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Brief Report

Measuring on the go: Response to Morra, Panesi, Traverso, and Usai

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A B S T R A C T

Morra, Panesi, Traverso, and Usai's (*Journal of Experimental Child Psychology*, 2017, Vol. 167, pp. 246–258) effort to clarify theoretical models and nomenclature confusion surrounding young children's executive functions development is laudable and important. In this article, we address some of the points these authors raised regarding our previous article (*Journal of Experimental Child Psychology*, 2017, Vol. 159, pp. 199–218). Although we agree that the Multidimensional Card Selection Task makes working memory demands, it goes beyond working memory to measure concurrent cognitive flexibility in preschoolers. Using this task will allow researchers to fine-tune our models of cognitive flexibility and executive functions development.

Introduction

Growth is often erratic and tumultuous. This is true for the growth of individual children (e.g., Lenroot & Giedd, 2006) as well as for the growth of scientific research fields (e.g., National Research Council, 2002). The field of executive functions is going through a growth spurt, resulting in varying levels of agreement among researchers as to the exact nomenclature and, indeed, even the structure of executive functions. For example, the ability to think of more than one aspect of a specific stimulus has been referred to in the literature as *cognitive flexibility* (Jacques & Zelazo, 2005), *representational*

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flexibility (Kloo, Perner, Aichhorn, & Schmidhuber, 2010), *set shifting* (Garon, Bryson, & Smith, 2008), *mental flexibility* (Smidts, Jacobs, & Anderson, 2004), and *attentional flexibility* (Stahl & Pry, 2005). Yet, these researchers all are examining the same fundamental skill of thinking of something in more than one way—a hallmark of human development regardless of the name we use to refer to it.

We appreciate Morra, Panesi, Traverso, and Usai's (2017) efforts to order the somewhat messy field of executive functions research. We agree wholly with these authors that the field requires a strong theoretical model and that more research is required to fully identify which specific skills should be included in the structure of executive functions as well as how they inter-relate. For instance, the inclusion of cognitive flexibility (our preferred term for describing the ability to think of something in more than one way) within the structure of executive functions is still unclear, and there is still debate around whether cognitive flexibility is a stand-alone, domain-general mechanism or a property of specific processes (e.g., flexible language, flexible problem solving; see Ionescu, 2012). These considerations, however, are beyond the scope of the current article. Here, we address specific points that Morra et al. (2017) raised in relation to our previous article (Podjarny, Kamawar, & Andrews, 2017).

We begin with the overall claim. Morra et al. (2017) argued that our Multidimensional Card Selection Task is not a concurrent cognitive flexibility task but rather a working memory task. We argue that although the Multidimensional Card Selection Task makes working memory demands, it goes beyond working memory to examine children's ability to consider multiple dimensions simultaneously. First, we address the idea that cognitive flexibility is synonymous with shifting and explain why concurrent cognitive flexibility can be a useful construct for researchers. Then, we examine two tasks, the Multidimensional Card Selection Task and the Direction Following Task, and scrutinize the differences between the two. Finally, we address methodological points raised by Morra et al. and discuss how to tackle them in future research.

Between shifting and concurrent cognitive flexibility

Morra et al. (2017) argued that there is no evidence to suggest that flexibility is anything more than shifting (i.e., the ability to overcome an established or learned mindset). However, the ability to coordinate several dimensions simultaneously is useful for several theoretical models offered to explain children's cognitive development. For instance, according to the Cognitive Complexity and Control Theory (Revised) model (Zelazo, Müller, Frye, & Marcovitch, 2003), children can succeed in switching the rule they use to sort bivalent cards (e.g., from sorting by color to sorting by shape; see Zelazo, 2006) only when they are able to coordinate between two branches of contradicting rules. In the area of Theory of Mind reasoning, Perner, Stummer, Sprung, and Doherty (2002) argued that the skill of integrating two perspectives at the same time, rather than ascribing to different perspectives at different times, is a critical skill in reasoning about others' mental states. Similarly, Piagetian conservation tasks are fundamentally about coordinating two dimensions at the same time. For example, when liquid is poured into a taller and narrower beaker, both the width and height of the liquid change simultaneously and proportionally. In other words, the skill of coordinating two (or more) dimensions simultaneously enables children to solve problems that they would be unable to solve if they were only switching between these dimensions consecutively.

