Self-Reflection and the Cognitive Control of Behavior: Implications for Learning

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Abstract:
In this article, we suggest that self-reflection and self-control--studied under the rubric of "executive function" (EF)—have the potential to transform the way in which learning occurs, allowing for the relatively rapid emergence of new behaviors. We describe 2 lines of research that indicate that reflecting on a task and its affordances helps children to respond flexibly in a more top-down fashion despite interference from prior learning or perceptually salient aspects of the task. Research on A-not-B tasks with infants and young children revealed that postswitch flexibility is an inverted U-shaped function of number of preswitch trials. Overlearning may provide additional opportunities for reflection, in part by freeing up cognitive resources as behavior becomes automatized. Findings from the Flexible Item Selection Task with preschoolers and adults revealed that, although labeling the relevant dimension facilitates performance, performance declines when participants are prohibited from labeling. Labeling one's perspective on a situation not only helps make that perspective an explicit object of consideration, but it may also help children access more abstract conceptual descriptions of a stimulus Research on EF has broad implications for the way in which human learning differs from learning in other species and the way in which human learning may change over the course of development.

Article:
Decades of research curing the first part of the 20th century contributed to a comprehensive characterization of the way in which relatively simple organisms, such as rats and pigeons, learn. Meanwhile, research on nonhuman primates called attention to the rapid emergence of new behaviors (see, e.g., Rumbaugh & Washburn, 2003, for a review), including those attributed to insight (Kohler, 1925) and the formation of learning sets (Harlow, 1949). Fundamental forms of learning (e.g., classical and operant conditioning) may well be shared by many species, but human beings are not simple organisms, and the emergence of new behaviors is even more obvious in our species than it is in other primates. Nonetheless, even while research on many aspects of human cognition has proceeded apace, research on human learning, and how this learning changes with age, experience, and the development of the brain, has lagged behind. In this article, we argue that in human beings, including those just learning language, self-reflection, and self-control—studied under the rubric of "executive function" (EF)—have the potential to transform radically the way in which learning occurs.

EF refers to the set of mental processes involved in the cognitive control of thought, action, and emotion—processes that include inhibition, shifting, and updating (e.g., Miyake et al., 2000). EF emerges early in development, undergoes marked changes during the first 5 years of life, and continues to develop well into adolescence (see Zelazo, Carlson, & Kesek, in press, for a review). Research with typically developing preschoolers has revealed that individual differences in EF are related to perspective taking/theory of mind (e.g., Carlson, Mandell, & Williams, 2004; Perner & Lang, 1999) and school readiness (e.g., Blair & Razza, 2007) and also that performance on measures of EF can be trained (e.g., Dowsett & Livesey, 2000; Kloo & Perner, 2003; Rueda, Rothbart, McCandliss, Saccomanno, & Posner, 2005). Preschool and school curricula designed to foster the development of E F have also yielded promising results (Diamond, Barnett, Thomas, & Munro, 2007; Riggs, Greenberg, Kusche, & Pentz, 2006).

Our approach to EF and its development is unique in its emphasis on the role that self-reflection plays in allowing cognitive control. Consistent with the Levels of Consciousness (LOC) model (e.g., Zelazo, 2004; Zelazo, Gao, & Todd, 2007), consciousness is seen as a graded phenomenon that may function on a number of different "levels" brought about through the recursive reprocessing of the contents of consciousness. According to the LOC model, there are at least four age-related increases in children's highest level of consciousness, and each level has distinct consequences for EF.

The LOC model starts with the assumption that infants at birth are endowed with minimal consciousness, the unreflective and present-oriented awareness of immediate perceptual stimulation. With age and experience, however, the contents of minimal consciousness can also become the object of conscious thought via one or more degrees of reflection or the recursive reprocessing of information. Each degree of reflection allows for more nuanced representations of a stimulus as it comes to be considered in relation to larger contexts. For example, children may go beyond merely seeing a ball and appreciating its affordances to noting that it is called "a ball," thinking about the relation between this ball and the ball they lost yesterday, and so on. As they elaborate their representation of a stimulus through additional, cumulative degrees of reflection, children increase the range of aspects of the situation to which they may respond—they increase their potential for top-down cognitive control and cognitive flexibility, and they liberate themselves from the tendency to respond only on the basis of the most salient aspects of the situation. Language plays an increasingly important role in this process; higher LOC allows for the formulation (and maintenance in working memory) of more complex systems of verbally mediated if-then rules linking stimuli and responses. These rule systems then allow for a deliberate, top-down selection of appropriate action plans even when prior learning pulls for a particular prepotent response.

