Khalifa-Gueta, S. (2018). The evolution of the western dragon. *ATHENS JOUR-*

NAL OF MEDITERRANEAN STUDIES, *4*(4), 265–290. https://doi.org/10.30958/ajms.4-4-1

Kingstone, A., Friesen, C. K., & Gazzaniga, M. S. (2000). Reflexive Joint Attention Depends on Lateralized Cortical Connections. *Psychological Science*, *11*(2), 159–166. https://doi.org/10.1111/1467-9280.00232

Kingstone, A., Tipper, C., Ristic, J., & Ngan, E. (2004). The eyes have it!: An fMRI investigation. *Brain and Cognition*, 3.

Klein, R. M. (2000). Inhibition of return. *Trends in Cognitive Sciences*, *4*(4), 138–147. https://doi.org/10.1016/S1364-6613(00)01452-2

Konstantinou, N., Beal, E., King, J.-R., & Lavie, N. (2014). Working memory load and distraction: Dissociable effects of visual maintenance and cognitive control. *Attention, Perception, & Psychophysics*, *76*(7), 1985–1997. https://doi.org/10.3758/s13414-014-0742-z

Konstantinou, N., & Lavie, N. (2013). Dissociable roles of different types of working memory load in visual detection. *Journal of Experimental Psychology: Human Perception and Performance*, *39*(4), 919–924. https://doi.org/10.1037/a0033037

Konstantinou, N., & Lavie, N. (2020). Effects of visual short-term memory load and attentional demand on the contrast response function. *Journal of Vision*, *20*(10), 6. https://doi.org/10.1167/jov.20.10.6

Kovács, Á. M., Téglás, E., & Endress, A. D. (2010). The Social Sense: Susceptibility to Others' Beliefs in Human Infants and Adults. *Science*, *330*(6012), 1830–1834. https://doi.org/10.1126/science.1190792

Kowler, E. (2011). Eye movements: The past 25years. *Vision Research*, *51*(13), 1457–1483. https://doi.org/10.1016/j.visres.2010.12.014

Kruschke, J. K. (2018). Rejecting or accepting parameter values in bayesian estimation. *Advances in Methods and Practices in Psychological Science*, *1*(2), 270–280. https://doi.org/10.1177/2515245918771304

Kruschke, J. K. (2013). Bayesian estimation supersedes the t test. *Journal of Experimental Psychology: General*, *142*(2), 573–603. https://doi.org/10.1037/a0029146

Kruschke, J. K. (2015). *Doing bayesian data analysis: A tutorial with r, JAGS, and stan.*

Kruschke, J. K., & Liddell, T. M. (2018a). Bayesian data analysis for newcomers. *Psychonomic Bulletin & Review*, *25*(1), 155–177. https://doi.org/10.3758/s13423-017-1272-1

Kruschke, J. K., & Liddell, T. M. (2018b). The bayesian new statistics: Hypothesis testing, estimation, meta-analysis, and power analysis from a bayesian perspective. *Psychonomic Bulletin & Review*, *25*(1), 178–206. https://doi.org/10.3758/s13423-016-1221-4

Kuhn, G., & Kingstone, A. (2009). Look away! Eyes and arrows engage oculomotor responses automatically. *Attention, Perception & Psychophysics*, *71*(2), 314–327. https://doi.org/10.3758/APP.71.2.314

Kulke, L., Johannsen, J., & Rakoczy, H. (2019). Why can some implicit Theory of Mind tasks be replicated and others cannot? A test of mentalizing versus submentalizing accounts. *PLOS ONE*, *14*(3), e0213772. https://doi.org/10.1371/journal.pone.0213772

Lakens, D. (2017). Equivalence Tests: A Practical Primer for *t* Tests, Correlations, and Meta-Analyses. *Social Psychological and Personality Science*, *8*(4), 355–362. https://doi.org/10.1177/1948550617697177

Langton, S. R. H. (2018). I don't see it your way: The dot perspective task does not gauge spontaneous perspective taking. *Vision*, *2*(1, 1), 6. https://doi.org/10.3390/vision2010006

Langton, S. R. H., & Bruce, V. (1999). Reflexive Visual Orienting in Response to the Social Attention of Others. *Visual Cognition*, *6*(5), 541–567. https://doi.org/10.1080/135062899394939

Lavie, N. (2010). Attention, Distraction, and Cognitive Control Under Load. *Current Directions in Psychological Science*, *19*(3), 143–148. https://doi.org/10.1177/0963721410370295

Lavie, N., Hirst, A., de Fockert, J. W., & Viding, E. (2004). Load Theory of Selective Attention and Cognitive Control. *Journal of Experimental Psychology: General*, *133*(3), 339–354. https://doi.org/10.1037/0096-3445.133.3.339

Lenth, R. V. (2021). *Emmeans: Estimated marginal means, aka least-squares means* [Manual]. https://CRAN.R-project.org/package=emmeans

Lieberman, M. D., Gaunt, R., Gilbert, D. T., & Trope, Y. (2002). Reflexion and reflection: A social cognitive neuroscience approach to attributional inference. In *Advances in Experimental Social Psychology* (Vol. 34, pp. 199–249). Elsevier. https://doi.org/10.1016/S0065-2601(02)80006-5

Lindley, D. V. (1975). The Future of Statistics: A Bayesian 21st Century. *Advances in Applied Probability*, *7*, 106. https://doi.org/10.2307/1426315

Liu, T., Stevens, S. T., & Carrasco, M. (2007). Comparing the time course and efficacy of spatial and feature-based attention. *Vision Research*, *47*(1), 108–113. https://doi.org/10.1016/j.visres.2006.09.017

Logan, G. D. (1992). Shapes of reaction-time distributions and shapes of learning curves: A test of the instance theory of automaticity. *Journal of Experimental Psychology. Learning, Memory, and Cognition*, *18*(5), 883–914. https://doi.org/10.1037//0278-7393.18.5.883

Lüdecke, D., Ben-Shachar, M., Patil, I., & Makowski, D. (2020). Extracting, computing and exploring the parameters of statistical models using r. *Journal of Open Source Software*, *5*(53), 2445. https://doi.org/10.21105/joss.02445

Lyngs, U. (2019). *Oxforddown: An oxford university thesis template for R markdown*. GitHub. https://doi.org/10.5281/zenodo.3484681

MacDorman, K. F., Srinivas, P., & Patel, H. (2013). The uncanny valley does not interfere with level 1 visual perspective taking. *Computers in Human Behavior*, *29*(4), 1671–1685. https://doi.org/10.1016/j.chb.2013.01.051

Makowski, D., Ben-Shachar, M. S., Chen, S. H. A., & Lüdecke, D. (2019). Indices of effect existence and significance in the bayesian framework. *Frontiers in Psychology*, *10*. https://doi.org/10.3389/fpsyg.2019.02767

Marciniak, K., Dicke, P. W., & Thier, P. (2015). Monkeys head-gaze following is fast, precise and not fully suppressible. *Proceedings of the Royal Society B: Biological Sciences*, *282*(1816), 20151020. https://doi.org/10.1098/rspb.2015.1020

Marotta, A., Lupiáñez, J., Martella, D., & Casagrande, M. (2012). Eye gaze versus arrows as spatial cues: Two qualitatively different modes of attentional selection. *Journal of Experimental Psychology: Human Perception and Performance*, *38*(2), 326–335. https://doi.org/10.1037/a0023959

Masangkay, Z. S., McCluskey, K. A., McIntyre, C. W., Sims-Knight, J., Vaughn, B. E., & Flavell, J. H. (1974). The Early Development of Inferences about the Visual Percepts of Others. *Child Development*, *45*(2), 357. https://doi.org/10.2307/1127956

Massaro, D. W., & Friedman, D. (1990). Models of integration given multiple sources of information. *Psychological Review*, *97*(2), 225.