It is important to note that we do not propose concurrent cognitive flexibility as a construct independent from switching cognitive flexibility; rather, we propose it as another aspect of the core skill of cognitive flexibility. However, as Morra et al. (2017) maintained, there seems to be a lack of empirical evidence to suggest even the existence of concurrent cognitive flexibility. In the literature examining the development of cognitive flexibility in preschoolers, it is certainly the case that the term *cognitive flexibility* is used as synonymous with *switching* (for a review, see Podjarny, 2015). Indeed, nearly all tasks used to measure cognitive flexibility in preschoolers, such as the Dimensional Change Card Sort (Zelazo, 2006), are in essence switching tasks (for a review, see Cragg & Chevalier, 2012). However, we believe that looking only at sequential tasks such as the Dimensional Change Card Sort precludes researchers from examining the coordination of several dimensions simultaneously, hence our proposal of concurrent cognitive flexibility.

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In our article (Podjarny et al., 2017), we examined several tasks that can be used to measure concurrent cognitive flexibility. Morra et al. (2017) noted that none of these works "suggested anything akin to concurrent flexibility to account for multiplicative classification" (p. 14). We absolutely agree that such work does not make mention of terms like *concurrent cognitive flexibility*. Our point—in our original article and in other work—is exactly that these tasks measure concurrent cognitive flexibility, but they do not refer to it as such (for a review, see Podjarny, 2015). For instance, in the matrix completion task used by Siegler and Svetina (2002), children are asked to integrate four dimensions (shape, color, size, and orientation) in order to replicate a given relation. The authors explicitly stated that they chose this task because it "measures in a particularly direct way the ability to focus on multiple dimensions rather than on just a single one" (p. 794). The concept of concurrent cognitive flexibility is valuable because it draws attention to an underlying skill, common across a range of tasks, that has not been directly investigated previously.

In addition, concurrent cognitive flexibility connects two research areas that seem to move in different spheres. On the one hand, there is the Piagetian and neo-Piagetian research into the development of decentration (e.g., Halford, 1980; Inhelder & Piaget, 1964; Moll, Meltzoff, Merzsch, & Tomasello, 2013). Decentration refers to the child's ability to consider several dimensions of a single stimulus and is exemplified in conservation and multiple classification tasks (see, e.g., Inhelder & Piaget, 1964). On the other hand, there is research into set shifting or switching cognitive flexibility, which originates in research into executive functions. This area also examines children's ability to consider several dimensions of a single stimulus but has traditionally operationalized this skill as considering the dimensions consecutively (see, e.g., Cragg & Chevalier, 2012; Deák, 2004; Diamond, 2006; Jacques & Zelazo, 2005; Snyder & Munakata, 2010). Hopefully, connecting these two fields will lead to a fruitful exchange of ideas between them. For example, the relation between abstraction and cognitive flexibility has not been experimentally investigated in the context of executive functions, and we are currently working on using Piagetian multiple classification tasks to do so (Podjarny, Kamawar, & Andrews, in preparation).

To investigate concurrent cognitive flexibility and its relation to other executive functions—including switching cognitive flexibility—we need tasks that measure this skill. The Multidimensional Card Selection Task was designed to be such a task. Morra et al. (2017) argued that the Multidimensional Card Selection Task is a working memory task based on a structural similarity between our task and the Direction Following Task. We disagree with this analysis. Although we agree that the surface similarity exists, there are critical differences between the two tasks. We begin by briefly describing the two tasks before closely examining the differences between them.

