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Differential inter-trial effects in the visual search of children, adolescents, and young adults

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ABSTRACT

We examined the age-related variation in one type of inter-trial effect of visual search, the distractor previewing effect (DPE), in affectively neutral and affectively charged contexts. In Experiment 1, children, adolescents, and young adults were faster to identify the shape of a color target when the color of the current distractors had already been previewed than when the target had been previewed in the preceding target-absent trial, indicative of a color-based DPE. The results revealed a greater DPE in children than in adolescents and young adults, but it can be attributed to children's slower RTs than the other two groups. In Experiment 2, children, adolescents, and young adults were instructed to respond to a schematic face that was different from the other two faces. Young adults were faster in searching for a threatening face among friendly ones when they had previewed a target-absent display consisting of friendly faces than that of threatening faces, indicating an emotional DPE. By contrast, children showed a reversed DPE under the same condition, whereas adolescents showed no DPE. Taken together, these results suggested that the three age groups were all able to create an inhibitory attentional bias on the basis of trial history in affectively neutral context, whereas children and adolescents were not able to create such an inhibitory attentional bias in affectively charged contexts in the same way as adults did. These findings implied that the development of attentional inhibition abilities in affectively charged contexts might be delayed compared to those in affectively neutral contexts.

1. Introduction

As an integral part of executive function, inhibitory control refers to the ability to resist temptations, distraction, or interference (Diamond, 2013). Inhibitory control abilities are crucial for both cognitive and socio-emotional development across lifespan (Zelazo, 2015), and deficiency in inhibitory control is associated with many developmental disorders, such as attention-deficit and hyperactivity disorders (ADHD), or autism (e.g., Geurts, van der Oord, & Crone, 2006; Ozonoff & Strayer, 1997).

1.1. Age-related development of inhibitory control

Inhibitory control abilities in childhood are associated not only with academic performance (Clark, Pritchard, & Woodward, 2010; Kim, Nordling, Yoon, Boldt, & Kochanska, 2013), but also with behavioral, cognitive, social, and emotional competencies (Garon, Bryson, & Smith, 2018). The development of inhibitory control is also important for adolescence, as the transition from childhood to adulthood requires refinement of both social and cognitive skills (Nelson, Leibenluft, McClure, & Pine, 2005). Adolescents are increasingly able to withhold their impulsive responses (Cohen-Gilbert & Thomas, 2013; Johnstone, Pleffer, Barry, Clarke, & Smith, 2005), and such improvement in inhibitory control might be attributed to maturation of prefrontal cortex (Luna, Padmanabhan, & O'Hearn, 2010).

Based on the emotionality of the contexts, inhibitory control can be classified into “cold” inhibitory control functioning in affectively neutral contexts or “hot” inhibitory control functioning in affectively charged contexts (Zelazo & Carlson, 2012). Previous studies have consistently shown that cold inhibitory control abilities develop linearly with age increase from childhood to adulthood, in a faster speed than hot inhibitory control (Carlson, 2005; Prencipe et al., 2011). By contrast, there has been mixed evidence regarding the developmental pattern of hot inhibitory control. Some studies have shown that hot inhibitory control abilities also develop linearly, indexed by increasingly better control from childhood, adolescence, to adulthood (Schel & Crone, 2013; Tottenham, Hare, & Casey, 2011); whereas other studies revealed a quadratic pattern, evidenced by that adolescents exhibited

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worse hot inhibitory control abilities than both children and adults (Aïte et al., 2018; Hare et al., 2008; Somerville, Hare, & Casey, 2011).

Numerous developmental studies of hot inhibitory control were conducted using the Go/Nogo task in which participants responded to certain stimuli but inhibited responding to other stimuli (Hare et al., 2008; Schel & Crone, 2013; Somerville et al., 2011; Tottenham et al., 2011). Therefore, these studies focused more on one component of inhibitory control, i.e., response inhibition which refers to the ability to refrain from prepotent responses (Luna et al., 2010). By contrast, the term of attentional inhibition often refers to the ability to suppress cognitive processing and to ignore task-irrelevant features (Howard, Johnson, & Pascual-Leone, 2014). The age-related development in attentional inhibition is often investigated using either the Negative Priming paradigm in which participants were slower to respond to previously ignored stimuli than to previously attended or non-previewed stimuli (Frings, Feix, Röthig, Brüser, & Junge, 2007; Pritchard & Neumann, 2004; Simone & McCormick, 1999), or the Inhibition of Return paradigm in which participants were slower to respond to targets at previously attended locations (MacPherson, Klein, & Moore, 2003). However, to our best knowledge, very few studies have examined and compared the development patterns of attentional inhibition in affectively neutral and charged contexts in one study. In order to do so, one type of inter-trial effects in visual search, the distractor-previewing effect (DPE), might be a powerful tool.

1.2. The distractor-previewing effect

A typical DPE refers to the result pattern that participants identified the shape of a color oddball (target) more rapidly when the distractor color was the same as the color of all items in the preceding target-absent trial, compared to when the current target shared the same color as those in the preceding target-absent trial (Ariga & Kawahara, 2004; Goolsby, Grabowecky, & Suzuki, 2005). For example, identifying the shape of a red target among green distractors (see Fig. 1 for illustrations) is faster when the preceding target-absent display consists of green items (distractor-previewed condition) than when it consists of red items (target-previewed condition).

