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Selective attention relates to the development of executive functions in 2,5- to 3-year-olds: A longitudinal study

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ABSTRACT

To study the central role of selective attention in the early development of executive functions (EFs), longitudinal relationships between selective attention, working memory, and simple response inhibition were explored. Selective attention, working memory, and simple response inhibition were assessed twice in our preschool sample (N = 273), which included a relatively large number of children from low SES families. The tasks were administered between age 2.5 (time 1) and 3 years (time 2). An analytical path model was tested to analyse the relationships simultaneously. The results indicate that selective attention at age 2.5 years predicts working memory and response inhibition at age 3 years. Controlling for gender, SES, home language, verbal ability, and age did not affect the strengths of these relationships.

1. Introduction

Executive Functions (EFs) refer to cognitive control processes aimed at regulating, organizing, and planning behaviour (Diamond & Lee, 2011) and have been found to be linked to good academic performance, good social skills, less criminal activity rates, and low substance abuse, or to overall success in life (Diamond, Barnett, Thomas, & Munro, 2007; Moffitt et al., 2011). Given the predictive validity of EF measures for such a wide range of developmental outcomes, EFs have increasingly become a focus point for early interventions. To target such interventions most optimally, it is essential that Executive Function (EF) development and its underlying factors are understood. However, although research on EF development at preschool age and beyond is flourishing, much less is known about EF development before the age of 3 years. Selective attention, or the ability to focus on a specific stimulus and to ignore other stimuli or distractors (Atkinson & Braddick, 2012; Mahone & Schneider, 2012; Plude, Enns, & Brodeur, 1994), has been hypothesized to constitute one of the core building blocks in infancy and toddlerhood on which (complex) EFs build as children grow older (Garon, Bryson, & Smith, 2008; Hendry, Jones, & Charman, 2016). Recent studies have indeed shown that measures of attention in infancy are predictive of EF in toddlerhood (Holmboe, Fearon, Csibra, Tucker, & Johnson, 2008; Johansson, Marciszko, Brocki, & Bohlin, 2015; Johansson, Marciszko, Gredebäck, Nyström, & Bohlin, 2015; Kochanska, Murray, & Harlan, 2000), providing initial evidence for the developmental model proposed by Garon et al. (2008) and Hendry, Jones, and Charman (2016). However, these previous studies were mostly small-sample laboratory studies with highly selective (i.e., high SES) groups of participants. As such, it is currently unknown whether results can be generalized to a wider population (including low SES children), and whether measures of selective attention remain of predictive value for EF development when assessed beyond infancy. This is particularly important, as intervention efforts aimed at boosting EF development, such as preschool remediation programmes, are likely to be targeted at low SES and/or immigrant children, and children often do not enroll into such programmes until some point during the 3rd year of life (for example, Department for Education, 2016; Government of the Netherlands, n.d.; U.S. Department of Health and Human Services, 2016). Therefore, the current study set out to investigate whether individual differences in selective attention at age 2.5 years, at a time when development of EF is particularly rapid (Gerardi-Caulton, 2000; Rueda, Posner, & Rothbart, 2005), predict EF at age 3 years in a large and heterogeneous sample. To this end, we used a previously validated battery of EF measures suitable for field-based assessment, focusing on core and relatively early emerging aspects of EF: inhibitory control and working memory (Mulder, Hoofs, Verhagen, Van der Veen, & Leseman, 2014). In the next sections, we first describe the general tenet of the hierarchical model of EF development, followed by

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a brief overview of current evidence regarding the relation between selective attention and early EF development.

1.1. Development of EFs

A number of researchers (e.g., Bull, Espy, & Wiebe, 2008; Davidson, Amso, Anderson, & Diamond, 2006; Miyake, Friedman, Emerson, Witzki, & Howerter, 2000) agree that EF comprises three basic interrelated cognitive processes, namely: updating of information in *working memory*, *inhibition* of responses, and *shifting* of attention sets or response sets. The hierarchical model of EF development postulates that there is a certain ordering in the development of these skills, with relatively simple and more basic EF skills providing the foundation on which more complex skills are built (Garon et al., 2008), as will be briefly reviewed below.

1.1.1. Working memory

A few days after birth, infants already demonstrate recognition memory, for example, the recognition of faces (Slater & Quinn, 2001). The ability to store and retrieve information over relatively short periods of time can be referred to as short-term memory (Astle & Scerif, 2011; Diamond, 2013). Memory span – the amount of visuospatial or phonological information that can be immediately recalled when it has been presented once – increases with age across childhood (Howard & Polich, 1985). *Working memory* involves both storing incoming visual or auditory information for brief periods of time, and actively performing cognitive operations on that information, such as updating or manipulation (Baddeley, 2003; Engel de Abreu, Conway, & Gathercole, 2010). As such, by definition, working memory relies on short-term memory. Working memory improves with age, from infancy through to adolescence and young adulthood (Diamond, Prevor, Callender, & Druin, 1997; Garon et al., 2008; Huizinga, Dolan, & Van der Molen, 2006).