Massironi, M., & Bruno, T. by N. (2001). *The psychology of graphic images: Seeing, drawing, communicating*. Psychology Press. https://books.google.com?id=auV4AgAAQBAJ

McElreath, R., & Safari, an O. M. C. (2020). *Statistical rethinking, 2nd edition*. https://learning.oreilly.com/library/view/-/9780429639142/?ar

Michael, J., & D'Ausilio, A. (2015). Domain-specific and domain-general processes in social perception – a complementary approach. *Consciousness and Cognition*, *36*, 434–437. https://doi.org/10.1016/j.concog.2014.12.009

Michael, J., Wolf, T., Letesson, C., Butterfill, S., Skewes, J., & Hohwy, J. (2018). Seeing it both ways: Using a double-cuing task to investigate the role of spatial cuing in Level-1 visual perspective-taking. *Journal of Experimental Psychology: Human Perception and Performance*, *44*(5), 693–702. https://doi.org/10.1037/xhp0000486

Mills, M., & Dodd, M. D. (2016). Which way is which? Examining symbolic control of attention with compound arrow cues. *Attention, Perception, & Psychophysics*, *78*(7), 2152–2163. https://doi.org/10.3758/s13414-016-1145-0

Moors, A., & De Houwer, J. (2006). Automaticity: A Theoretical and Conceptual Analysis. *Psychological Bulletin*, *132*(2), 297–326. https://doi.org/10.1037/0033-2909.132.2.297

Morgan, E. J., Freeth, M., & Smith, D. T. (2018). Mental state attributions mediate the gaze cueing effect. *Vision*, *2*(1, 1), 11. https://doi.org/10.3390/vision2010011

Müller, H. J., & Rabbitt, P. M. (1989). Reflexive and voluntary orienting of visual attention: Time course of activation and resistance to interruption. *Journal of Experimental Psychology: Human Perception and Performance*, *15*(2), 315–330. https://doi.org/10.1037/0096-1523.15.2.315

Munafò, M. R., Nosek, B. A., Bishop, D. V. M., Button, K. S., Chambers, C. D., Percie du Sert, N., Simonsohn, U., Wagenmakers, E.-J., Ware, J. J., & Ioannidis, J. P. A. (2017). A manifesto for reproducible science. *Nature Human Behaviour*, *1*(1), 0021. https://doi.org/10.1038/s41562-016-0021

Nakayama, K., & Martini, P. (2011). Situating visual search. *Vision Research*, *51*(13), 1526–1537. https://doi.org/10.1016/j.visres.2010.09.003

Nielsen, M. K., Slade, L., Levy, J. P., & Holmes, A. (2015). Inclined to see it your way: Do altercentric intrusion effects in visual perspective taking reflect an intrinsically social process? *Quarterly Journal of Experimental Psychology*, *68*(10), 1931–1951. https://doi.org/10.1080/17470218.2015.1023206

Nowakowski, P., Ciepiela, E., Harlak, D., Kocot, J., Kasztelnik, M., Bartyski, T., Meizner, J., Dyk, G., & Malawski, M. (2011). The Collage Authoring Environment. *Procedia Computer Science*, *4*, 608–617. https://doi.org/10.1016/j.procs.2011.04.064

Nuku, P., & Bekkering, H. (2008). Joint attention: Inferring what others perceive (and don't perceive). *Consciousness and Cognition*, *17*(1), 339–349. https://doi.org/10.1016/j.concog.2007.06.014

Nummenmaa, L., & Hietanen, J. K. (2009). How attentional systems process conflicting cues. The superiority of social over symbolic orienting revisited. *Journal of Experimental Psychology: Human Perception and Performance*, *35*(6), 1738–1754. https://doi.org/10.1037/a0016472

O'Grady, C., Scott-Phillips, T., Lavelle, S., & Smith, K. (2020). Perspective-taking is spontaneous but not automatic. *Quarterly Journal of Experimental Psychology*, *73*(10), 1605–1628. https://doi.org/10.1177/1747021820942479

Oberauer, K. (2019). Working Memory and Attention – A Conceptual Analysis and Review. *Journal of Cognition*, *2*(1), 36. https://doi.org/10.5334/joc.58

Open Science Collaboration. (2015). Estimating the reproducibility of psychological science. *Science*, *349*(6251), aac4716. https://doi.org/10.1126/science.aac4716

Palmer, E. M., Horowitz, T. S., Torralba, A., & Wolfe, J. M. (2011). What are the shapes of response time distributions in visual search? *Journal of Experimental Psychology. Human Perception and Performance*, *37*(1), 58–71. https://doi.org/10.1037/a0020747

Pashler, H. E. (1998). *The psychology of attention*. MIT.

Pearson, A., Ropar, D., & de C. Hamilton, A. F. (2013). A review of visual perspective taking in autism spectrum disorder. *Frontiers in Human Neuroscience*, *7*. https://doi.org/10.3389/fnhum.2013.00652

Perner, J., & Ruffman, T. (2005). Infants' Insight into the Mind: How Deep? *Science*, *308*(5719), 214–216. https://doi.org/10.1126/science.1111656

Perrett, D. I., Hietanen, J. K., Oram, M. W., & Benson, P. J. (1992). Organization and functions of cells responsive to faces in the temporal cortex. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences*, *335*(1273), 23–30. https://doi.org/10.1098/rstb.1992.0003

Pesimena, G., & Soranzo, A. (2022). Both the domain-general and the mentalising processes affect visual perspective taking. *Quarterly Journal of Experimental Psychology*, 174702182210943. https://doi.org/10.1177/17470218221094310

Pesimena, G., Wilson, C. J., Bertamini, M., & Soranzo, A. (2019). The role of perspective taking on attention: A review of the special issue on the reflexive attentional shift phenomenon. *Vision*, *3*(4, 4), 52. https://doi.org/10.3390/vision3040052

Pinsk, M. A., Doniger, G. M., & Kastner, S. (2004). Push-Pull Mechanism of Selective Attention in Human Extrastriate Cortex. *Journal of Neurophysiology*, *92*(1), 622–629. https://doi.org/10.1152/jn.00974.2003

Pomianowska, I., Germeys, F., Verfaillie, K., & Newell, F. N. (2012). The role of social cues in the deployment of spatial attention: Head-body relationships automatically activate directional spatial codes in a Simon task. *Frontiers in Integrative Neuroscience*, *6*. https://doi.org/10.3389/fnint.2012.00004

Posner, M. (1980). Orienting of Attention. *Quarterly Journal of Experimental Psychology*, *32*(1), 3–25. https://doi.org/10.1080/00335558008248231

Posner, M., & Coehn, Y. (1984). Components of visual orienting. *Attention and Performance X: Control of Language Processes*, *32*, 531.

