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Brief Report

When simple things are meaningful: Working memory strength predicts children's cognitive flexibility

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ABSTRACT

People often perseverate, repeating outdated behaviors despite correctly answering questions about rules they should be following. Children who perseverate are slower to respond to such questions than children who successfully switch to new rules, even after controlling for age and processing speed. Thus, switchers may have stronger working memory strength than perseverators, with stronger rule representations supporting both flexible switching and faster responses to questions. Alternatively, better inhibitory abilities may support switchers' faster responses by helping to resolve conflict. The current study tested these accounts using a new one-dimensional card sort. Even with all possible sources of conflict removed, switchers still responded faster than perseverators to questions about rules, supporting the graded working memory account.

Introduction

People are generally able to behave flexibly, breaking habits to deal with novel situations. However, sometimes people repeat old behaviors that are no longer appropriate. Such perseveration is apparent in older adults, children, prefrontal patients, and schizophrenics (Ashendorf & McCaffrey, 2008; Dunbar & Sussman, 1995; Rossell & David, 1997; Zelazo, 2004). For example, when 3-year-olds are presented with cards depicting blue trucks and red flowers, they will continue to sort them by the first rule they are given, color or shape, despite being instructed to sort them by the other rule (Kirkham & Diamond, 2003; Perner & Lang, 2002; Zelazo & Frye, 1998). However, they can answer simple queries about the rule they are failing to use. When asked where trucks go in the shape game they

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correctly point to the red truck, but when given a blue truck they put it with the blue flower (Zelazo, Frye, & Rapus, 1996). Six-year-olds show similar behavior when asked to switch from deciding whether a speaker is happy or sad based on sentence content to deciding based on intonation, perseverating on content despite correctly answering queries about the rules for happy and sad intonation (Morton & Munakata, 2002b).

Why do perseverators succeed at answering simple queries about the rules of a game but fail to respond according to those rules? The problem appears to reflect a difficulty in resolving conflict. When queries contain information about the two conflicting dimensions (e.g., "Where do blue trucks go in the shape game?"), children perseverate just as they do when sorting cards (Morton & Munakata, 2002b; Munakata & Yerys, 2001). We contrast two explanations for this difficulty. The graded working memory account posits that the critical factor is the strength of working memory representations (Munakata, 2001). Children perseverate because their memories for the current rule are not strong enough to overcome the conflict in multidimensional questions and cards, but they can answer simple queries because weaker working memory suffices when there is no conflict (as simulated in Morton & Munakata, 2002a). The directed inhibition account, in contrast, posits that the critical factor is inhibitory ability (Kirkham & Diamond, 2003; Zacks & Hasher, 1994). Children perseverate because they cannot inhibit information about the first dimension in multidimensional questions and cards, but they can answer simple queries because there is no information to inhibit.

The graded working memory account makes a unique prediction: Switchers should answer simple queries faster than perseverators. Stronger representations of the current rule (e.g., shape) provide top–down support for task-relevant representations (e.g., truck, flower). The greater this support, the faster those task-relevant representations can reach the threshold for driving a response. This prediction has been confirmed (Cepeda & Munakata, 2007). Six-year-olds completed a computerized three-dimensional (3D) card sort (Fig. 1A) with stimuli varying along three dimensions: shape, color, and size (Deák, 2003). Children who flexibly switched between the rules and children who perseverated were equally accurate in answering simple queries (e.g., "In the shape game, what do you press when you see a cat?"), but switchers responded faster than perseverators even after controlling for age and processing speed. Thus, stronger representations of the current rule may support both flexible switching with conflicting stimuli and faster responses with nonconflicting stimuli. This result appears to challenge directed inhibition accounts.

Directed inhibition may nonetheless have helped switchers to respond faster to simple queries because two potential sources of conflict might have been resolved through inhibition. First, targets varied along all three dimensions (e.g., large blue cat), so ability to inhibit other dimensions of the target

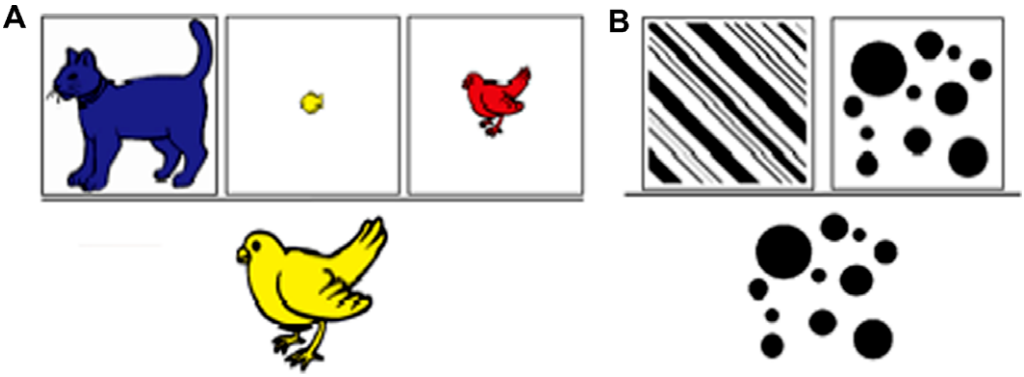

Fig. 1. (A) 3D card sort (adapted from Cepeda and Munakata, 2007). Participants selected one of the three target cards along the top row on each trial. Conflict stimuli matched each target on one dimension. No stimuli appeared on the lower half of the screen during simple query trials. (B) 1D card sort. Participants selected one of the two target cards on each trial. Stimuli exactly matched one of the two targets, so no inhibition of an irrelevant dimension was necessary to complete the task. No stimuli appeared on the lower half of the screen during auditory trials.