1.1.2. Inhibition

Similarly, simple response inhibition, or the ability to refrain from acting on impulse, precedes development of more complex forms of inhibition (Garon et al., 2008). Simple response inhibition involves the suppression of a dominant response (Kochanska et al., 2000; Van der Ven, Kroesbergen, Boom, & Leseman, 2012). One example is the ability to delay gratification, where the dominant response – giving in to the temptation – has to be suppressed. Simple response inhibition improves gradually with age (for example, from 22 to 33 months: Kochanska et al., 2000; and from 33 months to 66 months: Kochanska, Murray, & Coy, 1997). Carlson (2005) also showed that the percentage of children who passed a simple response inhibition task (such as *gift delay*) increased significantly with age (from the age of 3 years to the age of 5 years). Complex response inhibition implies that children not only suppress their primary response but also replace it by a subdominant behaviour (Karreman, Van Tuijl, Van Aken, & Deković, 2008). This requires children to remember and initiate the appropriate behaviour. Thus, in complex response inhibition, not only inhibition but also working memory is important. Like simple response inhibition, complex response inhibition improves with age. For example, Carlson (2005) showed that the percentage of children who passed a complex inhibition task (Stroop tasks such as “Grass/Snow” and “Bear/Dragon”) increased significantly from the age of 3 years to the age of 5 years.

1.1.3. Shifting

Shifting involves the ability to change flexibly between different tasks or between using different rules within the same task (Miyake et al., 2000). Shifting involves both working memory and inhibitory control processes (Blakey, Visser, & Caroll, 2016). Due to this relatively high level of complexity, children do not start to pass standard shifting tasks such as the Dimensional Card Sorting Task until after age 3 years (Zelazo, 2006). Although recent studies have started to include more basic shifting tasks for younger children too (for an overview, see Garon et al., 2008), these involve primarily lab-based measures which cannot easily be applied in field-based research. Similarly, at the time of the design of the current study, complex inhibition measures suitable for large-scale field-based research in toddlerhood were not available. As such, the current study is focused on the two core aspects of early EF: working memory and simple response inhibition.

1.2. Attention as foundation for EF development

The first 3 years of life are marked by rapid development of the ability to selectively attend to stimuli and ignore distracting information (Gerhardstein & Rovee-Collier, 2002; Scerif, Cornish, Wilding, Driver, & Karmiloff-Smith, 2004; Posner & Rothbart, 2007), and individual differences appear to be, at least partly, stable over time from the second half of the first year of life to 2.5 years of age (Kannass, Oakes, & Shaddy, 2006). In their developmental models, Garon et al. (2008) and Hendry et al. (2016) suggest that attention, and selective attention in particular, may provide one of the first ‘building blocks’ for, or precursors to, emerging EF, such as working memory and inhibitory control. Subsequently, across childhood and beyond, selective attention is assumed to continue to play a direct and important role in EF task performance (cf. Hendry et al., 2016), as regulating, organizing, and planning behaviour all involve attention.

A few longitudinal studies have shown that individual differences in infant selective attention predict EFs in toddlerhood. First, significant predictive relations from attention assessed in infancy to inhibitory control and working memory in toddlerhood have been observed (Holmboe et al., 2008; Johansson, Marciszko, Gredebäck et al., 2015). Moreover, Johansson, Marciszko, Brocki et al. (2015) found that infant attention predicted working memory at age 3 years. However, these studies all included small and mostly selected high SES samples with laboratory assessments. One exception is a study by Kochanska et al. (2000), which showed that observed attention in infancy predicted performance on a battery of inhibitory control measures at 22, but not 33 months in a sample of mixed SES backgrounds. Thus, there is converging evidence that infant attention serves as one of the core building blocks of emerging EF. However, replication in large heterogeneous samples is needed, and it is currently unclear whether selective attention remains a unique predictor of EF development when assessed beyond infancy. The present study aimed to address these issues, by studying if and how selective attention predicts EFs towards the beginning of the preschool period, including a large and diverse sample. Specifically, predictive relations from selective attention at age 2.5 years (time 1) to working memory and inhibitory control 6 months later, at age 3 years (time 2) were studied. Before turning to the goals of the present study, the theoretical rationale, including underlying mechanisms linking selective attention and EF, will be discussed. Furthermore, experimental work with older children and adults which provides evidence regarding the underlying mechanisms through which selective attention and EFs are linked, will be described.

1.3. Underlying mechanisms linking selective attention and EF

The central underlying mechanism linking selective attention and EFs is that an important function of selective attention is the ability to resolve conflicts among thoughts, feelings, and responses, whereas resolving conflicts is crucial for EF performance as well (Garon et al., 2008; Posner & Rothbart, 2007). Hence, orienting on relevant stimuli while ignoring other (possibly very attractive but,) irrelevant stimuli increases both working memory performance and inhibitory control. In addition, selective attentional orienting has been shown to aid in regulating and controlling emotions in young children (Harman, Rothbart, & Posner, 1997; Posner, Rothbart, Sheese, & Voelker, 2012; Rothbart, Sheese, Rueda, & Posner, 2011).

With regard to working memory, selective and focused attention is