Posner, M., Snyder, C. R., & Davidson, B. J. (1980). Attention and the detection of signals. *Journal of Experimental Psychology*, *109*(2), 160–174.

Poulin-Dubois, D., & Yott, J. (2018). Probing the depth of infants' theory of mind: Disunity in performance across paradigms. *Developmental Science*, *21*(4), e12600. https://doi.org/10.1111/desc.12600

Povinelli, D. J., & Davis, D. R. (1994). Differences between chimpanzees (Pan troglodytes) and humans (Homo sapiens) in the resting state of the index finger: Implications for pointing. *Journal of Comparative Psychology*, *108*(2), 134–139. https://doi.org/10.1037/0735-7036.108.2.134

Pratt, J., & Hommel, B. (2003). Symbolic control of visual attention: The role of working memory and attentional control settings. *Journal of Experimental Psychology. Human Perception and Performance*, *29*(5), 835–845. https://doi.org/10.1037/0096-1523.29.5.835

Premack, D., & Woodruff, G. (1978). Does the chimpanzee have a theory of mind? *Behavioral and Brain Sciences*, *1*(4), 515–526. https://doi.org/10.1017/S0140525X00076512

Prinzmetal, W., McCool, C., & Park, S. (2005). Attention: Reaction Time and Accuracy Reveal Different Mechanisms. *Journal of Experimental Psychology: General*, *134*(1), 73–92. https://doi.org/10.1037/0096-3445.134.1.73

Qian, Q., Song, M., & Shinomori, K. (2013). Gaze cueing as a function of perceived gaze direction: Gaze cueing. *Japanese Psychological Research*, *55*(3), 264–272. https://doi.org/10.1111/jpr.12001

Qureshi, A. W., Apperly, I. A., & Samson, D. (2010). Executive function is necessary for perspective selection, not Level-1 visual perspective calculation: Evidence from a dual-task study of adults. *Cognition*, *117*(2), 230–236. https://doi.org/10.1016/j.cognition.2010.08.003

Qureshi, A. W., & Monk, R. L. (2018). Executive function underlies both perspective selection and calculation in Level-1 visual perspective taking. *Psychonomic Bulletin & Review*, *25*(4), 1526–1534. https://doi.org/10.3758/s13423-018-1496-8

R Core Team. (2020). *A language and environment for statistical computing. R foundation for statistical computing*. https://www.R-project.org/

Reuss, H., Pohl, C., Kiesel, A., & Kunde, W. (2011). Follow the sign! Top-down contingent attentional capture of masked arrow cues. *Advances in Cognitive Psychology*, *7*, 82–91. https://doi.org/10.2478/v10053-008-0091-3

Ristic, J., Friesen, C. K., & Kingstone, A. (2002). Are eyes special? It depends on how you look at it. *Psychonomic Bulletin & Review*, *9*(3), 507–513. https://doi.org/10.3758/BF03196306

Ristic, J., & Kingstone, A. (2012). A new form of human spatial attention: Automated symbolic orienting. *Visual Cognition*, *20*(3), 244–264. https://doi.org/10.1080/13506285.2012.658101

Ristic, J., & Kingstone, A. (2006). Attention to Arrows: Pointing to a New Direction. *Quarterly Journal of Experimental Psychology*, *59*(11), 1921–1930. https://doi.org/10.1080/17470210500416367

Rosenthal, R. (1979). The file drawer problem and tolerance for null results. *Psychological Bulletin*, *86*(3), 638–641. https://doi.org/10.1037/0033-2909.86.3.638

Rouder, J. N., Lu, J., Speckman, P., Sun, D., & Jiang, Y. (2005). A hierarchical model for estimating response time distributions. *Psychonomic Bulletin & Review*, *12*(2), 195–223. https://doi.org/10.3758/BF03257252

Rouder, J. N., & Morey, R. D. (2011). A Bayes factor meta-analysis of Bem's ESP claim. *Psychonomic Bulletin & Review*, *18*(4), 682–689. https://doi.org/10.3758/s13423-011-0088-7

Rouder, J. N., Morey, R. D., Verhagen, J., Province, J. M., & Wagenmakers, E. (2016). Is There a Free Lunch in Inference? *Topics in Cognitive Science*, *8*(3), 520–547. https://doi.org/10.1111/tops.12214

Rouder, J. N., Morey, R. D., & Wagenmakers, E.-J. (2016). The Interplay between Subjectivity, Statistical Practice, and Psychological Science. *Collabra*, *2*(1), 6. https://doi.org/10.1525/collabra.28

Samson, D., Apperly, I. A., Braithwaite, J. J., Andrews, B. J., & Bodley Scott, S. E. (2010). Seeing it their way: Evidence for rapid and involuntary computation of what other people see. *Journal of Experimental Psychology: Human Perception and Performance*, *36*(5), 1255–1266. https://doi.org/10.1037/a0018729

Samson, D., Apperly, I. A., Kathirgamanathan, U., & Humphreys, G. W. (2005). Seeing it my way: A case of a selective deficit in inhibiting self-perspective. *Brain*, *128*(5), 1102–1111. https://doi.org/10.1093/brain/awh464

Santiesteban, I., Catmur, C., Hopkins, S. C., Bird, G., & Heyes, C. (2014). Avatars and arrows: Implicit mentalizing or domain-general processing? *Journal of Experimental Psychology: Human Perception and Performance*, *40*(3), 929–937. https://doi.org/10.1037/a0035175

Santiesteban, I., Shah, P., White, S., Bird, G., & Heyes, C. (2015). Mentalizing or submentalizing in a communication task? Evidence from autism and a camera control. *Psychonomic Bulletin & Review*, *22*(3), 844–849. https://doi.org/10.3758/s13423-014-0716-0

Schneider, D., Slaughter, V. P., & Dux, P. E. (2017). Current evidence for automatic Theory of Mind processing in adults. *Cognition*, *162*, 27–31. https://doi.org/10.1016/j.cognition.2017.01.018

Schönbrodt, F. D., Wagenmakers, E.-J., Zehetleitner, M., & Perugini, M. (2017). Sequential hypothesis testing with bayes factors: Efficiently testing mean differences. *Psychological Methods*, *22*(2), 322–339. https://doi.org/10.1037/met0000061

Scott, R. M., & Baillargeon, R. (2017). Early False-Belief Understanding. *Trends in Cognitive Sciences*, *21*(4), 237–249. https://doi.org/10.1016/j.tics.2017.01.012

Senju, A., Southgate, V., Miura, Y., Matsui, T., Hasegawa, T., Tojo, Y., Osanai, H., & Csibra, G. (2010). Absence of spontaneous action anticipation by false belief attribution in children with autism spectrum disorder. *Development and Psychopathology*, *22*(2), 353–360. https://doi.org/10.1017/S0954579410000106

Shepherd. (2010). Following gaze: Gaze-following behavior as a window into social cognition. *Frontiers in Integrative Neuroscience*. https://doi.org/10.3389/fnint.2010.00005