Experience, Reflection, EF, and Learning: Research Using Age-Appropriate A-Not-B Tasks

Marcovitch and Zelazo (2006, in press) have provided a formal, mathematical model of the emergence and early development of reflection and its influence on human behavior. According to their Hierarchical Competing Systems Model (HCSM), human behavior is a function of a competition between the influence of an evolutionarily conserved habit system and a representational system that develops by the addition of higher LOC. The two systems are organized hierarchically such that conscious representations can potentially override any effects of habit. Furthermore, reflection increases the influence of conscious representations and hence increases the likelihood that the effects of habit will be overridden. This competition can be illustrated by the simple example of taking out your keys to open your front door after a long day at the office. In the absence of reflection, your habit of selecting your office key from among those on your key chain may win out, resulting in a mildly embarrassing error. With reflection and perhaps even saying to yourself, "I need my house key," this error is unlikely to occur. The simple stimulus (keyhole) may be most strongly associated with the habit of selecting your office key, but reflection allows you to consider this stimulus in relation to its context (you are at home, not at work).

The competition between these two systems has been studied in the context of Piaget's (1954) A-not-B task. In the canonical task, intended for 8- to 12-month-old infants, an attractive object is hidden at one location (A) for several trials and then conspicuously hidden at a second hiding location (B). Many infants search perseveratively at Location A on the first 13 trial, committing the A-not-B error. The A-not-B task is well characterized as a measure of EF; successful performance requires that participants inhibit their learned tendencies to search at Location A, shift their task set from searching at Location A to searching at Location 13, and *update* their mental representations from an object at Location A to an object hidden at Location B. Furthermore, timely reflection on the task and its constraints should enhance success.

Marcovitch, Zelazo, and Schmuckler (2002; see also Marcovitch & Zelazo, in press) hypothesized that 9-monthold infants are unlikely to engage in self-initiated reflection in the same manner as older children and adults and should perseverate under standard conditions. They also reasoned, however, that while each A trial strengthens the habit to reach to A, habit strength should reach an asymptote. Meanwhile, each A trial also provides cumulative opportunities for reflection on the task and its affordances. At some point, the influence of reflection on behavior will outweigh the influence of habit strength. Indeed, overlearning should lead to more flexibility because the likelihood of reflection will increase as behavior becomes automatized, freeing up cognitive resources.

To test these hypotheses, Marcovitch et al. (2002) presented infants with 1, 6, or, 11 A trials prior to B trials and predicted that infants would have more difficulty after 6 A trials than after 1 A trial because of the difficulty in overcoming the stronger habit of reaching to Location A. However, they also predicted that infants would have less difficulty after 11 A trials than after 6 A trials because the overlearned practice of searching at Location A should free up cognitive resources that would allow for reflection on the task and its affordances. The results supported these predictions; infants had considerably more difficulty after 6 A trials than after 1 or 11A trials. This pattern of behavior is not limited to infancy. Marcovitch and Zelazo (2006, experiment 1) tested 2-year-old children on a multistep-multilocation search task, an age-appropriate modification of the A-not-B task. In this task, children watched as a candy was hidden in a plastic bag that was attached by a string to one of five cardboard swatches. To retrieve the candy, children had to perform a multistep procedure: remove a foam barrier, pull out a tray that revealed the five swatches, and select the appropriate swatch. Similar to their infant counterparts, 2-year-old children had more difficulty on B trials after 6 A trials than they did after 1 or 11 A trials. Once again, these results suggest that overlearning of A trials permits additional opportunities for reflection.

Further evidence for reflection arising from increased practice with toddlers can be seen in a search task with a homogeneous search space. Marcovitch and Zelazo (2006, experiment 2) employed an A-not-B type task in which objects were hidden in a sandbox first at one location (A) and then at another (B). Because the sand was always smoothed over before search was allowed, there was no clear demarcation of the hiding locations. In this task, the time taken to retrieve the object was used to assess knowledge of its location. On the first B trial, 2-year-old children needed more time to find the object after 11 A trials than after 3 or 7 A trials, indicating greater difficulty suppressing the habit of searching at Location A. However, children also needed less time to Find the object after 15 A trials than after 11 A trials. Although it may take more experience to achieve automaticity in the sandbox task than the multistep—multilocation search task, children again show a U-shaped pattern, consistent with the suggestion that, while habit strength increases with experience, so does the probability of reflection.

