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Conflict processing in kindergarten children: New evidence from distribution analyses reveals the dynamics of incorrect response activation and suppression

Solène Ambrosi[a], Mathieu Servant[b,c], Agnès Blaye[a,1], Boris Burle[b,*,1]

[a] Laboratoire de Psychologie Cognitive, Aix-Marseille Univ, CNRS, LPC, UMR 7290, 13331 Marseille, France
[b] Laboratoire de Neurosciences Cognitives, Aix-Marseille Univ, CNRS, LNC, UMR 7291, 13331 Marseille, France
[c] Department of Psychology, Vanderbilt University, Nashville, TN 37203, USA

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ABSTRACT

The development of cognitive control is known to follow a long and protracted development. However, whether the interference effect in conflict tasks in children would entail the same core processes as in adults, namely an automatic activation of incorrect response and its subsequent suppression, remains an open question. We applied distributional analyses to reaction times and accuracy of 5- and 6-year-old children performing three conflict tasks (flanker, Simon, and Stroop) in a within-participants design. This revealed both strong commonalities and differences between children and adults. As in adults, fast responses were more error prone than slow ones on incompatible trials, indicating a fast "automatic" activation of the incorrect response. In addition, the strength of this activation differed across tasks, following a pattern similar to that of adults. Moreover, modeling the data with a drift diffusion model adapted for conflict tasks allowed one to better assess the origin of the typical slowing down observed in children. Besides showing that advanced distribution analyses can be successfully applied to children, the current results support the notion that interference effects in 5- and 6-year-olds are driven by mechanisms very similar to the ones at play in adults but with different time courses.

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* Corresponding author.
E-mail address: boris.burle@univ-amu.fr (B. Burle).

[1] Shared last authorship.

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Introduction

Cognitive control refers to a set of higher cognitive functions that regulate behavior to ensure goal attainment. Recent studies have revealed that the efficiency of cognitive control during childhood can predict individual differences in many domains of cognitive development such as early language ability and theory of mind but also in academic achievement such as mathematics (Bull & Lee, 2014) and literacy (Colé, Duncan, & Blaye, 2014; see Diamond, 2013, 2014, for reviews). More generally, cognitive control proved to be more strongly correlated with school readiness than is IQ (e.g., Blair & Razza, 2007), and its efficiency during childhood revealed one of the best predictors of health and employment at adult age (Daly, Delaney, Egan, & Baumeister, 2015; Moffitt et al., 2011). The broad relevance of cognitive control in children stresses the importance of understanding its development.

Cognitive control in adults is often investigated through so-called "conflict tasks" such as the Stroop (Stroop, 1935), flanker (Eriksen & Eriksen, 1974), and Simon (Simon, 1990) tasks. Although those three tasks differ in some respects (see Kornblum, Hasbroucq, & Osman, 1990), they share a common structure where stimuli are composed of two dimensions; one dimension is relevant for the task and determines the correct response, whereas the second one, irrelevant for the task, shares common features with the stimulus or response sets. In the Stroop task, participants are requested to name the color of a written word. The word can be compatible with its color (e.g., "red" written in red) or incompatible (e.g., "green" written in red). In a standard version of the flanker task, participants must issue a right- or left-hand response as a function of the nature of a central letter (e.g., "H" or "S") flanked by distractors that can be a replication of the target (e.g., "HHH"–compatible trials) or a replication of the alternative target (e.g., "SHS"–incompatible trials). In the Simon task, a lateralized response is required to a nonspatial dimension (e.g., color) of stimuli that are presented either on the same side as the requested response (compatible trials) or on the opposite side (incompatible trials). In all those tasks, one usually assumes that the stimuli are processed along two parallel routes: a "fast" one, processing the irrelevant dimension in an automatic way, and a slower one, processing the relevant dimension in a more controlled way. On incompatible trials the irrelevant dimension tends to activate the incorrect response, which then needs to be suppressed to produce the correct response, whereas on compatible trials both the relevant and irrelevant dimensions lead to the same correct response. Worse performance (longer reaction time [RT] and higher error rate) on incompatible trials as compared with compatible ones indexes the interference effect induced by the irrelevant dimension on the processing of the relevant one.

Child-adapted versions of those tasks have been used to assess interference processing even in very young children ($\sim$3 or 4 years of age) (e.g., Davidson, Amso, Anderson, & Diamond, 2006; Gerstadt, Hong, & Diamond, 1994; Ikeda, Okuzumi, & Kokubun, 2013, 2014; Prevor & Diamond, 2005; Rueda et al., 2004; Wright, Waterman, Prescott, & Murdoch-Eaton, 2003). Developmental studies suggest long and protracted development of cognitive control (e.g., Cao et al., 2013; Luna & Sweeney, 2004; Macdonald, Beauchamp, Crigan, & Anderson, 2014; Prevor & Diamond, 2005; Ridderinkhof, van der Molen, Band, & Bashore, 1997), likely sustained by a late maturation of neural networks engaged in conflict resolution (see, e.g., Abundis-Gutiérrez, Checa, Castellanos, & Rosario Rueda, 2014; Durston & Casey, 2006; Rueda et al., 2004). These studies globally show decreased interference effects with age. However, interference effects have been evaluated with summary statistics blind to the dynamics of the interference effects and, hence, to the underlying processes. Indeed, during the past few years, there has been growing evidences that the mean RT and error rate provide incomplete information. More specifically, RT distributions are not normally distributed but instead have a characteristic heavy right tail. Analyzing the shape of the RT distributions can provide essential information. This can be done in different ways that are briefly summarized below. A first type of analysis consists in fitting statistical non-Gaussian distributions to the acquired data. Different theoretical distributions have been used such as the log-normal (Ulrich & Miller, 1993), ex-Gaussian (Burbeck & Luce, 1982; Hohle, 1965), gamma (McGill & Gibbon, 1965), and Weibull (Logan, 1988) distributions. After having fitted the chosen distribution, one can then average the parameters across participants and create an "average" distribution representative of all the participants. Software programs to fit such distribu-