Simon, J. R., Acosta, E., Mewaldt, S. P., & Speidel, C. R. (1976). The effect of an irrelevant directional cue on choice reaction time: Duration of the phenomenon and its relation to stages of processing. *Perception & Psychophysics*, *19*(1), 16–22. https://doi.org/10.3758/BF03199380

Simons, D. J., & Chabris, C. F. (1999). Gorillas in Our Midst: Sustained Inattentional Blindness for Dynamic Events. *Perception*, *28*(9), 1059–1074. https://doi.org/10.1068/p281059

Simpson, A. J., & Todd, A. R. (2017). Intergroup visual perspective-taking: Shared group membership impairs self-perspective inhibition but may facilitate perspective calculation. *Cognition*, *166*, 371–381. https://doi.org/10.1016/j.cognition.2017.06.003

Smith, E. E., & Jonides, J. (1999). Storage and Executive Processes in the Frontal

Lobes. *Science*, *283*(5408), 1657–1661. https://doi.org/10.1126/science.283.5408.1657

Sodian, B., Thoermer, C., & Metz, U. (2007). Now I see it but you don't: 14-month-olds can represent another person's visual perspective. *Developmental Science*, *10*(2), 199–204. https://doi.org/10.1111/j.1467-7687.2007.00580.x

Soranzo, A., Bertamini, M., & Cassidy, S. (2021). How Do Children Reason About Mirrors? A Comparison Between Adults, Typically Developed Children, and Children With Autism Spectrum Disorder. *Frontiers in Psychology*, *12*, 722213. https://doi.org/10.3389/fpsyg.2021.722213

Southgate, V., Senju, A., & Csibra, G. (2007). Action Anticipation Through Attribution of False Belief by 2-Year-Olds. *Psychological Science*, *18*(7), 587–592. https://doi.org/10.1111/j.1467-9280.2007.01944.x

Sperber, D., & Wilson, D. (1986). *Relevance: Communication and cognition* (Vol. 142). Citeseer.

Stephenson, B., & Wicklund, R. A. (1983). Self-directed attention and taking the other's perspective. *Journal of Experimental Social Psychology*, *19*(1), 58–77. https://doi.org/10.1016/0022-1031(83)90005-7

Stevens, S. A., West, G. L., Al-Aidroos, N., Weger, U. W., & Pratt, J. (2008). Testing whether gaze cues and arrow cues produce reflexive or volitional shifts of attention. *Psychonomic Bulletin & Review*, *15*(6), 1148–1153. https://doi.org/10.3758/PBR.15.6.1148

Stodden, V. (2015). Reproducing Statistical Results. *Annual Review of Statistics and Its Application*, *2*(1), 1–19. https://doi.org/10.1146/annurev-statistics-010814-020127

Surtees, A., Apperly, I., & Samson, D. (2013). Similarities and differences in visual and spatial perspective-taking processes. *Cognition*, *129*(2), 426–438. https://doi.org/10.1016/j.cognition.2013.06.008

Téglás, E., Gergely, A., Kupán, K., Miklósi, Á., & Topál, J. (2012). Dogs' Gaze Following Is Tuned to Human Communicative Signals. *Current Biology*, *22*(3), 209–212. https://doi.org/10.1016/j.cub.2011.12.018

Teufel, C., Alexis, D. M., Clayton, N. S., & Davis, G. (2010). Mental-state attribution drives rapid, reflexive gaze following. *Attention, Perception, & Psychophysics*, *72*(3), 695–705. https://doi.org/10.3758/APP.72.3.695

Teufel, C., Fletcher, P. C., & Davis, G. (2010). Seeing other minds: Attributed mental states influence perception. *Trends in Cognitive Sciences*, *14*(8), 376–382. https://doi.org/10.1016/j.tics.2010.05.005

Tipples, J. (2002). Eye gaze is not unique: Automatic orienting in response to uninformative arrows. *Psychonomic Bulletin & Review*, *9*(2), 314–318. https://doi.org/10.3758/BF03196287

Tomasello, M. (2018). How children come to understand false beliefs: A shared intentionality account. *Proceedings of the National Academy of Sciences*, *115*(34), 8491–8498. https://doi.org/10.1073/pnas.1804761115

Tomasello, M. (2008). *Origins of human communication*. MIT Press.

Tomasello, M., Call, J., & Hare, B. (2003). Chimpanzees understand psychological states - the question is which ones and to what extent. *Trends in Cognitive Sciences*, *7*(4), 153–156. https://doi.org/10.1016/s1364-6613(03)00035-4

Tomasello, M., Carpenter, M., Call, J., Behne, T., & Moll, H. (2005). Understanding and sharing intentions: The origins of cultural cognition. *Behavioral and Brain Sciences*, *28*(5), 675–691. https://doi.org/10.1017/S0140525X05000129

Träuble, B., Marinovi, V., & Pauen, S. (2010). Early Theory of Mind Competencies: Do Infants Understand Others' Beliefs?: EARLY THEORY OF MIND COMPETENCIES. *Infancy*, *15*(4), 434–444. https://doi.org/10.1111/j.1532-7078.2009.00025.x

Tukey, J. W. (1977). *Exploratory data analysis* (Vol. 2). Reading, Mass.

van Ede, F., de Lange, F. P., & Maris, E. (2012). Attentional Cues Affect Accuracy and Reaction Time via Different Cognitive and Neural Processes. *Journal of Neuroscience*, *32*(30), 10408–10412. https://doi.org/10.1523/JNEUROSCI.1337-12.2012

VandenBos, G. R. (Ed.). (2015). *APA dictionary of psychology (2nd ed.)*. American Psychological Association. https://doi.org/10.1037/14646-000

Vuilleumier, P. (2002). Perceived gaze direction in faces and spatial attention: A study in patients with parietal damage and unilateral neglect. *Neuropsychologia*, *40*(7), 1013–1026. https://doi.org/10.1016/S0028-3932(01)00153-1

Wagenmakers, E.-J., Marsman, M., Jamil, T., Ly, A., Verhagen, J., Love, J., Selker, R., Gronau, Q. F., míra, M., Epskamp, S., Matzke, D., Rouder, J. N., & Morey, R. D. (2018). Bayesian inference for psychology. Part I: Theoretical advantages and practical ramifications. *Psychonomic Bulletin & Review*, *25*(1), 35–57. https://doi.org/10.3758/s13423-017-1343-3

Wasserstein, R. L., Schirm, A. L., & Lazar, N. A. (2019). Moving to a World Beyond "$p < 0.05$." *The American Statistician*, *73*, 1–19. https://doi.org/10.1080/00031305.2019.1583913

Wegener, D., Galashan, F. O., Aurich, M. K., & Kreiter, A. K. (2014). Attentional spreading to task-irrelevant object features: Experimental support and a 3-

step model of attention for object-based selection and feature-based processing modulation. *Frontiers in Human Neuroscience*, *8*. https://doi.org/10.3389/fnhum.2014.00414

Wellman, H. M., Cross, D., & Watson, J. (2001). Meta-Analysis of Theory-of-Mind Development: The Truth about False Belief. *Child Development*, *72*(3), 655–684. http://www.jstor.org/stable/1132444

Whelan, R. (2008). Effective Analysis of Reaction Time Data. *The Psychological Record*, *58*(3), 475–482. https://doi.org/10.1007/BF03395630

