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Cognitive Flexibility in Young Children: A New Perspective

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Abstract:	Cognitive flexibility is the ability to rapidly adjust our thoughts and behaviors in response to changes around us. Although the preschool period has been hugely influential in helping to develop our understanding of how this vital ability emerges, progress has been greatly slowed in recent years due to a combination of methodological issues. The authors outline recent developments in the field that have directly addressed these issues, and have led to both a more nuanced definition of cognitive flexibility, and to a number of promising new experimental paradigms. For future research, it will be essential that studies target both a broader range of ages, and a broader range of behaviors, in order to give a full account of how cognitive flexibility emerges in early childhood.

Abstract

Cognitive flexibility is the ability to rapidly adjust our thoughts and behaviors in response to changes around us. Although the preschool period has been hugely influential in helping to develop our understanding of how this vital ability emerges, progress has been greatly slowed in recent years due to a combination of methodological issues. The authors outline recent developments in the field that have directly addressed these issues, and have led to both a more nuanced definition of cognitive flexibility, and to a number of promising new experimental paradigms. For future research, it will be essential that studies target both a broader range of ages, and a broader range of behaviors, in order to give a full account of how cognitive flexibility emerges in early childhood.

Key words: COGNITIVE FLEXIBILITY; EXECUTIVE FUNCTION; INHIBITORY CONTROL; WORKING MEMORY

Introduction

One of the defining features of human cognition is its flexibility (1, 2, 3). Cognitive flexibility (CF) allows us to rapidly adapt our thoughts and behaviors in response to changing environmental demands and task goals (4). CF is generally regarded as the emergent property of successful cognition (5), underpinned by executive functions (EF) - specifically working memory and inhibitory control (6). Improvements in CF during the preschool years have been linked to better theory of mind skills (7), better language and reading ability (8, 9) and improvements across a range of academic skills (10, 11). The preschool period has thus been an important focal point for studying the development of flexible goal-oriented behavior.

The canonical view of CF development

In its simplest sense, CF is the ability to bring a new behavior to an old or ongoing situation. Typically, this is operationalized by tasks that require children to update a task rule - often by sorting stimuli in two different ways. Perhaps the best example of this is the Dimension Change Card Sort task (DCCS; 12, 13). On the standard DCCS task, children sort cards depicting colored shapes into trays, first by one rule (e.g. color), and then by a different rule (e.g. shape). The to-be-sorted cards match one tray according to color, and the other tray according to shape – so for example, children might sort cards depicting red fish and blue cats into trays depicting blue fish and red cats. In order to sort correctly, the child must update the rule they use to guide their behavior.

Preschoolers' performance follows a clear trajectory. Three-year-olds are able to sort the cards consistently according to the initial rule. However, after the rule changes, most continue to use the initial rule, and so incorrectly perseverate. In contrast, 4-year-olds are able to successfully switch rules (13). This developmental shift from perseverative to flexible performance is an extremely robust finding (e.g. 14, 15, 16), and has led many to seek to explain the developmental processes that allow children to overcome this perseveration (see 17 and 6 for reviews). However, while this approach initially led to considerable advances in understanding CF, a number of issues have become apparent, which have hindered further progress in the field.

CF is poorly defined

Perhaps the most pressing issue is that CF itself is poorly defined. Commonly used definitions tend to be couched in the terms of the task with which it is assessed - in other words, if a child is able to switch from sorting by one rule to sorting by another, then they demonstrate good CF. While this appears to be a serviceable working definition, it quickly loses its utility when one considers the large number of separate demands that must be met in order to succeed on typical CF tasks. In addition to the core demand of updating the task rule, these also include the need to selectively attend to different aspects of a stimulus; the need to resolve response conflict (that is, to select the correct rule when different aspects of a single stimulus are priming two conflicting rules); and the ability to coordinate and deploy these skills in concert. All of these are likely to contribute to good CF. However, there is no reason to suggest that children must meet *all* these demands simultaneously in order to show CF. Despite this, succeeding on standard CF tasks requires children to meet these separate demands simultaneously. Acknowledging and addressing the multifaceted nature of CF is crucial for making further progress in understanding its development.

