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Distractibility with advancing age and Parkinson's disease

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ABSTRACT

Focused attention can be compromised by the neurodegenerative processes associated with both healthy aging and Parkinson's disease (PD). Deficits in ignoring distractors with reflexive or overlearned response links have been attributed to impaired inhibition. The current research assessed whether similar deficits occur for distractors with recently learned arbitrary response associations, for which sensorimotor transformations are far less automatic and therefore considerably easier to resist. We used a selective attention task that evaluated distractibility and the use of distractor inhibition within the same context. The task involved stimuli that were arbitrarily assigned to responses based on a rule learned during the testing session. Performance showed that distraction increased with both healthy aging and PD. Moreover, these increases in distraction were accompanied by decreases in overt evidence of distractor inhibition, which appear to reflect at least in part a failure of reactive inhibition. Comparison of the deficits in the two groups indicates that the key difference reflects severity, rather than distinct symptoms, suggesting that they stem from neural changes associated with both aging and PD. These results demonstrate that aging- and PD-related hyper-distractibility and impaired inhibition during focused attention affect stimuli without prepotent response links, which implicates dopaminergic networks in the strategic control of arbitrary visuomotor transformations.

Impaired visual attention is a major source of disability that adversely affects daily activities in both neurologically healthy aging populations (e.g., Anstey, Wood, Lord, & Walker, 2005; Hoffman, McDowd, Atchley, & Dubinsky, 2005; Richardson & Marottoli, 2003) and in patients with Parkinson's disease (PD, e.g., Stolwyk, Charlton, Triggs, Iansek, & Bradshaw, 2006; Uc et al., 2005, 2007). For example, recent research in older adults indicates that safe driving performance can be predicted by the efficacy of inhibition during a visual attention task (Bedard et al., 2006). Despite the importance of understanding the breakdown of focused attention with advancing age and PD, a number of questions remain regarding the stimulus conditions that lead to hyper-distractibility and the deficient attentional mechanisms involved. In addition, while a number of studies have reported similar selective attention deficits associated with advancing age and PD, because few studies have assessed both, comparisons have had to be made across experiments. Thus, it remains unclear whether advancing age and PD cause distinct symptoms. Overlap in the neurological changes that occur with advancing age and PD could potentially account for common changes in selective attention. In particular, dopaminergic deficits arise with both and have been linked to executive functions, including selective attention (Kaasinen & Rinne, 2002; Volkow et al., 1998).

1. Distractors with prepotent response links: effects of advancing age and PD

Numerous studies have reported hyper-distractibility to stimuli with overlearned and reflexive response links in aging populations and in patients with PD. For example, both groups exhibit difficulty ignoring distracting words during Stroop tests (Aging and PD: Henik, Singh, Beckley, & Rafal, 1993; Aging: Troyer, Leach, & Strauss, 2006), and elderly adults show hyper-distraction to letters during letter reading (Langley, Overmier, Knopman, & Prod'Homme, 1998). In addition, both groups exhibit difficulty suppressing a reflexive eye movement toward a sudden visual onset in the periphery (PD: Chan, Armstrong, Pari, Riopelle, & Munoz, 2005; Aging: Olincy, Ross, Youngd, & Freedman, 1997), inhibiting word reading (PD: Mari-Beffa, Hayes, Machado, & Hindle, 2005; Aging: Troyer et al., 2006) and ignoring spatial information triggered by target location (Aging: Castel, Balota, Hutchison, Logan, & Yap, 2007; PD: Praamstra & Plat, 2001). PD patients also experience difficulty ignoring spatial information triggered by distracting arrows (Praamstra, Stegeman, Cools, & Horstink, 1998). With two exceptions (Langley et al., 1998; Praamstra et al., 1998), these studies attributed the hyper-responsiveness prompted by stimuli with prepotent response links to impaired inhibition.

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Hyper-distractibility could alternatively reflect a deficit in amplifying target-related information (Langley et al., 1998), given that reducing the effects of a distracting stimulus on behavior can be achieved by inhibiting neural activity associated with the distractor or by facilitating neural activity associated with the target (Egner & Hirsch, 2005; Gazzaley, Cooney, McEvoy, Knight, & D'Esposito, 2005; for a discussion see Nieuwenhuis & Yeung, 2005). That is, because both distractor inhibition and target amplification can be used to focus one's attention in the face of distraction, impairment of either mechanism could cause increased distractibility. Interestingly, increased distraction and impaired distractor inhibition have not necessarily co-occurred in aging and PD populations, calling into question the impaired inhibition account of hyper-distractibility. For example, Langley et al. (1998) reported an age-related increase in distraction in the absence of an age-related decline in distractor inhibition, which led these authors to propose that deficits in enhancing target information may underlie age-related deficits in focused attention. Similar claims have been made about focused attention deficits in PD patients by Troche, Trenkwalder, Morelli-Canelo, Gibbons, and Rammsayer (2006), who concluded that the ability to inhibit distracting information remains intact and that PD-related selective attention deficits instead reflect problems with amplifying target information. Thus, the connection between hyper-distractibility and deficits in inhibiting distracting information remains unclear. Nonetheless, for distractors with a reflexive or overlearned response link, sufficient evidence has emerged demonstrating that both advancing age and PD increase distractibility and, at least under some conditions, compromise distractor inhibition.