Wiese, E., Wykowska, A., Zwickel, J., & Müller, H. J. (2012). I See What You Mean: How Attentional Selection Is Shaped by Ascribing Intentions to Others. *PLoS ONE*, *7*(9), e45391. https://doi.org/10.1371/journal.pone.0045391

Wilson, C. J., Soranzo, A., & Bertamini, M. (2017). Attentional interference is modulated by salience not sentience. *Acta Psychologica*, *178*, 56–65. https://doi.org/10.1016/j.actpsy.2017.05.010

Wimmer, H. (1983). Beliefs about beliefs: Representation and constraining function of wrong beliefs in young children's understanding of deception. *Cognition*, *13*(1), 103–128. https://doi.org/10.1016/0010-0277(83)90004-5

Wolfe, J. M. (2021). Guided Search 6.0: An updated model of visual search. *Psychonomic Bulletin & Review*, *28*(4), 1060–1092. https://doi.org/10.3758/s13423-020-01859-9

Yang, P., Wang, M., Jin, Z., & Li, L. (2015). Visual short-term memory load modulates the early attention and perception of task-irrelevant emotional faces. *Frontiers in Human Neuroscience*, *9*. https://doi.org/10.3389/fnhum.2015.00490

Yantis, S. (1996). Attentional capture in vision. In A. F. Kramer, M. G. H. Coles, & G. D. Logan (Eds.), *Converging operations in the study of visual selective attention.* (pp. 45–76). American Psychological Association. https://doi.org/10.1037/10187-002

Yantis, S., Schwarzbach, J., Serences, J. T., Carlson, R. L., Steinmetz, M. A., Pekar, J. J., & Courtney, S. M. (2002). Transient neural activity in human parietal cortex during spatial attention shifts. *Nature Neuroscience*, *5*(10), 995–1002. https://doi.org/10.1038/nn921

Zimmermann, J. T., Meuser, S., Hinterwimmer, S., & Vogeley, K. (2021). Preserved Perspective Taking in Free Indirect Discourse in Autism Spectrum Disorder. *Frontiers in Psychology*, *12*, 675633. https://doi.org/10.3389/fpsyg.2021.675633

Zwickel, J. (2009). Agency attribution and visuospatial perspective taking. *Psychonomic Bulletin & Review*, *16*(6), 1089–1093. https://doi.org/10.3758/PBR.16.6.1089

Appendices

A
Appendix A

A.1 The importance of reproducible scientific report

This section introduces and discusses the importance of reproducible scientific reports. The discussion around the importance of reproducibility and *Open Science* informed the development of this thesis. *Open Science* principles have been applied to this thesis in order to ensure reproducibility. This thesis was written using the Markdown syntax and various R codes were used to generate the analysis, tables, and figures within Rmarkdown.

In 2016 Baker (2016) published the results of a survey of 1,576 researchers who took a brief on-line questionnaire on reproducibility in research. Among these, more than 70% of researchers answered that they failed to reproduce another scientist's experiment and, in some cases, even their own (Ioannidis et al., 2015). Whilst there is no single standard for evaluating replication success, a striking example of this reproducibility crisis is the Open Science Collaboration (2015), where despite employing original authors' materials, pre-review for methodological fidelity, and sufficient statistical power to detect the original effect sizes, a significant portion of replications produced weaker evidence than the original findings. Scientific knowledge builds up over time. Each scientific discovery should be treated as an attestation rather than a definitive conclusion. If a scientific discovery cannot be independently validated, it cannot be considered an empirical fact. Furthermore, if literature contains illusory evidence rather than genuine results, the scientific process' effectiveness may be jeopardised (Cacioppo et al., 2015). It must be emphasized that this staggering amount of evidence suggesting the existence of a large amount of unreliable and non-replicable studies is "mainly" not due to malicious practices implemented by researchers in bad faith (Cacioppo et al., 2015). Whilst these instances certainly exist and have seldom emerged, most of the studies that failed to be replicated went through a process of genuine data collection and statistical analysis. In 2015, the U.S. National Science Foundation Subcommittee on Replicability in Science Advisory highlighted the importance of reproducibility in Social, Behavioural, and Economic Sciences. In this document, the subcommittee, in an effort to promote and pursue robust research practice, outlined a set of definitions and recommendations. Of particular interest is the given definition of *robust* scientific findings (Cacioppo et al., 2015). The subcommittee defined as *robust* those findings that are *reproducible*, *replicable*, and *generalizable*. At this point, it is vital to correctly define these three terms. In this thesis, they will be defined according to the definitions provided by the U.S. National Science Foundation. This thesis will focus on the first two: *reproducible* and *replicable*.

- Are defined as *reproducible* those results that can be re-obtained by a second researcher whilst using the same material and procedure of the original investigator.

- Are defined as *replicable* those results that can be re-obtained by a second researcher whilst using the same material but a different data set from the original investigator.

The need for *reproducible* and *replicable* studies has been further supported in the past years by a large number of researchers proposing a series of measures that could improve the ongoing reproducibility crisis (ASA, 2022; Munafò et al., 2017; Nowakowski et al., 2011). Whilst tackling the issue with different approaches, all the proposed measures conveyed that a change in conventional scientific practices is required. Despite the development and proliferation of computer-aided research methodologies in the last twenty years, in fact, the mechanisms by which scientific results and achievements are conveyed to the public and scientific community have remained unaltered. Scientific advances are still communicated by means of scientific articles, which, due to their nature and structure, do not allow for quick verification, repeatability and reuse of results and findings (Nowakowski et al., 2011). With this in mind, the newly proposed measures aim to promote transparency and *Open Science* (Munafò et al., 2017; Nowakowski et al., 2011). According to Munafo et al.(2017, p. 5), the term *Open Science* refers to "*the process of making the content and process of producing evidence and claims transparent and accessible to others*". In reality, science typically lacks openness with many published articles not available without a subscription and with most of the data and code employed to obtain certain results not publicly available in repositories. In order to meet the goal of a more *Open Science*, three main specific recommendation and criteria that each accessible and transparent study should meet can be defined:

- Data Access: All resources used to collect, transform, and analyse data should be kept in a publicly available on-line storage site such as the Open Science

Framework (OSF; osf.io), a free and open-source project management tool that supports researchers throughout their entire project life cycle.

- Executability: The code employed to run the analysis should be broken down in smaller chunks that can be re-used by third parties, and it should be consistent and meaningful. It also should be readable by other computers without major efforts from other users.

- Documented: Each stage of analysis must be documented in far greater detail than can be contained in a publication in order to completely recreate a study. The origin of the data, methods, workflow, software and packages employed in the study should all be documented and stored.

Fortunately, nowadays different approaches to achieve these three main criteria are available. Among these, an approach to a reproducible workflow that keeps the methods and data closely linked to the communication of the study is based on the use of R, Markdown, an online storage solution such as OSF and a reference management software such as Zotero. Thanks to the combination of these it is possible therefore to integrate within a single reproducible and shareable set of files, code, analysis output and regular text.