Research addresses a narrow age range

For decades, there has been an extensive focus on how CF develops in 3- and 4-year-old children. This focus has generally been for methodological, rather than theoretical, reasons. The incidental demands of most CF tasks make them unsuitable for children younger than 3 years. CF tasks typically require children to follow quite lengthy instructions. They also demand good selective attention (e.g. so children focus on only stimulus *shape*, while ignoring its *color*). Moreover, preschool CF measures typically use a very small set size (i.e. few exemplars of the rules to be sorted by - such as *red* and *blue* for color); counterintuitively, small set sizes have been shown to increase the difficulty of switching between rules (18). This combination of diverse demands means that early competencies in CF in younger children may get overlooked. (Although the focus of this paper is on CF in younger children, it is also worth noting that many important changes in CF also occur after the age of five (19, 20) and that the focus on 3- and 4-year-olds has left these changes out of the standard view of CF development.)

Overemphasising perseveration

The shift from perseveration to flexible behavior is commonly considered the key transition in the early development of cognitive control (6, 21, 12). However, there are grounds to think that the role of perseveration may have been greatly overstated. As an illustration: after the rule changes on the DCCS task, children have only two options available to them: to select the correct response, or to select the response that was correct according to the initial rule. Since children can only *either* sort correctly *or* make a perseverative response, all errors they make will *by definition* appear to be perseverative errors. CF tasks of this kind can therefore tell us nothing about errors arising through inattention, distraction, failure to maintain task set, or through any other means. It is entirely possible that the apparent prevalence of perseveration among preschoolers is in fact an artefact of task design (see 22, 23, for similar assertions).

Theoretical impasse

This focus on a single type of error within a narrow age band has made it difficult to derive distinct, falsifiable theories to explain the development of CF. Nevertheless, two influential accounts have been proposed to explain how CF develops in childhood. The Graded Representations account proposes that working memory underpins CF development by allowing children to maintain task rules (24). Conversely, the Attentional Inertia account argues that inhibitory control is crucial to CF development, as it allows children to suppress their attention to the no-longer-relevant dimension of a stimulus when the rule changes (25). Both accounts offer explanations for why 3-year-olds perseverate and 4-year-olds can switch their behavior. However, it has proven particularly difficult to test between these two accounts: manipulations intended to reduce working memory demands could plausibly be explained as reducing inhibitory demands instead, and vice versa (25). Further theoretical advances require a more diverse evidence base as a matter of urgency.

Recent advances in CF development

In recent years, important steps have been taken to make progress on all these fronts. Below, we outline developments of particular relevance for making progress in our understanding of the emergence of CF.

Measuring early developments in CF

An important methodological step has been to develop tasks that reduce incidental demands, and separate distinct components of CF, so that CF can be studied in finer detail and across a wider age range. For example, the Switching, Inhibition and Flexibility task (SwIFT) measures the emergence of CF in children as young as 2 years (26) and into adulthood (18). The SwIFT is a switching task in which children decide which of two colorful shapes matches a prompt image on the relevant dimension for that trial (typically either color or shape, with the rule changing half-way through the task). The SwIFT is administered on a touchscreen computer, so that responses are simple for even very young children. Language demands are minimal ("Touch the one that's the same [color/shape]"), and large set-sizes are used to minimize stimulus-priming errors. By manipulating the type of information in the stimuli, it is possible to vary the kind of error that can be made on the task, and thus to study perseverative errors and distraction errors separately. As we will now outline, data from this task make it clear that 2-year-olds are – in some circumstances – already capable of demonstrating basic CF skills.

