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Cool versus hot executive function: A new approach to executive function

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Abstract

Executive function (EF) refers to the higher order thought processes, including inhibitory control, working memory, and attention considered essential to problem-solving and future oriented behaviour. Traditionally, research on EF has focused on cool cognitive aspects, elicited by relatively abstract tasks. More recently there has been growing interest in the development of hot aspects of EF, seen in situations that are emotionally and motivationally significant. In this paper, we first describe the emergence of hot executive function and its distinction to cool executive function. We then examine whether there is enough evidence to support distinct cool and hot EF subcomponents. The implications of how this distinction can be used to make sense of abnormal child development are also considered. We propose that more research in this area will increase understanding of how cognitive development affects development and inform more targeted interventions in children with behavioural difficulties.

Keywords: Executive function, emotions, motivation, child development

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Introduction

Executive Function (EF) refers to a set of goal-directed, future-orientated cognitive skills that are essential for adaptive behaviour, including the ability to organise oneself, problem solve and social behaviour (Anderson, 1998). Although the organisation of EF is debated, it is generally agreed that EF encompasses skills such as inhibitory control, cognitive flexibility and working memory (Miyake et al., 2000). Traditionally EF has been viewed through a purely cognitive lens, meaning the role of emotion and motivation in EF has largely been neglected. Indeed, perspectives, theories and assessments of EF have historically focussed on purely cognitive skills that are elicited under relatively abstract, decontextualized, non-affective conditions (Peterson & Welsh, 2014). Over the past decade, there has been a rising interest in the role of motivation and affect in EF, leading researchers to pay greater attention to the role of EF in emotionally charged and social situations. This broader conceptualisation of EF has important implications for research into child development because EF has been found to be a strong predictor of school readiness, academic achievement and social behaviour (Brock, Rimm-Kaufman, Nathanson, & Grimm, 2009; Jacobson, Williford, & Pianta, 2011).

The Emergence of Hot Executive Function

The movement away from a purely cognitive conceptualisation of EF can be largely credited to the work of Zelazo and Müller. In 2002 these authors published a paper which proposed that EF varies according to the motivational significance of a situation. They outlined a distinction between cool EF: evoked under relatively abstract, non-affective situations, and hot EF: evoked under motivationally significant, affective conditions (Zelazo & Carlson, 2012; Zelazo & Müller, 2002). When confronted with an affective or personally meaningful problem that an individual is motivated to solve, the affective, hot aspects of EF are most likely to be elicited. Thus, hot EF, as opposed to cool EF, is elicited when people care about the problem they are attempting to

solve, such as problems in the domain of self and social understanding (Zelazo et al., 2005). Indeed, hot EF has been found to be associated with the orbitofrontal cortex and ventromedial regions, two largely overlapping brain regions that are strongly connected to limbic areas, which are associated with emotional and social processing (Happaney, Zelazo, & Stuss, 2004). Whereas research into the organisation and development of cool EF is vast, research into hot EF is only around a decade old and consequently understanding of hot EF lags behind (Peterson & Welsh, 2014).

The organisation of cool EF is better understood than the organisation of hot EF. Cool EF refers to the cognitive skills traditionally perceived to encompass EF, including inhibitory control, working memory and cognitive flexibility when used in affectively neutral situations (Zelazo & Müller, 2002). In contrast, hot EF has been posited to include affective cognitive abilities, such as the ability to delay gratification and affective decision making. However, there is some contradiction in the literature regarding the composition of hot EF. While some researchers have proposed that social-cognitive abilities, such as theory of mind, emotional intelligence and moral judgement, should be included under the umbrella of hot EF (e.g Anderson, Anderson, Jacobs, & Spencer-Smith, 2008), others have suggested that the manifestation of these abilities is closely associated with, but not actually, hot EF (e.g Zelazo, Qu, & Müller, 2005). Further research in this area would therefore be valuable.

This broader conceptualisation of EF as including cool and hot components has important implications for research into typical and atypical development. The distinction between cool and hot EF has the potential to inform research regarding the role of EF in clinical disorders as EF deficits have been found in a variety of childhood disorders, including autism and ADHD (Hill, 2004; Hughes, Dunn, & White, 1998). Zelazo and Müller (2002) suggested that whereas autism may be characterised by primary deficits in hot EF with secondary impairments in cool EF, ADHD may have the opposite profile. In addition, cool and hot EF has been found to be differently implicated in children's academic and social development. Cool EF has been found to be more strongly associated with children's academic achievement, while hot EF has been found to be more strongly implicated in children's disruptive and social behaviour (Brocki, Nyberg, Thorell, & Bohlin, 2007; Garner & Waajid, 2012; Willoughby, Kupersmidt, Voegler-Lee, & Bryant, 2011). Further researchinto the role of cool and hot EF in children's development therefore has the potential to shed new light on typical and atypical development. However, it is important to bear in mind that although a distinction has been made between cool and hot EF, they are proposed to be part of a coordinated system in which they typically work together (Zelazo & Carlson, 2012). Indeed, a common method of solving hot, motivationally significant problems is to reflect upon the problem, reconceptualise the problem in a more neutral, decontextualized way and try to solve it using cool EF (Zelazo & Cunningham, 2007).

Is there Support for Independent Cool and Hot EF Constructs

Emerging research investigating whether there is support for distinct cool and hot EF constructs has found contradictory results. Hongwanishkul et al. (2005) examined the development of cool and hot EF in children 3 to 5 years of age and found that development across the two domains did not substantially differ; with both cool and hot EF exhibiting similar levels or improvements after 3 years of age. This does not support the view of separate constructs, with distinct developmental paths. Furthermore, after controlling for age and intelligence, performance on cool EF tasks was correlated with performance on hot EF tasks. Further research has also found that children's performance on cool and hot tasks was moderately positively correlated (Willoughby et al., 2011). This does not provide strong evidence for distinct cool and hot EF constructs.

More recent research has used factor analysis to explore whether a distinction between cool and hot EF can be identified. While some research has found weak support for a two factor model including cool and hot dimensions in children (Masten et al., 2012), other research has found that a two factor model fitted children's EF abilities better than a one factor model (Willoughby et al., 2011). A recent study which explored whether a one or two factor model best accounted for children's (3 - 6 years of age) inhibition under conditions of varying motivational significance found that there was no significant difference between the one factor and two factor model (Allan & Lonigan, 2014). Both models provided a good fit to the data. The researchers concluded that a one factor model was the best fitting model based on parsimony. This study, however, examined only one subcomponent of EF: inhibition. An important focus for future research, therefore, is to explore whether there is evidence to support distinct cool and hot EF subcomponents.

Conclusions and Future Directions

The emergence of hot EF has therefore paved the way for a broader conceptualisation of EF that takes into consideration the motivational and affective elements of

EF. The distinction between cool and hot EF encourages researchers to consider the role of EF in everyday decision making and problem solving that rarely occurs in the absence of motivational or emotional consequences. This distinction may also shed new light on child development. However, research into hot EF lags behind that of cool EF; leaving many unanswered questions regarding hot EF. In particular the development and organisation of hot EF is poorly understood in comparison to cool EF. Considering the role of hot as well as cool EF in developmental research has the potential to highlight different EF profiles in typical and atypically developing children. This will ultimately increase understanding of child development and inform interventions. It is hoped that this line of research will increase understanding of how cognitive development affects social development and inform more targeted interventions.

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