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Changes in the spatial spread of attention with ageing

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ABSTRACT

Spatial attention is a necessary cognitive process, allowing for the direction of limited capacity resources to varying locations in the visual field for improved visual processing. Thus, understanding how ageing influences these processes is vital. The current study explored the relationship between the spatial spread of attention and healthy ageing using an inhibition of return task to tap visual attention processing. This task allowed us to measure the spatial distribution of inhibition, and thus acted as a marker for attentional spread. Past research has indicated minimal age differences in inhibitory spread. However, these studies used placeholder stimuli, which may have restricted the range over which age differences could be reliably measured. To address this, in Experiment One, we measured the relationship between the spatial spread of inhibition and healthy ageing using a method which did not employ placeholders. In contrast to past research, an age difference in inhibitory spread was observed, where in comparison to younger adults, older adults exhibited a relatively restricted spread of attention. Experiment Two then confirmed these findings, by directly comparing inhibitory spread for placeholder present and placeholder absent conditions, across younger and older adults. Again, it was found that age differences in inhibitory spread emerged, but only in the placeholder absent condition. Possible reasons for the observed age differences in attention are discussed.

1. Introduction

Selective spatial attention allows for the allocation of the brain's finite cognitive resources for efficient processing of relevant visual information, while filtering out irrelevant visual noise (Broadbent, 1982; Carrasco, 2011; Desimone & Duncan, 1995; Kastner & Pinsk, 2004; Posner, 1980; Posner, Snyder, & Davidson, 1980). The aim of the current study was to clarify the relationship between healthy ageing and the dynamics of one aspect of selective spatial attention: the distribution of attention across space. This is important because the relative distribution of spatial attention may underscore differences in visual search efficiency, perceptual sensitivity, distractor processing, and working-memory capacity (e.g. Bleckley, Durso, Crutchfield, Engle, & Khanna, 2003; Cave & Chen, 2016; Eriksen & James, 1986; Goodhew, Lawrence, & Edwards, 2017; Goodhew, Shen, & Edwards, 2016; Greenwood & Parasuraman, 1999, 2004; Hoyer, Cerella, & Buchler, 2011; Pringle, Irwin, Kramer, & Atchley, 2001; Theeuwes, Kramer, & Belopolsky, 2004). It is therefore imperative that the operation of attentional spread with ageing is understood in great detail. Yet current evidence for changes in attentional distribution across the lifespan is mixed. While some studies reveal substantial age differences in the capacity to spread spatial attention (Gottlob & Madden, 1999; Greenwood & Parasuraman, 1999, 2004; Hüttermann, Bock, & Memmert, 2012; Kosslyn, Brown, & Dror, 1999; Pesce, Guidetti, Baldari, Tessitore, & Capranica, 2005), others indicate none, or only small differences (Hartley & Kieley, 1995; Hartley, Kieley, & Mckenzie, 1992; Langley, Gayzur, Saville, Morlock, & Bagne, 2011; Madden & Gottlob, 1997; McCalley, Bouwhuis, & Juola, 1995; Quigley, Andersen, & Müller, 2012).

Previous research has demonstrated a strong link between working memory capacity and visual attention (Bleckley et al., 2003; Kreitz, Furley, Memmert, & Simons, 2015). Likewise, there are well known declines in working memory capacity with age (Hedden & Gabrieli, 2004; Mattay et al., 2006; Verhaeghen & Salthouse, 1997). Therefore, the contradictory effects of ageing on attentional spread are surprising. That is, if changes in working memory capacity do underlie changes in attentional spread, one would expect more consistent age differences in the literature, with older adults showing differences in the distribution of attention across space (Rolle, Anguera, Skinner, Voytek, & Gazzaley, 2017). Here, similar to Rolle et al. (2017), and Erel and Levy (2016), we believe that one reason for these contradictory findings are the different methods which have previously been used to claim age equivalency in the spatial distribution of attention. Specifically, we believe that these methods may not have been sensitive enough to uncover the potentially subtle, and fine-grained changes in attentional processing across the lifespan.

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A key method utilised to explore the dynamics of visual attention is the spatial-cueing paradigm (Posner, 1980; Posner & Cohen, 1984). Here, attention is oriented via a non-informative peripheral cue to a potential target location. Following this, a target is presented at either the same (valid) or different (invalid) location to the cue. Target detection response times are then compared between validly and invalidly cued locations. When the target is presented shortly after the cue, a facilitation effect is observed, where response times are faster for the validly cued compared to invalidly cued location. However, if the target is presented approximately 300 ms or more following the cue, an inhibitory effect is observed, where target detection response times are comparatively slower. This is labelled Inhibition of Return (IOR), and is theorised to reflect an effective reorienting of visual attention to novel spatial locations (Berlucchi, 2006; Posner, Rafal, Choate, & Vaughan, 1985; Klein & MacInnes, 1999).

The spatial cueing paradigm can be used to quantify attentional spread by measuring the relative change in either facilitation or inhibition surrounding an attended location (e.g. Bennett & Pratt, 2001; Downing, 1988; Klein, Christie, & Morris, 2005; LaBerge, 1983; LaBerge & Brown, 1989). That is, while the strength of attention is strongest at the location of the cue, attentional effects also spread to regions surrounding the cue. This is seen via a change in response time as the spatial disparity between the cued and the target location grows. The gradient change in attention across space can be used to infer attentional spread, and to compare both individual and group differences in spatial attention (for example, see Bennett & Pratt, 2001; Taylor, Chan, Bennett, & Pratt, 2015; Wilson, Lowe, Ruppel, Pratt, & Ferber, 2016). Regression coefficients describing the slope between cue-target distance and reaction time are calculated for population groups. These coefficients are then compared between groups to infer potential differences in the 'roll-off' of attentional resources. A higher value coefficient indicates a steeper rate in the decline of visual attention across space, and therefore, a relatively restricted spread of attention, while a lower value coefficient suggests a comparatively shallower drop off in attention, implying a broader spread of visual attention resources (Wilson et al., 2016).

