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Chimpanzee Cognitive Control

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Abstract

Cognitive-control processes are a feature of human cognition. Recent comparative tests have shown that some nonhuman animals might share aspects of cognitive control with humans. Two of the executive processes that constitute cognitive control are metacognition and self-control; here, recent experiments with chimpanzees are described that demonstrated metacognitive monitoring and control when these animals engaged in an information-seeking task. Chimpanzees also showed strategic responding in a self-control task by exhibiting self-distraction as an aid to delay of gratification. These demonstrations indicate continuity with similar human cognitive capacities, and the performances of chimpanzees in these kinds of tests have implications for considering the nature of the intelligence of these animals and the evolution of human cognition.

Keywords

cognitive control, chimpanzees, metacognition, self-control, delay of gratification

Cognitive control involves a number of regulatory or executive processes that allocate attention, manipulate and evaluate available information (and, when necessary, seek additional information), plan future behaviors, and deal with distraction and impulsivity when they are threats to goal achievement. These processes are considered a feature of human cognition and an important developmental milestone (Davidson, Amso, Anderson, & Diamond, 2006; Posner & Snyder, 1975). Some critical features of cognitive-control processes are that, unlike automatic processes, they require sustained attention, are limited in terms of capacity, and are directed selectively and effortfully by the subject (Schneider & Shiffrin, 1977).

Cognitive control is not a single ability. It is a complex construct that subsumes multiple abilities, and it often involves self-knowledge, including the representation of one's goals and mental states. Among the various executive processes that constitute cognitive control are self-control and metacognition. Self-control is required to resist a more immediately available and valued outcome in favor of a more preferred reward that can only be obtained later or with more effort. Self-control has been extensively studied in humans, notably in work with children that has emphasized delay of gratification (e.g., the marshmallow test; Mischel, Shoda, & Rodriguez, 1989) and research on how to anticipate and potentially reduce or eliminate impulsive responses that occur when self-control is weak or depleted (e.g., Muraven & Baumeister, 2000).

Metacognition, which also has been studied extensively in human adults and children, supports adaptive cognitive control by allowing individuals to "think about thinking" (Metcalfe & Shimamura, 1994; Nelson, 1992). Metacognition involves awareness of comprehension, confidence about past or future task performance through prospective and retrospective monitoring, and behavioral flexibility in modifying responses or changing strategies to gather information or reduce uncertainty. Some theorists have suggested that the emergence of self-control in human development is linked to the ability to represent one's own mental states in part through metacognition (Sodian & Frith, 2008), although the nature of this relation remains to be fully described.

Given the importance of cognitive-control processes for humans and the interest in understanding the potential evolutionary emergence of these capacities in our species, there has been a strong focus of inquiry into self-control and metacognition in comparative research. Much of what we know about the parameters that support or impede self-control in both humans and nonhuman animals comes from comparative work (e.g., Logue, 1988), and more recently there has been concerted effort

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to examine the question of whether nonhuman animals show metacognitive capacities similar to those of humans (e.g., Beran, Brandl, Perner, & Proust, 2012; Smith & Washburn, 2005). At Georgia State University's Language Research Center, chimpanzees have participated in studies examining both of these aspects of cognitive control. Their performances indicate a psychological continuity with humans in controlled cognition that serves to benefit the animals by maximizing rewards from their environment.

Strategic Delay of Gratification

Delay of gratification typically is studied by allowing individuals to choose between smaller-sooner or larger-later rewards (intertemporal choice; Logue, 1988), or between taking one desired item immediately or getting a better item after a fixed delay interval (as in the marshmallow test). Other interesting approaches had shown that methodological variations sometimes had large effects on impulsivity and controlled responding in chimpanzees (e.g., Boysen & Berntson, 1995). In our research with chimpanzees and other primates, we devised a test inspired by a method of studying children's delay of gratification (e.g., Toner & Smith, 1977). The *accumulation test* continuously increases the value of the immediate reward and allows subjects to learn that waiting even longer will continue that accumulation. In essence, the task works like leaving money in an interest-bearing account: The longer one waits without taking out money (or eating the food reward, in this case), the more one accumulates. But the attractiveness of the presently available accumulation also increases over time, as do the length of deprivation and thus motivation to take it.