Towards a clearer definition of CF

Over the last 20 years, it has been commonplace to assess children's CF using tasks that require children to switch rules whilst also resolving response conflict and other incidental demands (e.g., 27, 28, 29, 13). This approach has been perfectly appropriate for many research questions. However, it is increasingly clear that preschool CF comprises a family of distinct processes, and future progress towards understanding these processes will be directly proportionate to our ability to clearly delineate them. The common feature across all CF tasks is the requirement to update behavior, from using one rule to using a different rule. This rule updating can happen under a variety of circumstances, and with many different kinds of additional demands. Intentionally reducing these demands will allow us to assess how CF emerges in younger preschoolers.

As an example, in a recent study, 2- to 4-year-olds completed two different versions of the SwIFT, with contrasting task demands (26). In the Conflicting condition, children had to switch rules while also resolving response conflict (i.e. it was possible for them to continue to sort stimuli using the previous rule - as in the standard DCCS task). In the Distracting condition, children had to switch rules while ignoring distracting task-irrelevant information (i.e. it was not possible to continue to sort stimuli using the previous rule). Switching in the Distracting condition should be easier, since the stimuli to be sorted don't contain any information related to the old rule. However, the presence of distracting, task-irrelevant information may still disrupt children's ability to focus on the rule they should be using. These two types of flexible behavior – switching while resolving response conflict, and switching while ignoring task-irrelevant information – showed distinct developmental trajectories. Furthermore, they were underpinned by different EFs. Children's ability to switch while resolving response conflict significantly improved between 3 and 3.5 years, and was related to children's working memory. Conversely, children's ability to switch rule while ignoring task-irrelevant information significantly improved between 2 and 3 years, and was related to children's inhibitory control. Clearly, the conditions under which rules must be updated can be highly variable, and are likely to have a significant effect on children's performance.

These data show that even in the absence of response conflict, young preschoolers still find switching rules challenging (26, 30). Switching rules in the face of distracting information is a distinct but no less important type of CF than that assessed in standard CF tasks, and shows significant development between two and three years (31). Intriguingly, however, not all task-irrelevant information is equally distracting for young children. When 2- and 3-year-old children were required to switch rules while ignoring information, they *only* made errors if the to-be-ignored information had been relevant before the rule changed. When the to-be-ignored information was instead a novel dimension unrelated to the task - for example, if children had to ignore *shape* information after sorting stimuli based on *pattern* - they had little difficulty in ignoring it and switching rule. In fact, their performance was indistinguishable from a condition where children did not switch tasks at all. Preschoolers' distraction errors, therefore, are not simply erratic, inattentive responses; rather, they appear to be goal-related in nature, reflecting persisting attentional biases relating to a previous goal (31). By deconstructing CF into its separate components, we see firstly that in some circumstances, children as young as two years are quite capable of switching rules; and secondly, that there are a number of achievements they reach prior to succeeding on standard CF tasks at age four. The broader point here is that CF is not a single skill, and that rather than seeking to find a single definition of CF, or find an optimal CF task, we should be more explicitly aware of the different demands that young children must meet on different tasks, and incorporate these differences in our explanations of how CF emerges.

Rethinking perseveration

We noted earlier that many CF measures only detect perseverative errors. When more versatile measures of CF are used, a more varied pattern of responding is seen (30, 32, 23). For example, in the Flexible Induction of Meaning (FIM) task (33), children are required to select a match for a target object from an array of four objects - three that share different properties with the target (shape, texture, or an affixed part) and one that shares no properties with the target. The task requires CF, as children have to switch between attending to different properties of an object according to the cue given by the experimenter (e.g. "looks like a…", "is made of…" and "has a…"). Approximately a quarter of children perseverated on this task (fewer than would be expected on the DCCS task). Notably 16% of the younger preschoolers responded unsystematically, neither perseverating nor switching (a pattern we refer to as "mixed responding" - see also the PAST, 30). Thus, when different types of error are possible, perseveration is a far less prevalent behavior.