These findings may help us to make sense of earlier work with older children and adults on the effects of overlearning on reversal learning in intra- and extradimensional shift tasks (e.g., Esposito, 1975). One classic extradimensional shift task is the Wisconsin Card Sorting Test (WCST; Berg, 1948). In the WCST, participants are given test cards that vary on three dimensions (shape, color, and number) and must discover the rule for matching them to target cards that also vary on these dimensions. After sorting correctly by this rule for a certain number of consecutive trials (i.e., the number of reinforced trials), the rule changes and participants must then infer the new rule. Grant and Berg (1948) and Grant and Cost (1954) varied the number o reinforced trials and found that adults were less likely to perseverate, and more likely to switch, as a direct function of the number of reinforced trials. This pattern is expected based on the HCSM because the likelihood of reflection should he considerably greater in adults than in infants, allowing adults more easily to override the influence of habits. Still, with each additional preswitch trial, adults were more likely to reflect on the task and its affordances, allowing for cognitive flexibility versus stimulus control (for overlearning with adults in other contexts, see Nelson, Leonesio, Shimamura, Landwehr, & Narens, 1982; Rohrer, Taylor, Pashler, Wixted, & Cepeda, 2005).

In children, then, and to a greater degree in adults, reflection may make it possible immediately to override habits of responding. Overlearning and other circumstances that foster reflection may promote cognitive flexibility and allow for more rapid learning and relearning. Reflection and the top-down cognitive control that it makes possible may account for the rapid emergence of new behaviors in situations in which habits would otherwise prevail.

Labeling and Reflection: Results From the Flexible Item Selection Task

Another manipulation that may be expected to foster reflection is labeling. In particular, labeling one's perspective on a situation may help make that perspective an explicit object of consideration, which in turn could help one to select flexibly any particular perspective from which to reason. Jacques, Zelazo, and Laurence (2007) further hypothesized that language may promote cognitive flexibility by allowing children to access more abstract conceptual representations of stimuli instead of being tied to perceptually salient representations.

To examine the effects of labeling on cognitive flexibility, Jacques et al. (2007) assessed 3- to 5-year-olds in several labeling conditions on the Flexible Item Selection Task (FIST; Jacques & Zelazo, 2001). The FIST, developed on the basis of the Visual—Verbal Test (Feldman & Drasgow,1951), provides participants with three items (e.g., small blue shoe, small red shoe, and small red teapot) and requires them first to select a pair that is alike on one dimension (Selection 1, e.g., two shoes) and then to select a second pair that is alike on another dimension (Selection 2; e.g., two red items). On each trial, items vary on two of three dimensions (e.g., color and shape), and an irrelevant dimension is held constant across items (e.g., size). Thus, one *pivot* item (red shoe) must be selected twice on two different dimensions. Cognitive flexibility is inferred from participants' ability to select the second pair correctly. Specifically, Selection 1 demonstrates participants' ability to choose two nonidentical items that are similar on one dimension. However, given good Selection 1 performance, correct Selection 2 performance indicates cognitive flexibility. Jacques et al. demonstrated that labeling the relevant dimension on Selection 1 significantly helped cognitive flexibility in 4-year-olds on Selection 2, whereas labeling the irrelevant one did not. Moreover, relevant labels helped whether children were asked to label the stimuli themselves or whether the experimenter did the labeling. In addition, labeling the stimuli using the attribute term (e.g., "both red") or the higher order dimensional term (e.g., "both the same color") were both helpful. Labeling the matching pair (e.g., "both red") was as effective as labeling only the remaining item (e.g., "not that blue one"). Finally, FIST performance was significantly correlated with preschoolers' receptive language development and with their own tendency to label stimuli spontaneously.

Jacques et al. (2007) also explored labeling effects in adults using a dual-task approach on the FIST. In an initial pres Ludy designed to find equivalent verbal and nonverbal secondary tasks, adult participants completed a simple reaction time task while performing several secondary tasks.