Originally, chimpanzees were given this test in a manual format in which food items were transferred from an out-of-reach supply into a bowl that was in their testing enclosure and that they could eat from at any time (Beran, 2002). The longer they waited to eat, however, the more food that was transferred. These animals were successful with the task, waiting for multiple minutes for all food items that could be obtained. Subsequent variations of the task manipulated the reward visibility and—an important control—automated the task so that no experimenters were present while the trial was ongoing, leaving the chimpanzees alone with the accumulating food reward. Even with these manipulations, the chimpanzees waited multiple minutes to gain a larger food reward (e.g., Beran & Evans, 2006).

This set the stage for asking whether chimpanzees might be capable of strategically directing and focusing their attention to facilitate better delay of gratification, similar to the strategic delay choices that children learn to utilize (e.g., Mischel et al., 1989). We assessed this by introducing three test conditions that varied in terms of whether self-control was required and whether items were given to the chimpanzees (Evans & Beran, 2007). In all conditions, an automated food dispenser dropped food items into a tube that was in the chimpanzees' enclosure and that had an end cap that could be detached to access whatever was in the end of the tube. Experimenters monitored the chimpanzees from another area using a closed-circuit video feed, and as soon as a chimpanzee disconnected the tube and ate a food item, the trial ended and no more food was delivered.

In the baseline condition, this tube was in the enclosure with the chimpanzees, and they could disconnect the tube and eat the contents whenever they wanted. Nothing else was present on those trials. The other two conditions involved also giving the chimpanzees items during the trial that they could interact with (e.g., magazines, crayons, paper, and similar items; Fig. 1a). In these two conditions, we calculated the total time that the chimpanzees engaged with those items and how many rewards they accumulated. In one of the two conditions, the chimpanzees also had the food tube in the enclosure with them, so they again had to demonstrate delay of gratification in not taking and eating the food items. In the other condition, however, the tube remained just out of reach on the outside of the enclosure. Food items were dispensed in the same way as in the other conditions, and the items were visible, but the chimpanzees had no need to delay gratification because they could not access the food tube until a predetermined delay interval ended. This delay interval was yoked to the delay intervals the chimpanzees generated in the condition with the accessible tube and items in which they did have to delay gratification to get more food.

The chimpanzees waited longer to eat food rewards when they had access to the tube and also had access to items compared to when the tube was accessible but there were no items. This was not surprising, because access to items in this case could have resulted in the chimpanzees using those items because they were there as a competing activity, and this would have led to a distraction from the accumulating food items. The critical result is shown in Figure 1b. Here, we compared how often items were manipulated by the chimpanzees in the condition where they had to maintain delay of gratification (i.e., delay maintenance was *self-imposed*) versus the condition where the delay was *externally imposed* by the experimenters who left the tube out of reach. Both conditions involved having to wait to get a high-preference food, but only one condition required that the chimpanzees had to control their behavior actively in order to succeed in the task.

The results were clear: When self-imposed delay maintenance was required, sometimes for as long as 20

