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Development of hot and cool executive functions in middle childhood: Three-year growth curves of decision making and working memory updating

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ABSTRACT

Although middle childhood is an important period for the development of hot and cool executive functions (EFs), longitudinal studies investigating trajectories of childhood EF development are still limited and little is known about predictors for individual developmental trajectories. The current study examined the development of two typical facets of cool and hot EFs over a 3-year period during middle childhood, comparing younger (6- and 7-year-olds at the first wave [T1]; $n = 621$) and older (8- and 9-year-olds at T1; $n = 975$) cohort of children. "Cool" working memory updating (WM) was assessed using a backward digit span task, and "hot" decision making (DM) was assessed using a child variant of the Iowa Gambling Task. Linear latent growth curve analyses revealed evidence for developmental growth as well as interindividual variance in the initial level and rate of change in both EF facets. Initial level of WM was positively associated with age (both between and within cohorts), socioeconomic status, verbal ability, and processing speed, whereas initial levels of DM were, in addition to a (potentially age-related) cohort effect, exclusively predicted by gender, with boys outperforming girls. None of the variables predicted the rate of change, that is, the developmental trajectories. However, younger children, as compared with older children, had slightly steeper WM growth curves over time, hinting at a leveling off in the development of WM during middle childhood. In sum, these data add important evidence to the understanding of hot and cool EF development during middle childhood.

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Introduction

Executive functions (EFs), a set of cognitive skills necessary for goal-directed behavior and self-control, are correlates and predictors of a large range of social and cognitive developmental outcomes over the lifespan (Best, Miller, & Jones, 2009; Hughes & Ensor, 2011; Moffitt et al., 2011). The most prominent and most extensively studied developmental period for EFs is preschool age (Carlson, Zelazo, & Faja, 2013). However, EF performance shows medium to large age-related increases during middle childhood (between 5 and 11 years; Romine & Reynolds, 2005). Age-related increases then become smaller from 11 to 14 years, but there is consensus that EF development continues throughout adolescence (Hughes, 2011). Different facets of EFs, such as inhibitory control, flexibility, and working memory updating (WM), seem to follow distinct developmental trajectories (Best & Miller, 2010; Hughes, 2011). Furthermore, it has been suggested that "hot" EFs (which are needed in situations that elicit emotion, motivation, or a conflict between immediate reward and long-term goals) show a more decelerated development during childhood than "cool" EFs (which support goal-directed behavior under relatively decontextualized, nonemotional conditions; Peterson & Welsh, 2014; Prencipe et al., 2011). Given the importance of EFs for children's cognitive and social functioning, it is crucial to understand how EFs develop and to identify predictors for the course of individual EF development during middle childhood, which is a period of increased self-regulatory demands (Otero & Barker, 2014). In the current study, we used growth curve modeling to tackle these questions and to examine developmental trajectories of one hot EF facet and one cool EF facet across a 3-year period, comparing younger and older age cohorts (ages at the first wave [T1] = 6–7 and 8–9 years, respectively).

Development of cool working memory updating

Cool EFs have often been operationalized following a tripartite structure using measures of inhibitory control, flexibility, and WM (Miyake et al., 2000). Whereas in preschoolers a unitary EF factor was frequently found to be the best fitting model, differentiation of EF facets seems to increase during childhood. In school-aged children, at least two distinct cool EF components can be found, namely flexibility (or set shifting) and WM (Carlson et al., 2013). Unlike simple working memory tasks that merely require the maintenance of information (e.g., forward digit span), executive working memory tasks (e.g., backward digit span) call for maintenance and manipulation of information (Best & Miller, 2010). Childhood development of WM has been studied mainly using cross-sectional designs (Carlson et al., 2013). For example, in a cross-sectional study with four age groups from 7-year-olds to young adults, WM capacity increased until the age of 15 years, followed by stabilization, whereas an inhibitory component of the task showed increased capacity until young adulthood (Carriedo, Corral, Montoro, Herrero, & Rucián, 2016). In the same vein, Best and Miller (2010) concluded in their review of EF development that most studies including large age ranges suggest linear WM development from preschool throughout adolescence.

However, there is also evidence for nonlinear WM development during middle childhood. Using a cross-sectional approach in 6- to 13-year-olds, Brocki and Bohlin (2004) found small improvements for a combined factor of WM and verbal fluency across the examined age range, with developmental spurts occurring around the ages of 8 and 12 years. Discontinuities in WM development, albeit with a different time course, also appeared in a 2-year longitudinal study using the backward color recall task, an analogue of the backward digit span (Röthlisberger, Neuenschwander, Cimeli, & Roebers, 2013). Here, large WM improvements were found in the younger cohort (starting in prekindergarten) and a slight leveling off was found in the older cohort (starting in kindergarten). To sum up, the cool EF facet WM develops throughout childhood and adolescence. Some evidence (Brocki & Bohlin, 2004; Röthlisberger et al., 2013) suggests developmental spurts at certain age periods during middle childhood, but because the findings are somewhat inconsistent, we aimed at thoroughly elucidating WM development during middle childhood by using a 3-year longitudinal design with three measurement waves and by comparison of two age cohorts.