Between the Multidimensional Card Selection Task and the Direction Following Task

In the Multidimensional Card Selection Task, children are presented with an array of eight cards, each with a single item on it. These items differ along three dimensions: shape, color, and size. Children are asked to select cards that match the description given by the researcher across three phases (requests differ in terms of the number of dimensions indicated, by phase). In each array, there are two cards that serve as unique targets for each of the three phases as well as two distractors. In Phase 1, children are asked to select cards based on a unidimensional description (e.g., all the hearts). Then, in Phase 2, children are asked to select cards based on a bidimensional description (e.g., all the yellow triangles). Finally, in Phase 3, children are asked to select cards based on a tridimensional description (e.g., all the small red circles). The cards are placed back into the array after each phase.

Prior to receiving the test trials, children received a memory baseline trial that was similar to the test trials except that requests consisted of up to three values of a single dimension for each phase. Thus, children first were asked to select cards based on one value of a single dimension (e.g., all the hearts), then were asked to select cards based on two values of the same dimension (e.g., all the hearts and all the stars), and finally were asked to select cards based on three values of the same dimension (e.g., all the hearts, stars, and triangles). In short, whereas the memory baseline trial required children to consider the union of the sets indicated by the descriptors, the test trials required children to consider an intersection of the descriptors. The memory baseline was designed to examine the possibility that children's performance on the Multidimensional Card Selection Task was driven only by their ability to hold three descriptors in mind. Thus, if children's performances on the baseline trial and test trials were not significantly different, it would be very likely that the only skill at play was working memory. However, this was not the case (see below).

In the Direction Following Task, a task that was designed to measure M-capacity (Pascual-Leone & Johnson, 2011), children are shown two boards. The first contains 20 tokens differing in shape, color, and size. The second (adjacent) board contains 10 spaces that differ in size and color. Children are asked to place a specific token on a specific space (e.g., "Place a small blue square on a yellow space"). Morra et al. (2017) noted that both the Direction Following Task and the Multidimensional Card Selection Task require children to select an item based on a varying number of features (from one to three descriptors). Based on these similarities, the authors claimed that our task is, like the Direction Following Task, a measure of working memory. Morra et al. did concede that there are differences between the tasks. We argue that these differences are fundamental to the taxonomy of the tasks and should not be glossed over.

One clear difference between the Multidimensional Card Selection Task and the Direction Following Task is in the working memory demands that the two tasks make. Specifically, in the Multidimensional Card Selection Task, children only need to select the cards described by the researcher and then hand them to the researcher. In contrast, in the Direction Following Task, children must also select the space in which to place the token. The Direction Following Task requires children to hold multiple sets of multiple-dimension items (at least one token and one space) in mind and, thus, likely makes heavier working memory demands as compared with the Multidimensional Card Selection Task. It is possible, given the task demands, to argue that the Direction Following Task is a working memory task that involves concurrent cognitive flexibility.

Another important difference between the two tasks is that in the Direction Following Task children need to process an array of 20 tokens of which they are asked to select 1 token, whereas in the Multidimensional Card Selection Task children are presented with an array of only eight cards of which they are asked to select two cards. Larger sets provide a greater challenge for both adults and children. The number of items participants must process affects both their working memory performance (Bayliss, Jarrold, Riby, & Baddeley, 2003; Halford, Maybery, & Bain, 1988) and their cognitive flexibility performance (Cragg & Chevalier, 2012). Thus, the larger set size of the Direction Following Task, as compared with the Multidimensional Card Selection Task, provides greater challenges, especially for children. In summary, it is clear that the Direction Following Task requires a much more intense involvement of working memory and information processing than does the Multidimensional Card Selection Task.

We agree with Morra et al. (2017) that the Multidimensional Card Selection Task makes some working memory demands. In fact, we argued in our article (Podjarny et al., 2017) that concurrent cognitive flexibility tasks in general make greater working memory demands than do switching cognitive flexibility tasks because participants are required to coordinate several dimensions simultaneously. However, as we mentioned before, the Multidimensional Card Selection Task goes beyond simply making working memory demands. The task demand of selecting cards based on a multidimensional description is what distinguishes it from working memory tasks that simply require children to hold a certain number of items in mind. Several studies have demonstrated that it is the requirement to integrate two (or more) dimensions within the same stimulus that presents an issue for young children (see, e.g., Bennett & Müller, 2010; Kloo & Perner, 2005; Zelazo et al., 2003). In addition, as we mentioned above, there are several theoretical models that consider the integration of two or more dimensions as the critical skill for flexible thought (see, e.g., Halford, Wilson, & Phillips, 1998; Perner et al., 2002; Zelazo et al., 2003).