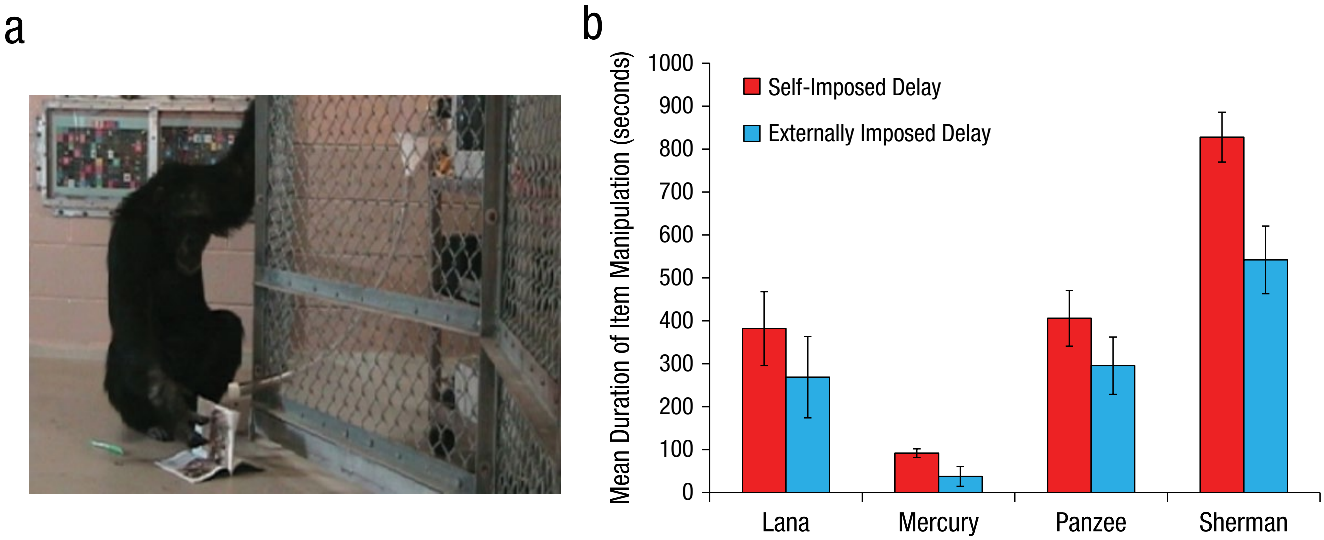

Fig. 1. Illustration of the experimental setup and results from Evans and Beran (2007). Panel (a) shows chimpanzee Sherman with items he could use for self-distraction during the accumulation test. The automated dispenser delivered food items one at a time into the tube that projected into his enclosure, and food items continued to accumulate as long as Sherman did not disconnect that tube and eat any food items. Panel (b) shows the mean cumulative duration of item manipulation for each chimpanzee. Error bars indicate standard errors of the mean. Delay maintenance was self-imposed (each chimpanzee had to keep itself from taking the food items) or externally imposed (the tube with the food items was out of reach but still visible). Three chimpanzees showed a statistically greater level of item manipulation in the self-imposed condition than the externally imposed condition—Mercury: paired $t(9) = 2.49$, $p = .034$; Panzee: paired $t(9) = 3.27$, $p = .01$; Sherman: paired $t(9) = 4.52$, $p = .001$. Lana did not show a difference, paired $t(9) = 0.92$, $p = .38$. Data are from Evans and Beran (2007).

minutes, three of the four chimpanzees engaged with the items for longer than when delay was externally imposed. Self-distraction occurred much less frequently when no self-imposed delay maintenance was required than when it was required. These three chimpanzees apparently knew when they needed to do something to boost or support their self-control, and they did something that was quite effective.

Metacognition

In another study (Beran, Smith, & Perdue, 2013), these chimpanzees observed one event in one location and then responded to what they knew about that event in another location. The chimpanzees did this by using the Language Research Center's lexigram keyboard system, which is a communication system of visuographic symbols that represent objects, locations, individuals, actions, and other aspects of the chimpanzees' environment. We made use of this unique capacity in these language-trained chimpanzees to ask whether the chimpanzees "know what they know" and could actively seek information that was needed in an object-naming task.

Previous information-seeking tasks given to animals and children (e.g., Basile, Hampton, Suomi, & Murray, 2009; Call & Carpenter, 2001) involved finding where food was hidden, with the claim that metacognitive control was at work when subjects reached when they knew where rewards were located but looked first when they did not know where they were located. Our task extended this procedure to instead ask chimpanzees to name what they had seen, in an effort to address concerns that earlier studies might have involved nonmetacognitive processes based on learned rules, such as reaching for food that had been seen but otherwise looking for food (see Call, 2010; Marsh & MacDonald, 2012).

At the outset of trials in our first experiment (Beran et al., 2013), a chimpanzee saw the first experimenter (E1) enter the test area with an opaque container, with a preferred food item inside. These items all had lexigram names that the chimpanzees knew, so they could name any of the possible items that were used. In some trials, E1 showed the chimpanzee what was in the container (*known* condition), but in other trials, the contents of the container could not be seen (*unknown* condition). E1 moved that container to another enclosure and left the test area. The chimpanzee then could move to that second enclosure where the container was located and where there was a second experimenter (E2) who was naive as to what was in the container and to whether the chimpanzee had seen what was in it. E2 was near a lexigram keyboard, and he observed what the chimpanzee indicated on that keyboard. When the chimpanzee touched a lexigram to name the item, E2 went to the container, and if the name matched the item type, the chimpanzee received the item as a reward. Critically, the