The DPE is not due to response inhibition, as this effect was not influenced by whether a response was executed on the target-absent trials (Lleras, Kawahara, Wan, & Ariga, 2008). In an event-related potential (ERP) study, Shin, Wan, Fabiani, Gratton, and Lleras (2008) found no correlation between the DPE and an electrophysiological marker of response preparation process, the Lateralized Readiness Potential (LRP). The DPE reflects inhibition of focused attention, which might be considered as a "feature" analog to attentional inhibition in the spatial domain (Lleras et al., 2008). For example, Inhibition of Return might reflect a bias not to focus attention on "failed" and "rejected" locations on which participants previously attended but did not find a target (Klein, 2000). Similarly, the DPE reflects a bias not to focus attention on "failed" and "rejected" feature that participants previously viewed (on the preceding target-absent trial) but failed to find a color oddball. Specifically, being unable to find a target on a target-absent trial might create an inhibitory attentional bias against selecting the feature that participants have viewed on a target-absent trial on the following target-present trial (Levinthal & Lleras, 2008; Wan & Lleras, 2010). Such an attentional inhibition in the DPE is evidenced by smaller and delayed N2pc component, a psychophysiological index of attention (Shin et al., 2008; Shin & Bartholow, 2013; Shin & Chong, 2016), as well as by longer saccadic latencies to the target and less accurate saccades in the target-previewed condition (Caddigan & Lleras, 2010).

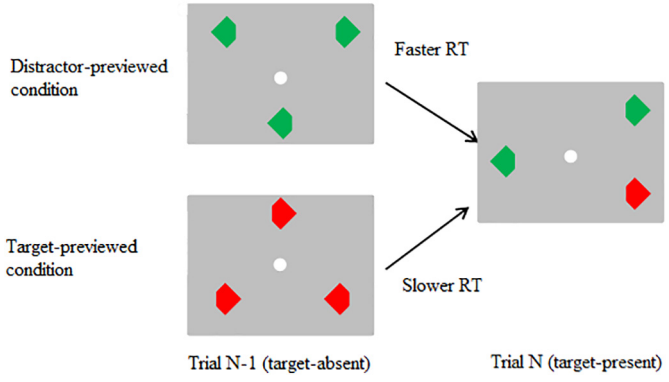

Fig. 1. An illustration of the DPE in color-based search. The experimental task is to find the diamond shape which has a different color from the other two items and then to identify whether the left or right corner of this target is missing.

In addition to feature-based searches as illustrated in Fig. 1, the DPE has also been observed with young adults' category-based searches among house/face categories (Lleras, Kawahara, & Levinthal, 2009), or among pictures expressing different emotions (namely the emotional DPE, Mu & Wan, 2014). Similarly, older adults have also shown the DPE categories in visual search for color oddballs (Wan, Voss, & Lleras, 2011) and for negatively valenced faces (Wan, Tian, & Lleras, 2014). Specifically, Wan and colleagues (2011) found that older adults even showed a greater color-based DPE than young adults, but such an enlarged DPE with older adults was proportional to the increase in their overall RTs. In Wan et al.'s (2014) study, young and older adults searched for a unique face among a set of three schematic faces of emotions and identified the location of a red dot adjacent to the target. Both age groups were faster in searching for a negative face among neutral faces after they had previewed a display of neutral faces than after they had previewed negative faces, indicative of an emotional DPE. Collectively, the findings of these two studies suggested that adults' ability to guide attention away from previously "failed" and "rejected" feature or category is well preserved in older adults, implying that attentional inhibition abilities in affectively neutral and charged contexts might be intact till late adulthood. Unfortunately, to our best knowledge, it remains unclear whether children and adolescents are also able to show the DPE pattern in affectively neutral or charged contexts.

1.3. The present study

In the present study, we aimed to compare the color-based and emotion-based DPEs in children, adolescents, and young adults, and to examine age-related variation in cool inhibitory control in affectively neutral contexts and hot inhibitory control in affectively charged contexts, respectively. Two questions were addressed in two experiments, respectively.

The first question is about whether children and adolescents are able to create an attentional inhibition in affectively neutral contexts, indexed by the color-based DPE. We expected to observe significant color-based DPEs in children and adolescents for two reasons. First, previous research on the Contextual Cueing effect have suggested that young children are able to learn from recent trial history of visual search, evidenced by that being repeated exposed to the same arrangement of random items could guide children's attention and facilitate their visual search (Couperus, Hunt, Nelson, & Thomas, 2011; Darby, Burling, & Yoshida, 2014; Dixon, Zelazo, & De Rosa, 2010; Merrill, Conners, Roskos, Klinger, & Klinger, 2013). For example, when repeatedly performing visual search tasks, 9- and 10-year-old children were able to learn to use the identity and location of the distracting items to predict the location of the target (Yang & Merrill, 2018), suggesting that they were able to learn from recent visual search experience to guide attention. Second, typically developing children showed no deficits in attentional inhibition in affectively neutral contexts, evidence by that both the Negative Priming (Frings et al., 2007; Pritchard & Neumann, 2004; Simone & McCormick, 1999) and Inhibition of Return with neutral stimuli were observed in children