This view is further supported by evidence derived from statistical modelling techniques used with older children. Dauvier and colleagues used a finite mixture of general linear models to examine how switching performance varied in five- and six-year-olds (34). A number of distinct performance profiles were reported: in addition to flexible switchers and perseverators, many children were classified as mixed responders, or as children who changed behavior halfway through the task, from perseverating to switching. These data offer grounds to reject the suggestion that perseverative errors are the starting point of CF development (25, 21, 35), and that the status of perseveration should be reconsidered.

We propose that perseveration is best thought of not as a problem to be overcome, but rather as a developmental milestone. This idea is best illustrated by considering how 2-year-olds perform on CF tasks (26). Two-year-olds are quite capable of sorting objects according to an initial rule. However, when that rule changes, 2-year-olds respond haphazardly, neither reliably switching nor reliably perseverating. Their behavior reflects a lack of effective top-down control. By around three years, children's post-switch performance shifts from unsystematic responding to perseverative responding – reliably sorting by the no-longer-relevant rule. This might be considered quantitatively poorer performance, since they make errors on almost every trial. However, it could also be regarded as a qualitative *improvement*, as these children produce systematic rule-governed behavior (albeit with the wrong rule). The gradual shift away from mixed responding in children is associated with better working memory (26), consistent with the idea that mixed responding arises from an inability to maintain rules strongly (36).

A similar three-stage pattern of unstable behavior, followed by stable, incorrect behavior, followed by flexible behavior has also been seen much earlier in development (37, 38). On the classic A-not-B task (39), 8-month olds typically perseverate by reaching for a toy in the location it was in previously, rather than in its current location. By around 12 months, infants overcome this perseverative error, reaching correctly to the B location. However, in a longitudinal study, Clearfield and colleagues found that prior to making the perseverative error, 5-month-olds responded unsystematically, sometimes reaching for B and sometimes reaching toward A. As a consequence, 5-month-olds made *more* correct reaches than 8-month-olds. Infants' A-not-B performance thus showed an increase in perseveration between 5 months and 8 months, as unstable behavior was replaced with systematic "incorrect" responding (37). As with preschool CF, considering children's behavior across a broader age span shows that perseverative behavior is not merely a problem to be overcome, but instead represents the onset of stable, rule-driven behaviour – and is thus a qualitative improvement on the unsystematic responding that preceded it.

Towards a new account of CF development

The research presented here begins to suggest a more nuanced account of how CF emerges in early development. A crucial ongoing task will be to better specify the roles played by the key executive functions. Working memory is crucial when there are strong requirements for children to maintain the task goal. This is consistent with research with older preschoolers which finds that working memory is vital on switching tasks when there is a strong need to maintain the current task goal (7). Interestingly, it is also consistent with work in adults which shows that working memory plays a unique role in resolving cognitive conflict – when relevant and irrelevant task information elicit competing responses that need to be resolved (40). Across development, working memory enables the resolution of response conflict through the maintenance and updating of task goals. This is consistent with the Graded Representations account of CF development (36). However, this account can be constrained by recognising that working memory is not important in *all* CF tasks: when response conflict is removed, and children have to ignore task-irrelevant information, working memory is not related to CF performance. In such situations, inhibitory control appears to be key (26), likely by helping children to overcome attentional biases towards information related to the previous rule. This idea is central to the Attentional Inertia account (25). Although this account was originally intended to explain why children perseverate on measures of CF, recent findings suggest that this account is actually better suited to explain preschoolers' distraction errors.

Summary and Conclusions

Together, the research presented here demonstrates that CF has a longer and more complex developmental trajectory than previously thought. Fully understanding this development will require both a more nuanced consideration of what CF is, and the wider use of tasks capable of separating each distinct element. Clarifying the specific contributions made by working memory and inhibitory control has greatly enhanced our understanding of how complex, flexible behavior comes online. Essential to further progress is the understanding that CF is a family of processes, and that each process is likely to have its own costs and developmental trajectory. This will allow us to derive better, broader based theoretical accounts for the emergence of complex goal-oriented behavior in the first years of life.

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