Although we acknowledge that there is an oculomotor component to IOR, here, we are primarily interested in the attentional component of IOR (e.g. Hunt & Kingstone, 2003; Kingstone & Pratt, 1999). That is, we wish to explore location based IOR patterns when eye movements are restricted. This will allow us to measure a form of IOR more closely related to covert orienting (e.g., see Chica, Taylor, Lupiáñez, & Klein, 2010). Similar work has recently been conducted by Wilson et al. (2016). Here, inhibitory slopes were used to explore potential personality differences in the distribution of attention. They measured the big five personality traits (Neuroticism, Extraversion, Openness, Conscientiousness, and Agreeableness; Digman, 1990), and then correlated these with individual IOR gradients. Importantly, by measuring a form of IOR which emphasised covert attention, the authors were able to equate their results to attentional spread. That is, the slope of IOR was seen as inferring previous preferential attending, and thus, indicative of how attention may have been initially distributed when initially oriented to a cued location. Overall, Wilson and colleagues found that personality traits Openness and Conscientiousness predict IOR slope, where those with higher Openness scores had broader attention, and those with higher conscientiousness scores had narrower attention. This demonstrates how the spatial distribution of IOR can be used to draw inferences about individual and group differences in the spatial spread of attention.

Studies comparing differences in younger and older adult's spread of attention have predominantly found only minimal changes in the gradient of both facilitation and inhibition, regardless of the manipulation of attentional spread, and have concluded that the distribution of attention surrounding a cued region is equivalent with ageing (Hartley et al., 1992; Hartley & Kieley, 1995; Langley et al., 2011). Here, we will focus on analysing previous work which measures age changes in the spread of IOR, as this is the primary measure of interest used in the current study. We have chosen to measure IOR, instead of facilitation, as the longer time course of IOR means that attention can be sufficiently spread around the cued location to measure age differences with a high level of sensitivity (Wilson et al., 2016). Likewise, as Jefferies et al. (2015) have shown that older adults take slightly longer to contract attention, the longer time course of the IOR paradigm seems most appropriate.

To our knowledge, only two studies to date have directly examined the effect of ageing on the spatial distribution of IOR (Hartley & Kieley, 1995; Langley et al., 2011). In both studies, while ageing influenced response times, such that older adults had slower target detection speeds than younger adults, it was concluded that ageing did not influence the distribution of IOR. This conclusion was reached, even though some of the experiments within these studies did in fact, find an age change in response time, as the distance between the cue and target grew (although this finding was not consistent). Given that the spatial spread of IOR can be used to infer the spread of visual attention across space, these mixed findings indicate that the spatial distribution of attention did not reliably vary as a function of age. However, both studies employed a particular methodology, which recent evidence suggests may constrain the spread of attention across space. That is, in both Hartley and Kieley (1995), and Langley et al. (2011), attention was cued via the brightening placeholder boxes (see Fig. 1). Research examining the influence of placeholders on the spatial distribution of inhibition in a younger adult sample suggests that placeholders may limit the bounds that attentional resources spread to in the visual field (Taylor et al., 2015). In other words, the presence versus absence of placeholders can result in qualitatively different effects of visual attention (Hilchey, Pratt, & Christie, 2016; Nicol, Watter, Gray, & Shore, 2009; Taylor et al., 2015). For instance, although not directly comparing attentional slopes, Hilchey et al. (2016) found that the magnitude of IOR is often greater when placeholders are present in the display. Thus, the conclusions of both Langley et al. (2011), and Hartley and Kieley (1995) may not be generalizable to placeholder absent conditions.

More specifically, in Taylor et al. (2015), attention was cued to one of four possible locations, with target detection measured at 121 possible locations. In the placeholder present condition, possible cued locations were drawn and remained on the visual display for the duration of the trial. In the placeholder absent condition, the cue location was presented briefly, and did not remain in the visual display. Crucially, in the placeholder present condition, response times to target detection at placeholder locations were significantly slower compared to target detection outside of placeholder locations, irrespective of the placeholder cued. However, in the placeholder absent condition, response times to target detection decreased as cue-target distance increased, regardless of whether the target fell in one of the four potential cue locations. Thus, placeholder presence markedly influenced the distribution of IOR, such that attention was affixed to the location of the placeholders, lowering the sensitivity of the model to describe the cue-

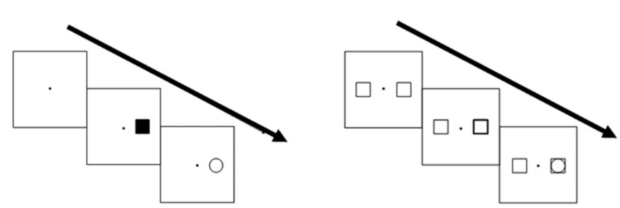

Fig. 1. Placeholder absent (left) and Placeholder present (right) cueing paradigms. In the placeholder absent condition, a transient stimulus, the square, is presented to attract attention. In the placeholder present condition, attention is attracted through the brief brightening of a placeholder box, indicated by the bolded line. In both conditions, the participant's task is to detect the circle as quickly as possible.