2. Distractors with arbitrary response links: effects of advancing age and PD

In contrast, the effects of distractors with arbitrary response associations and the capability of aging and parkinsonian brains to inhibit them remain considerably less clear. Given that stimuli with prepotent versus arbitrary response associations differ in terms of both the robustness of their effects (e.g., Henik, Ro, Merrill, Rafal, & Safadi, 1999) and the neural substrates involved in processing them (e.g., Grol, de Lange, Verstraten, Passingham, & Toni, 2006; Murray, Bussey, & Wise, 2000; Toni, Rushworth, & Passingham, 2001; Wise & Murray, 2000), it cannot be assumed that populations exhibiting hyper-distractibility to the former would experience a similar problem to the latter. Logically, it could be the case that deficits in strategically suppressing the influence of stimuli become evident in the context of strong response links, but not in the context of weaker response links due to the relative ease of preventing the visuomotor transformation.

Some focused attention research has reported hyper-distractibility to stimuli with recently learned arbitrary response associations in aging populations (Cerella, 1985, Experiment 3; Zeef & Kok, 1993; Zeef, Sonke, Kok, Buiten, & Kenemans, 1996) but not in patients with PD (Cagigas, Filoteo, Stricker, Rilling, & Friedrich, 2007; Lee, Wild, Hollnagel, & Grafman, 1999). This indicates that the ability to ignore stimuli with arbitrary response links deteriorates with healthy aging but is not affected by PD. The implications of this with regard to inhibiting distractors with arbitrary response associations is that inhibitory deficits may arise with advancing age but not with PD, assuming that the age-related hyper-distractibility reflects a deficit in inhibiting distracting information. As stated above, hyper-distractibility could instead reflect a deficit in amplifying target information (see Langley et al., 1998).

3. Distractors with arbitrary response links: compatibility effects

Exposure to a distractor initially leads to the facilitation of associated processes even when the response-relevant stimulus occurs predictably at fixation and the distractors are positioned in predictable peripheral positions. Consequently, distractor-related compatibility effects emerge. For example, in the context of a task with a small set of targets arbitrarily assigned to specific responses (e.g., press one button if you see one target and press another button if you see another target), as in the classical Eriksen flanker task, viewing a distractor in close temporal proximity to a compatible target reduces response latencies compared to an incompatible target (Eriksen & Eriksen, 1974). The relative reduction in response latencies on compatible compared to incompatible trials will be referred to as a positive compatibility effect. Positive compatibility effects have been attributed to the compatibility of distractor- and target-related neural activity at both early (perceptual) and late (response) levels of processing (Coles, Gratton, Bashore, Eriksen, & Donchin, 1985).

In neurologically healthy young adults, the positive compatibility effect that emerges when a distractor and target appear in close temporal proximity reverses when the distractor precedes the target by several hundred milliseconds (Machado, Wyatt, Devine, & Knight, 2007). This reversal of the compatibility effect can be explained by mounting inhibition of distractor-related activity delaying responses to compatible targets, which produces a negative compatibility effect (i.e., slower responses on compatible trials than incompatible trials). This time-dependent biphasic pattern is consistent with previous reports that inhibition of distracting information can be utilized to reduce distraction and prevent unwarranted responses (e.g., Aron, 2007; Houghton & Tipper, 1996) but it takes time to buildup (Houghton & Tipper, 1996).

4. The current research

The current study used the paradigm reported by Machado et al. (2007) because it enables the assessment of both distractibility and the use of distractor inhibition within a single context. By considering the time course of distraction, we aimed to provide a detailed description of how aging brains and brains with PD deal with distractors that have arbitrary response associations during focused attention. Specifically, with this method, we can provide evidence as to whether any increase in distractibility can be attributed to reduced distractor inhibition. Our experiment used non-verbal stimuli in order to avoid word-related hyper-priming, which has been reported to occur with both advancing age (e.g., Laver, 2000) and PD (reviewed in Mari-Beffa et al., 2005). In addition, the responses involved eye movements, as PD affects the oculomotor system less severely than the skeletomotor system (Bekkering et al., 2001; Kaasinen & Rinne, 2002). We measured the impact of distractor–target compatibility on response latencies as a function of the distractor–target stimulus onset asynchrony (SOA) in order to reveal how the effects of the distractor change across time (see Fig. 1).

In order to assess the effects of aging and PD on distractibility and the use of distractor inhibition, we compared the performance of neurologically healthy young adults, neurologically healthy elderly adults, and elderly adults with PD. In accordance with the pattern of results reported by Machado et al. (2007), we expected the young adults to show a positive compatibility effect at the short distractor–target SOA and a negative compatibility effect at the long distractor–target SOA. The question here was how aging and PD would influence the compatibility effects. Positive compatibility effects provide a measure of distractibility. An enlarged positive