RMarkdown is a variant of Markdown with embedded R code chunks that may be used to produce repeatable reports in a different series of formats such as Html, word, or pdf. Whilst Markdown allows us to produce readable text that can be easily converted to a different output, Rmarkdown permits the use of R code that will be run within the document and will create output that will be printed out directly within the text. We can therefore print tables, figures and run statistical analysis directly from our unique Rmarkdown file, without dragging and dropping information tables and figures from other software and without manually drawing the tables. Moreover, and most importantly, if something changes in our data, the analysis, figures, and tables will be automatically updated the next time we run the Rmarkdown file, without any manual rewriting. Additionally, thanks to the Open-Source nature of Markdown and R, researchers that wish to replicate a study created with Rmarkdown and available on OSF, can do it in a few steps, by just downloading and running the Rmarkdown script on their own machine. Furthermore, the Rmarkdown package is developed and maintained by RStudio and benefits from excellent documentation and supports and integrates into the RStudio editor. In line with these *Open Science* practices, the content of this thesis has been entirely developed to be reproducible and replicable. This thesis has been written using the Markdown syntax language, whilst the analysis, the tables and the figures have been generated within Rmarkdown as results of different chunks of R codes.

A.2 The necessity of a Bayesian approach

Because the current debate in literature volves around the ability of different type of cues to generate the interference effect phenomenon it is really important to scrutinize the statistical approach employed by different studies in the current literature. Bayesian parameter estimation and Bayesian hypothesis testing represent the most known and attractive alternative to the largely used classical "frequentist inference" approach based on confidence intervals and p values. In the next chapters, the downfall of the frequentist approach and the benefit of adopting a Bayesian approach to analyse and investigate behavioural data such as RTs and Error rates will be discussed.

To understand the reason why a Bayesian approach is needed, we must first look at the downfall of the frequentist approach and in particular to the reproducibility crisis which became an important topic in psychological sciences. The reasons behind this reproducibility crisis include sample deficiencies, low power, incorrect application and interpretation of statistical tests and misalignment of data with research questions (Hubbard, 2019; Stodden, 2015) . In an effort to address the reproducibility crisis and aiming at improving statistical practices, the American Statistical Association launched in the past years a number of initiatives. Among these The American statistician special issue *"Statistical Inference in the 21st Century: A World Beyond p < 0.05,"* in which the ASA tries to tackle the misuse and abuse of Null Hypothesis Significance Testing (NHST) and of p-value (Hubbard, 2019). Despite the effort however, Hubbard (2019) highlighted how, even though a "dramatic citation count" of 32,360 on 25 articles that severely criticize NHST and its impact on good practice during the last 50 years, the use of NHST in empirical work has increased during the past years reaching more than 93% in the most recent years. However, it must be clear that the problem with NHST is not the tool itself but mostly how the use of this tool has evolved and how different interpretation of the results provided have become commonly used during the years (Wasserstein et al., 2019). Among these the main issue may easily be identified with the definition of "Statistically significant" results and all its variants such as "non-significant", etc. These sentences are now commonly used by psychologists around the world, however their meaning is often misinterpreted. The definition of "statistically significant" results became popular after Fisher's first publication of his Statistical methods for Research Workers book (Fisher, 1992). The meaning of this expression became, however, nowadays quite different from its original intended use. Edgeworth (1885), who firstly introduced the use of this expression, intended to denote as statistically significant all that results that warranted further scrutiny (Wasserstein et al., 2019). NHST and specifically the expression *"statistically significant"* is employed to draw a sharp line between the presence and the absence of an effect. Thus, leading to a dichotomization of results and of the values of p-value which have become entrenched in statistical analysis in psychological sciences (Cumming, 2014). However, p-values by themselves are not able to convey the importance or the presence of an association as well as their absence. This dichotomization furthermore encourages researchers to ignore potentially important observed differences as non-significant results are often overlooked and branded as non-useful. This dichotomization results in what is known as the "file drawer problem" (Rosenthal, 1979; Wasserstein et al., 2019). Because studies which reported "non-significant" results are often branded as non-worthy, or non-useful, these are not usually submitted for publication. The "file drawer problem" goes back to ages before the publication of Rosenthal (1979), where different behavioural researchers and statisticians in fact already suspected that the studies published in the behavioural sciences field were a small, biased sample of the studies that were being actually conducted, with 95% of the studies who never made out of the drawer representing those studies that showed a non-significant p-value ($p > 0.05$). Thus, distorting the literature biasing the description of which effects should be reported and discussed in study results and which should not. As stated by Wasserstein et al. (2019) *"whether a p-value passes any arbitrary threshold should not be considered at all when deciding which results to present or highlight"*. These problems around the *"sacred p value"* of 0.05 have been reviewed in an article by Cohen in 1994 in which the author argued that *"NHST not only failed to support the advance of psychology as a science but also seriously impeded it"* (Cohen, 1994). It is interesting to note how this "attack" to the NHST is not by any means a recent matter. Different works criticizing the NHST were published within the first half of the last century, with the oldest one by Berkson (1938) back till the 1938. Despite the misuse and misunderstanding around NHST, one of its biggest problems, when it is employed in psychological science to test different hypothesis, is that NHST is not really answering our questions and it is not telling us what we want to know.

To better clarify this, it is essential to differentiate between what it is often taught to students across different statistical courses, what is actually NHST and what is the p-value telling us. Often students are taught that p-value indicates the probability that our data are not due to chance and that they are therefore due to the effect or the association of the variables in question. This definition of p-value is however not only wrong, but also inappropriate, as moves the focus away from what actual p-values are telling us. This can be summed up with the question "Given these data, what is the probability that H0 is true?", however the real question that NHST is answering is "Given that H0 is true, what is the probability of these or more extreme data?" (Cohen, 1994). In his article, Cumming (2014) supported and advanced different ways to shift from the dichotomist NHST to the *"new statistics"* which would instead be based on parameter estimations. Thus, according to the author, improving research integrity and providing more quantitative successful discipline. The author released a twenty-five points list to improve research integrity and the use of psychological research. Among these, two points in particular stand out and are mainly related to the aim of this chapter; Point 9: *"Do not trust any p-value"* and Point 10: *"Whenever possible, avoid using statistical significance or p values; simply omit any mention of NHST"* (Cumming, 2014). In backing up these points, the author underlined that one of the major problems related to NHST and p-values: P values are heavily affected by the sample size of the dataset. Different sample sizes may results in surprisingly enormous variation in p-values (Cumming, 2014, 2008). The author advanced different approaches to tackle this issue and move towards a new and integrity-based statistics shifting away from the NHST. It is essential to note how all these methods have a commonality. They are all based on parameter estimation rather than a dichotomous choice:

- Estimate effect sizes and interpret confidence intervals
- Run exploratory analysis as suggested by Tukey (1977)
- Employ robust methods
- Employ Bayesian methods

The latter in particular became commonly used in some disciplines and just recently have being employed in Psychological sciences (Kruschke, 2013; Kruschke & Liddell, 2018a, 2018b). Bayesian approaches to credible interval estimates, model assessment and selection, and meta-analysis are extremely useful and trustworthy (Cumming, 2014).