Methodological points

We now address two methodological points raised by Morra et al. (2017). The first concerns the Multidimensional Card Selection Task memory baseline. We based the memory baseline trial on the work of Zelazo et al. (2003), who used a "unidimensional" trial to demonstrate that children's difficulties on the Dimensional Change Card Sort do not stem merely from a difficulty to remember the rules. These authors compared children's ability to remember four distinct rules with the integrated rules employed in the Dimensional Card Sort Task. The purpose of the memory baseline was to check whether children's difficulties on the Multidimensional Card Selection Task could be explained simply by a difficulty in remembering three descriptors. We found that children performed well on the memory baseline trial and, importantly, significantly better on this trial than on flexibility trials, in which they needed to coordinate up to three different dimensions (e.g., shape, color, and size; see Podjarny et al., 2017).

Morra et al. (2017) argued that the memory baseline is repetitive because the first item is mentioned as part of the second request, and these two items are mentioned as part of the third request (e.g., stars, then stars and hearts, and then finally stars, hearts, and triangles). Therefore, it includes a component of rehearsal. This, they argued, can explain children's better performance on the memory baseline trial. It is possible that the repetition contributed to children's superior performance on the memory baseline trial, and future research should address this empirical question. For instance, it would be straightforward to have a memory baseline that requires children to provide first all the hearts, then all the circles and diamonds, and then all the triangles, stars, and squares. We expect that children's performance on this modified memory baseline task would still be significantly better than their performance on cognitive flexibility trials because the critical difference between the two would still be maintained. In other words, the baseline would still require children to attend to only a single dimension, whereas the test trials would require children to coordinate several dimensions.

Another methodological point Morra et al. (2017) raised is that the Self-Ordered Pointing Task we used in our study does not measure working memory. Therefore, they argued, the lack of correlation between it and the Multidimensional Card Selection Task should not be taken as evidence of a distinction between what the Multidimensional Card Selection Task measures and working memory. Although in hindsight we appreciate that the Self-Ordered Pointing Task was not the best task in this context, and we do not plan on using it as a working memory task in future research, it had been used and referred to as a measure of working memory previously (see, e.g., Hongwanishkul, Happaney, Lee, & Zelazo, 2005; Mahy & Moses, 2015). Moreover, in the sense that it requires children to maintain the order in which they selected the pictures and to update this order with every selection they make, it would seem that, at least at face value, the Self-Ordered Pointing Task should measure working memory (see Cragg & Nation, 2007). As we noted in our original article, we chose this task because it involved a motor response (pointing) to visual stimuli (pictures) with verbal labels in the same way that the Multidimensional Card Selection Task involves a motor response (selecting and handing) to visual stimuli (cards) with verbal labels. Given that the Self-Ordered Pointing Task employed the same modalities as our cognitive flexibility tasks, we selected it so as to avoid attributing any lack of correlations to the differing modalities. As pointed out by Miyake et al. (2000), because executive functions are regulatory processes, performance on the tasks that measure executive functions necessarily includes variance that results from the performance of the modalities these processes regulate. Because of this inherent "task impurity," Miyake et al. emphasized the importance of task selection in terms of modalities for both response and stimuli processing.

Conclusion

We wholeheartedly agree with Morra et al.'s (2017) conclusion that there is a need for more research and greater consistency in terminology in the field of developmental executive functions. However, it is important to remember that the road to a comprehensive theoretical model is paved with empirical trial-and-error modifications. We need versatile tasks that provide researchers with the ability to examine the different facets of cognitive flexibility development. Our task is but one step forward in the joint endeavor to chart the complex developmental trajectories of executive functions during childhood. As part of this endeavor, we welcome researchers to examine the different aspects of the Multidimensional Card Selection Task and to scrutinize its usability as a concurrent cognitive flexibility measure.

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