RESPONSE

Sorting between theories of perseveration: performance in conflict tasks requires memory, attention and inhibition

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Two commentaries have raised interesting and important questions regarding our theory of attentional inertia. Happaney and Zelazo declare that children's ability to self-reflect, and thus formulate higher-order rules, explains good performance on the card sort task. Self-reflection and rule formulation are descriptive, but do they provide an explanation, or insight into the mechanism? It is claimed that what CCC theory adds is an explanation of *how* inhibition and attentional refocusing occur. But then, CCC theory does not explain *how* reflection and higher-order rule use occur. How does one determine that a child has reflected on a rule? Is it by good performance on the task? Happaney and Zelazo say our theory of attentional inertia does not directly discount CCC theory. What evidence would? The CCC theory seems to us unfalsifiable. 'Reflection' needs to be better operationalized; its components and the mechanism driving it better understood.

Happaney and Zelazo suggest our reaction time results with adults are compatible with CCC theory. We disagree. The demand on reflection should be constant regardless of which dimension is switched to or from. Yet we found adults were faster on the first dimension throughout the lengthy session, even when not switching.

Happaney and Zelazo find our label-condition results consistent with CCC theory because (a) labeling might provide children with a more sophisticated conceptual structure, allowing them to reflect on the relevant rules, or (b) '[i]f labeling improved performance in some other way, this would not undermine CCC theory'. Again, CCC theory appears unfalsifiable.

Children's success in the label condition suggests their problem is in redirecting their attention to the newly relevant dimension when looking at a stimulus relevant, in incompatible ways, to both sets of rules. Important confirmation for that, and refutation of CCC theory, comes from Brooks, Hanauer, Padowska and Rosman (2003) and Perner and Lang (2002), who found that 3-year-olds succeeded on a task with an identical hierarchical rule structure to the card sort (two games, each with two embedded rules) with the stimuli presented post-switch relevant in incompatible ways to both sets of rules, *but* unlike card sort, shifting attention from one dimension to another was never required.

Happeney and Zelazo suggest that CCC theory can account for results on the day-night task. We feel that trying to make that task fit a hierarchical, embedded rule structure is unnecessarily complicated. There is no need to posit reflection as part of the task. The day-night latency results are compatible with *any* theory of what the difficulty is for children, including that it is difficult to inhibit the canonical answer.

Before turning to the important substantive issues raised by Munakata, Morton and Yerys, a misunderstanding about our procedure should be rectified. Munakata *et al.* wrote that we are arguing 'that because the experimenter emphasizes the rule change and repeats the new rules before each trial, children's perseveration cannot be attributed to memory problems or failure to realize the rules have changed'. That is not what we are saying. We argue that memory demands are *minimized* by the experimenter's repetition of the rules; memory is *demonstrated* by the child's correct pointing in response to the knowledge question. We take the latter as convincing evidence of memory.

Munakata *et al.* request clarification of our thinking: 'Are inhibiting, disengaging, refocusing and switching identical or separate processes?' They are *not* the same. Inhibition makes possible disengaging, refocusing and switching. Inhibition is a prerequisite for the others.

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Munakata *et al.* ask how these terms go beyond mere description. They go beyond by addressing why and by making predictions. For example, inhibition must not only be instituted, but when what was inhibited is again relevant, inhibition must be un-done. The context in which you perform a task (did you recently inhibit it?) matters. We predict that children should succeed in switching dimensions at a younger age (3 years), and older children and adults show less reaction time switch cost, if stimuli relevant to only one dimension are used during the pre-switch block (Block 1). This is a strong prediction: With the post-switch block identical to the one 3-year-olds now fail, we predict success. The only change: Stimulus characteristics relevant post-switch were not inhibited pre-switch.

Munakata *et al.* suggest that our logic is circular. We generated a condition we felt tested our hypothesis and took confirmation of our prediction as evidence in favor of our hypothesis. Alternative explanations of our findings present opportunities for experiments to test between interpretations. Munakata *et al.*'s claim that there is insufficient memory activation for children to perform correctly in the card sort task, as evidenced by children's poor performance, could also be accused of circularity.

One of the alternative accounts Munakata *et al.* would like to have seen us address is by Aguiar and Baillargeon (2000). Their explanation is unable to account for the persistence of errors, especially on the A-not-B task in the face of explicit feedback that the infant erred. The error on the first B trial should alert infants that there's been a change. That infants continue to make the same error trial after trial seems a fatal problem for the Aguiar-Baillargeon account. In the card sort task, children are alerted to the game change by the elaborate introduction to the new game and repetition/query of the rules.

Munakata *et al.* feel that we discount a memory interpretation too readily, citing the existence of multiple memory systems. We do not see the relevance of multiple systems. Answering questions explicitly requires explicit memory, as does explicitly sorting the cards. It is unlikely that a child remembers when asked the knowledge questions, forgets or remembers less well a moment later when sorting a card, and then remembers moments later when again queried verbally. We think, when sorting, the conflicting information pulls the child's attention away from the rule the child knows and remembers. The child needs to inhibit that pull and focus attention on the relevant stimulus dimension and its rules.

We agree wholeheartedly with Munakata *et al.* that 'children may have limited memory for a new rule . . . sufficient for tasks that do not involve conflict, but insufficient for tasks that involve conflict'. Now, *why* is that statement so? The answer is that a conflict situation adds an additional inhibitory requirement not present in the non-conflict situation.

Munakata *et al.* incorporate inhibition into their memory account and then claim that memory can account for everything: 'An alternate view from the memory perspective is that maintaining information active . . . supports relevant representations . . . and through inhibitory interactions throughout cortex, leads other (irrelevant) representations to be less active'. To maintain focus on something in memory (or in visual attention) requires concentrating on what is relevant and inhibiting attention to irrelevant, compelling distractors. Activation and inhibition are both required; Munakata *et al.* apparently agree. If inhibition of not-X always accompanies activation of X (which Munakata *et al.* might be saying), then it follows that (a) inhibition is still given a role and (b) memory (activation) and inhibition covary and are not dissociable. These processes *can*, however, be dissociated developmentally (in children: Diamond, 2001; in adults: Sweeney, Rosano, Berman & Luna, 2001) and neurally (Bunge, Ochsner, Desmond, Glover & Gabrieli, 2001; Belmonte & Yurgelun-Todd, 2003; Pollman, Weidner, Humphreys, Olivers, Müller, Lohmann, Wiggins & Watson, 2003). A position similar to Munakata *et al.*'s has been advocated in the language domain: Increased activation of appropriate meanings is said to cause decreased activation of inappropriate meanings (McClelland & Kawamoto, 1986; Waltz & Pollack, 1985). However, Gernsbacher and Faust (1991) found activation and inhibition dissociable there as well: As inappropriate meanings decreased in activation, appropriate meanings did *not* increase in activation.

Children demonstrate that they remember the card sort rules when responding to knowledge questions. Why then do they err? We propose that it is because in the presence of conflict children are pulled to focus on the previously relevant dimension and its rules ('attentional inertia'); overcoming that tendency requires inhibition.

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