In the aforementioned paragraphs, the reasons to shift away from the dichotomic thinking about the presence or absence of an effect have been discussed in light of a frequentist approach. In this paragraph, the frequentist approach and Bayesian approach to parameter estimation with quantified uncertainty will be discussed. In recent years, the use of a Bayesian approach to tackle data analysis in psychological sciences has seen a growing interest and support. However, the call for a shift from the frequentist approach in favour of a Bayesian one goes further back in time, when Edwards et al. (1963) published an article titled *"Bayesian Statistical Inference for Psychological Research"*. This was then followed by a work by Lindley (1975) titled *"The future of statistics – a Bayesian 21st century"* in which the author points out his thesis according to which the only good statistics is the Bayesian one. Most recently authors such as Kruschke & Liddell (2018b) and Wagenmakers et al. (2018)

lead the way for a wider use of the Bayesian approach in Psychological sciences highlighting how Bayesian parameter estimation an hypothesis testing represent valuable and better alternatives of the classical and commonly used frequentist estimation and NHST based on confidence intervals and p values. Among the different reasons and advantages why Bayesian approach represents a better alternative, the distinguish feature of Bayesian Statistics is that all unknown quantities are considered random variables.(Lindley, 1975)

The following paragraph aims to provide a general description of the basic idea of Bayesian data analysis and how this will be employed in the different experiments of this thesis in an effort to provide a general understanding of how Bayesian data analysis works in an intuitive and useful way, providing a conceptual framework which can support and explain the choice of specific data analysis employed in the different experiments. When Bayesian analysis is introduced to Psychology student, this always seems easy simple and intuitive. This is because the main idea of Bayesian analysis is based on the relocation of credibility across possibilities. This is so simple that everyone of us already do it in everyday life (Kruschke & Liddell, 2018a; Wagenmakers et al., 2018).

Imagine that you are organizing a picnic in a cloudy day of winter. Based on your knowledge, you will probably pack your waterproof jacket thinking that there will be a high probability of rain. However, when new information about the weather, suggesting that it will be a dry day, become available, you will reconsider the probability of rain given the new available information. This reallocating of credibility across different possibilities is at the base of the Bayesian theorem, which does exactly the same using precise mathematics (Kruschke & Liddell, 2018a). The different possibilities which may explain our data are values of parameters in mathematical descriptions. In our example, we started with a prior allocation of data, which can be quite vague and spread or really specific based on our previous knowledge of the phenomenon (e.g. it is winter and cloudy), then we collected more data (weather news) and reallocated the credibility to parameter values that are consistent within the data (new probability of raining in this specific day). The goal of Bayesian analysis is therefore “to provide an explicit distribution of credibility across the range of candidate parameter values”(Kruschke & Liddell, 2018a). This explicit distribution is known as posterior distribution due to it being originated after new data are considered. This distribution is investigated and analysed to find out which is the most credible interval and the range of the most credible values under the null or the alternative hypothesis. Because the measures of the uncertainty are based directly on posterior credible intervals and can provide information about the most credible interval of our parameter under specific hypothesis, there is no need for p values and p values based estimations . Bayesian parameter estimation seldom yields a single estimate, but rather a range of estimates with variable plausibility; and Bayesian hypothesis testing rarely results in the falsification of a theory, but rather a redistribution of probability between competing explanations (Kruschke & Liddell, 2018a, 2018b; Wagenmakers et al., 2018).

It is vital at this point to highlight the main difference between any p values based estimations and the Bayesian estimation of parameters. At this point of the chapter, we will compare and discuss the main differences between frequentist and Bayesian hypothesis testing, the latter will be further discussed later in the chapter where different methods of Bayesian hypothesis testing will be compared. Whenever we decide to test a hypothesis via inferential statistics, two hypotheses (one of which based on the researcher theory) are taken in consideration. The first one is H0, which is known as null hypothesis and the second one is H1, known as the alternative hypothesis. Thus, the naïve observer would think that independently from the approach chosen by the researcher, results would produce a three way distinction (Dienes & Mclatchie, 2018):

- Strongest evidence in favour of H0
- Strongest evidence in favour of H1
- Failure to discriminate between the two hypotheses.

In order to achieve this, it is essential however to know and understand what each hypothesis predicts. In other words, a prediction must be done for both H0 and H1. An explicit specified prediction is known as "model"(Dienes & Mclatchie, 2018). However, this is not the case when the frequentist approach is used. The classical frequentist approach, based on p value and known as NHST, as mentioned above, does in fact predict only the probability of the data given H0 to be true, but does not provide any model for H1. As stated by Dienes & Mclatchie, (-Dienes & Mclatchie (2018), p 28): *"A significant effect indicates that there is evidence for at least one particular population parameter and against H0; but it may not be evidence for a specific theory that allows a range of population values, and so it may not be evidence for one's actual theory"*. In other words, it is impossible for the researcher to make prediction for both hypotheses as only the model for H0 is provided by this method. For this reason, no matter how large p values are, they only provide evidence against H0, without being able to distinguish between evidence in favour of H0 with no evidence at all. It becomes clear that, if this is our aim, a researcher must know the probability of each parameter distribution , (the models of H0 and H1), given the theory (Rouder, Morey, & Wagenmakers, 2016;

Rouder, Morey, Verhagen, et al., 2016). This is exactly the inferential step that is at the base of the Bayesian approach. Unlike NHST which only yields the probability of generating specific data given H0 to be true, the Bayesian approach can produce the relative probabilities of different hypotheses, providing therefore quantifiable information about whether the null hypothesis is more credible than the alternative. It is evident how this is a main desiderata for those domains or studies (such as the studies presented in this thesis) where providing evidence in favour of the null hypothesis is the goal (Dienes, 2016, 2014; Kruschke & Liddell, 2018a, 2018b). Because is out of the aim of this paragraph and thesis, the mathematical formulas and passages needed to obtain these evidence won't be discussed here. However, a description of how it is possible to measure evidence in favour of one of different hypotheses will be provided in the following sub-paragraphs.

A.2.1 The Bayesian Factor

The first method, employed by many, is by means of the Bayes Factor (BF). This is at the base of what is known as a Bayesian hypothesis testing and it can be seen as the counterpart of NHST. The Bayes factor (BF) can be interpreted as the extent to which the data sway our relative belief from one hypothesis to the other after new data have been taken in consideration. This is determined by comparing the hypotheses' abilities to predict the observed data (Etz & Vandekerckhove, 2018). The Bayes Factor provides a continuous measure of evidence for H1 over H0, with a value of 1 signifying that the evidence does not favour either model over the other.

Whilst the BF represents a continuous measure, in order to standardize boundaries and meanings of each BF, some rough guidelines were provided by Jeffreys (1961), which suggested that a BF of about 3 or BF $< 1/3$ (when evidence are in favour of H0) is comparable to $p < 0.05$. Differently from the fixed p value in the frequentist approach, Jeffreys defined however, other boundaries. In fact, while a BF = 3 represented "substantial" evidence, in other words evidence that were worth to be explored, a BF comprised between 3 and 10 represented moderate evidence, between 10 and 30 strong and so on. It must be noted however that these boundaries are not fixed as the p value and different authors suggest different boundaries. For example a boundary of 6 (Schönbrodt et al., 2017) and 10 (Etz & Vandekerckhove, 2018, 2016) have been suggested more recently. This must be based on the contexts and on the practical aspects of the different sorts of data and analyses and on the prior probabilities of the hypotheses. This becomes clear when we look at the definition of BF. As mentioned above, the Bayes factor can be interpreted as the extent to which the data sway our relative belief from one hypothesis to the other after new data have been taken in consideration. This means that the BF alone does not indicate the posterior probabilities of one hypothesis over the other, it instead indicates the degree of change from the prior odds between the two hypotheses to the posterior odds (Kruschke & Liddell, 2018b). Whilst BFs will be equal to the posterior odds when the priors odds of the two hypotheses are equal, when one of the hypotheses has very high prior odds, the BF may still indicate a shift away from that hypothesis. Thus, while a shift towards the less probable hypothesis may be indicated by the BF, the hypothesis with higher prior odds may still remain the hypothesis with the higher probability. (for some examples see: Kruschke & Liddell, 2018b; Rouder & Morey, 2011). This means that it may not be useful basing a null hypothesis testing decision on BF only when this is the case.