Saying "toyboat" and hp smacking had equivalent effects on the primary task. In the actual experiment, adults performed an adult version of the FIST under three dual-task conditions: verbal (articulatory) suppression, nonverbal suppression, and no suppression. The nonverbal suppression condition was included to assess whether any decrements in performance on the primary task might result from limiting general cognitive resources, as opposed to limiting labeling. Jacques et al. predicted that, if language is important for cognitive flexibility, Selection 2 (but not Selection l) performance would be worse under verbal suppression than under nonverbal or no suppression. Consistent with their predictions, the authors found that only Selection 2 performance on the FIST was significantly worse under verbal suppression than under nonverbal or no suppression, suggesting that language continues to be important for flexible thinking in adults.

These results are also consistent with existing results on task switching (e.g., Baddeley, Chincotta, & Adlam, 2001; Kray, Eber, & Lindenberger, 2004; Mecklinger, von Cramon, Springer, & Matthes-von Cramon, 1999) and other related tasks (e.g., Baldo et al., 2005; Dunbar & Sussman, 1995; Glucksberg & Weisberg, 1966; Hermer-Vazquez, Spelke, & Katsnelson, 1999), although they are more compelling than some existing dual-task findings because the secondary tasks were equated to ensure that type of processes used (i.e., verbal vs. nonverbal) and secondary task difficulty were not confounded and because a fairly uncomplicated measure of cognitive flexibility was used. The verbal suppression-related difficulties found in adults in this study complement the labeling-related effects found with children on this same task (Jacques et al., 2007)
These results are consistent with the suggestion that labeling is an effective way to promote reflection and cognitive flexibility (see also Kirkham, Cruess, & Diamond, 2003; Towse, Redbond, Houston-Price, &Cook, 2000; see Jacques & Zelazo, 2005, for a review). To explain their specific pattern of results with both children and adults on this particular measure of cognitive flexibility, however, Jacques et al. (2007) argued that labels

may help performance on the FIST for reasons beyond promoting reflection. Specifically, because labels convey meaning about specific exemplars, identifying exemplars using distinct labels can help to accentuate the contrastive relations that exist between exemplars of the same hierarchically arranged dimension (e.g., red vs. blue items as instances of the color dimension), allowing children to represent and reason from higher order dimensions (e.g., color). Without language, the authors proposed, children are bound to consider only the lower order instances, effectively tying the children to the immediate here and now. By definition, higher order dimensions ire not grounded in concrete representations (Nelson, 1988) Consequently, symbolic tags help users to reason more easily from these conceptual representations, allowing them to be less influenced by perceptually salient instances. All these aspects of labels may help symbol users to go beyond perceptually salient information, resulting in greater cognitive flexibility and the relatively rapid emergence of new behavior.

DISCUSSION

We have argued that reflection makes EF possible, and EF in turn transforms the way in which learning occurs, allowing for cognitive flexibility and the ability to override consciously the influence of habits or predispositions and responses suggested by the immediate perceptual environment. The roots of reflection are present early in life, at least by the end of the 1st year. The research summarized here suggests that both overlearning and labeling appear to be effective methods for helping children to reflect on a task and respond in a more top-down fashion despite interference from prior learning or perceptually salient aspects of a situation. Overlearning provides additional opportunities for reflection, and it may also free up cognitive resources as behavior becomes automatized. Labeling one's perspective on a situation not only helps make that perspective an explicit object of consideration, but it may also help children access more abstract conceptual descriptions of a stimulus.

The proposed consequences of EF for learning may help explain the growing body of evidence that suggests that individual differences in EF are an important predictor of school readiness and success (e.g., Blair, 2002). Recent research by McClelland and colleagues (e.g., McClelland, Acock, & Morrison, 2006; McClelland et al., 2007) has been particularly informative in establishing links between EF and education in early childhood. In one study, these authors examined behavioral regulation (attention, working memory, and inhibitory control) in 4- and 5-year-old children (McClelland et al., 2007). Behavioral regulation was assessed via the Head-to-Toes task in which children were asked to do the opposite of what an experimenter requested (e.g., touch head when asked to touch toes and vice versa), thus requiring that they inhibit the natural urge to follow the experimenter's commands. Children who exhibited better self-regulation skills performed better on measures of literacy, vocabulary, and mathematics.

Clearly, research on EF has broad implications for the way in which human learning differs from learning in other species and the way in which human learning may change over the course of development. From our perspective, it may be beneficial to study conditions under which reflection is elicited in an effort to promote improvements in self-control and higher order thought. Although this research is still in its infancy, it provides a promising gateway to understanding and improving the way in which we teach our children to teach themselves.

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