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Perceptual–motor constraints on decision making: The case of the manual search behavior for hidden objects in toddlers

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ABSTRACT

In the C-not-B task, 2.5-year-old children tend to look for an object in a location to which the hiding agent moved his hand (C) after moving an object from A to B. In three experiments, the authors investigated the nature of the constraints underlying toddlers' performance in this task. In Experiment 1, 2.5-year-olds were tested in a new version of the C-not-B task to investigate whether reaching with a detour leads to inhibition of direct visuomotor activation. The findings show that toddlers succeed more in the C-not-B task when a transparent barrier obstructs the path of the reaching movement. The results of Experiment 2 indicate that the successful performance of the children with a barrier cannot merely be the consequence of the longer duration of arm movements. In Experiment 3, pointing responses generated more toddlers' success in the C-not-B task than did reaching responses. These experiments suggest that decision-making processes and judgments in toddlers are affected by constraints intrinsic to the perceptual–motor system.

Introduction

Young children have difficulty in exercising inhibitory control over their behavior. A number of studies have exposed the weak inhibitory control of young children over their manual actions by using different types of tasks. The A-not-B task consists first of repeated hidings and findings of objects in one location (A) and then a shift trial in which the object is hidden at a second location (B). If delayed for a few seconds, 8- to 12-month-old infants often continue searching at the A location. For several

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decades, developmental psychologists have explored the A-not-B error and proposed several alternative suppositions, including the motor memory hypothesis. In a dynamical systems framework, the A-not-B error may emerge in infants because memories from previous reaching activities create the directional bias to reach in the direction of past activity (e.g., Clearfield, Diedrich, Smith, & Thelen, 2006; Diedrich, Thelen, Smith, & Corbetta, 2000; Smith, 2005; Thelen, Schöner, Scheier, & Smith, 2001). Diamond and Goldman-Rakic (1989) explained that the A-not-B error stems from the consequence of both working memory limitations and difficulties in inhibiting a motor response. In Diamond and Goldman-Rakic's analysis, during the A-not-B task, the infant must inhibit the motor response that was produced on the previous trial. That is, the conditioned behavioral tendency or "habit" to reach to A must be inhibited when the toy is hidden under B if the participant is to reach correctly. Diamond (1985) conducted a series of experiments that revealed that longer delays increase A-not-B errors. According to the author, working memory limitations can account for these results; participants produce their conditioned behavioral tendency to repeat a rewarded response when their ability to remember (i.e., where the toy was last hidden) has been exceeded. Indeed, in Diamond's account, the key abilities for success on the A-not-B task are inhibitory control and working memory, namely the ability to inhibit the prepotent tendency to reach back to A and the ability to remember where the reward was last hidden (Diamond, 2001).

The C-not-B task (Rivière & Lécuyer, 2003) is a three-location search task involving invisible displacements of an object. In this task, a child is shown the experimenter's hand that contains a toy. The experimenter's hand then successively disappears under the three cloths (A, B, and then C). The experimenter silently releases the toy under the second cloth (B). In this task, the child's attention was drawn to the last hiding site by the movement of the experimenter's hand. However, in this situation, the child could find which of the visited locations contained the object on the basis of a visual clue, namely the bump that the hidden object made in the B cloth that covered it. Children aged 2 years 5 months fail this task by being strongly biased toward the last cloth that the experimenter's hand passes under; this has been labeled the *C-not-B error.* In our account, the perception of the experimenter's hand emerging from the last hiding place while empty may have triggered an automatic motor response, namely the reaching movement directed toward the C cloth. Such a motor program automatically activated by an environmental stimulus was termed *motor routine.* This motor routine is the motor tendency to search for things in the direction where they, or more precisely their containers, were last seen. Toddlers may commit the C-not-B error because their weak inhibitory control is insufficient to stop this prepotent response. The neural mechanisms that conspire to produce such motor routines begin to be explained. Thus, Erlhagen and Schöner (2002) proposed a neural network account of motor programming. In this theoretical framework, movement parameters are represented by activation fields, that is, distributions of activation defined over metric spaces. The fields develop under the influence of various sources of localized input representing information about upcoming movements. One such source is a memory trace of activation distributions representing the recent motor history.

In the go/no-go task, participants are told to respond to one stimulus on go trials but to make no response to another stimulus on no-go trials. Responding on no-go trials is assumed to reflect a failure to inhibit the go response. In the developmental go/no-go task used by Livesey and Morgan (1991), children are shown a number of boxes. They are told that boxes with one shape on the lid contain treats (go trials), whereas boxes with another shape are empty (no-go trials). Then, children are asked to open the boxes containing treats. Young children tend to open all of the boxes. Simpson and Riggs (2007) suggested that (a) inhibitory control is a major factor in 3.5-year-olds' performance on this task and (b) box opening is prepotent because opening is the habitual action associated with the function of a box and because children are planning to respond in this way on the task.

In the Luria hand game (Luria, Pribram, & Homskaya, 1964), children are trained to perform two different hand gestures, and during testing children must do the gesture that is different from the gesture made by the experimenter. Hughes (1998) suggested that this task requires children to override a prepotent response (i.e., the tendency to mimic the experimenter's actions) in order to execute a rule-guided action and to evaluate and modify their actions in response to feedback. Children aged 3.5 years and older display difficulties in this task (Flynn, O'Malley, & Wood, 2004).

In the domain of strategic deception, Carlson, Moses, and Hix (1998) suspected that a lack of inhibitory control might be implicated in 3-year-olds' failures on pointing tasks. They argued that veridical