A.2.2 Moving from Bayesian Null hypothesis testing towards Bayesian estimation

Just like p-values by themselves are not able to convey the importance or the presence of an association as well as their absence, Bayes factors are unable to convey the magnitude of an effect. It is clear therefore, that this general problem is the consequence of the null value hypothesis testing [1] (Kruschke & Liddell, 2018a). Bayes

The results of a hypothesis test do not in fact provide any information regarding the magnitude of the effect or the uncertainty of its estimate, which are essential to understand the data. Similarly to the Null-hypothesis testing in frequentist statistic, the Bayesian approach presents three undesirable consequences:

- a null hypothesis can be rejected by a trivially small effect;
- a null hypothesis can be rejected even though there is high uncertainty in its magnitude;
- a null hypothesis can be accepted by a Bayes factor even though the interval estimate of the magnitude includes a wide range of non-null values.

However, as previously stated, one of the major drawbacks of null-hypothesis testing is that it is prone to false “black and white thinking,” which ignores the size and uncertainty of the effect. In both frequentist and Bayesian approach, when a null-hypothesis is not rejected (p value) or is accepted (Bayes factor), researchers are often led to believe that a non-significant result is in practice evidence for a null-hypothesis. This is especially relevant in psychology. As pointed out by Kruschke & Liddell (2018a) and Dienes (2016) , taking as example the articles

[1] It must be noted that Bayesian allows for testing of hypotheses different from the null, in that case, it would be defined as point-value hypothesis testing.

published in the Journal of Experimental Psychology: General, in most of the articles (32 out of 34), the authors took a non-significant result as evidence of the null-hypothesis and claiming no effect without presenting any estimate of effects size and its interval of uncertainty. To this end, just like in the frequentist statistic, presenting only the Bayes Factor is the counterpart of basing a data analysis only on p-value in a frequentist approach. In other words, shifting from a frequentist approach to a Bayesian approach would not resolve the issue linked with downfall of the frequentist approach and the reproducibility crisis; The Bayes Factor would only replace the p-value in what has been defined by Gigerenzer (2004) the "ritual of mindless statistics (Gigerenzer, 2004; Gigerenzer & Marewski, 2015). This is because, just like the p value in the frequentist approach, the Bayes factor does not provide any information about the magnitude of the effect and about the uncertainty of the estimate. Consequently, while employing a Bayesian approach by mean of a BF over a frequentist approach can provide important information about the relative probabilities of the different hypothesis, this method still risks to fall in that dichotomous thinking that should be instead avoided.

Whilst the Bayes Factor cannot provide these information, in a Bayesian analysis, the uncertainty of the estimate is represented by how spread is the posterior distribution (Kruschke & Liddell, 2018b). A large uncertainty will result in a posterior distribution spanning across a wider range of possible parameters, on the contrary a small uncertainty will result in a really small and precise set of possible parameters.

The *Highest Density Interval* is a convenient method for summarising uncertainty and the distribution of the posterior (HDI). The HDI uses the technical phrase "probability density" rather than the popular but appropriate term "credibility." The HDI summarises the distribution and its uncertainty by creating an interval that encompasses a specific proportion of the distribution, typically 95% or 89% (Kruschke, 2018, 2013; Makowski et al., 2019).

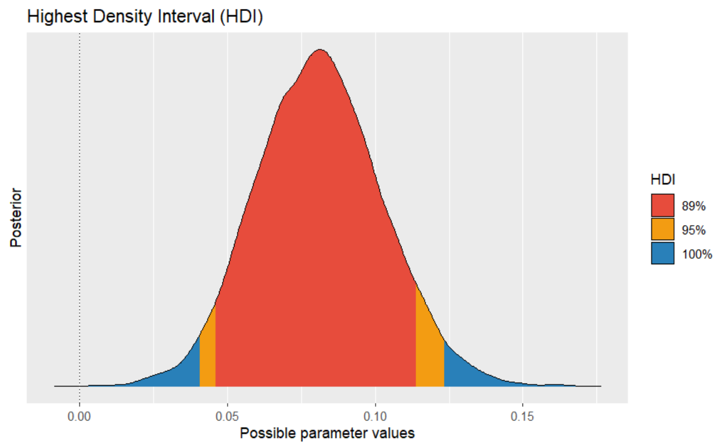
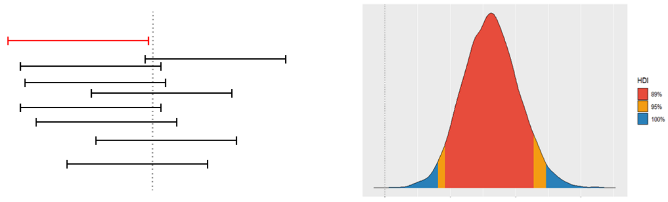


Figure A.1: Example of 89 and 95 percent HDIs of a posterior distribution.

When non-bayesian researchers are introduced for the first time to the concept of HDI, these are often surprised to notice how its definition corresponds to the "incorrect" interpretation that most have of the frequentist Confidence Intervals (CI). These are in fact often misinterpreted as if they were a posterior distribution (Kruschke & Liddell, 2018a). When someone gives you a CI, for example a 95% CI, its most probable interpretation will be that "there are 95% probability that the true value is comprised between the extreme of the CI". This however is a Bayesian interpretation of the CI, with the researcher interpreting the CI as if it was an HDI. The HDI explicitly refers to an actual probability, as its interval captures our uncertainty about the location of the parameter values and therefore it can be explained as a probabilistic statement. On the contrary, the frequentist CI captures the uncertainty about the interval comprised between its extreme. We would say therefore that "if the experiment is repeated many times in 95% of the cases, the computed CI will contain the true parameters" (A.2). Furthermore, because the CI is computed around p value, just like p-value this is affected by different stopping rule choices and sample sizes (Kruschke & Liddell, 2018b). The most important characteristic which differentiates the CI from HDI, is that CI does not carry any distributional information. The boundaries of the CIs in fact simply define the range of parameter values that would not be rejected by the chosen p-value cut off (Kruschke & Liddell, 2018b). Thus, there is no information about which of the single parameters within the CI are the most probable. This is the reason why in (A.2) CI are represented with a single line instead of the density bell of the HDI.



95 % Confidence Interval **89%, 95% and 100% HDI**

Figure A.2: CI vs HDI. On the left the graphical representation of a frequentist CI; On the right the graphical representation of a Bayesian HDI. It is evident how CI do not possess any information about the density of the parameter.