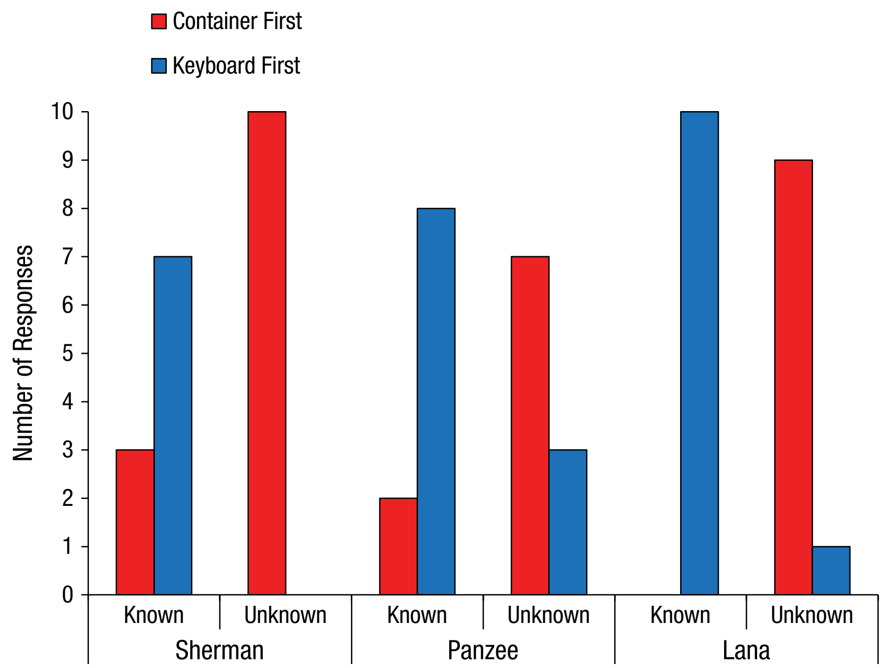

Fig. 2. Results from the Beran, Smith, and Perdue (2013) regarding chimpanzee metacognition. Each chimpanzee completed 10 trials where the container in which they had seen food was moved to the second enclosure (*known* condition), and 10 trials in which the other container was moved (*unknown* condition). All three chimpanzees were more likely to go to the keyboard rather than look in the container in the *known* condition, but the reverse was true for the *unknown* condition. Thus, these chimpanzees named items when they knew the item they had seen was in the container that was moved, but they waited to name the item and instead looked in the container first when the item they had seen was not in the container that was moved. Adapted from "Language-Trained Chimpanzees (*Pan troglodytes*) Name What They Have Seen but Look First at What They Have Not Seen," by M. J. Beran, J. D. Smith, and B. M. Perdue, 2013, *Psychological Science, 24*, p. 664. Copyright 2013 by the Association for Psychological Science. Adapted with permission.

container was located at a distance from E2 and the lexigram keyboard, so the chimpanzee had to choose whether immediately to move to the keyboard and provide a name for the item or to move to the container and first look into it to see what was inside. All chimpanzees showed more immediate naming on *known* trials, in which they already should have been able to name what was in the container, but they searched the container first on *unknown* trials, when they could not know the item's name without first looking into the container. This suggested metacognitive monitoring.

However, it was possible that a nonmetacognitive strategy could have been used by the chimpanzees that might have produced the same results without requiring cognitive control through memory monitoring and information-seeking responses. It was possible that the chimpanzees learned to approach a container when no food had been seen but to name any food item that had been seen. In a second experiment, two containers were presented at the start of the trial. Each container held a different type of food, and the food in one container was always shown to the chimpanzee whereas the food in the other container was not. The critical manipulation was that, on half of the trials, the container with the revealed food item then was moved to the second enclosure where naming occurred (*known* condition), whereas in the other half of trials, the container whose food item had not been revealed was the one that was moved (*unknown* condition). Thus, in the first case, the chimpanzees had seen what was inside the container that moved, whereas in the second case, they had not, but in both cases they had seen a food item. The key thing they had to recognize and remember as they moved to the second location was whether the item they had seen was in the container that moved or did not move. It was not appropriate simply to name what had been seen, as could have been done in the earlier experiment.

The results are shown in Figure 2. All chimpanzees were more likely to name the item they had seen in the *known* condition, but they were more likely to first look into the moved container in the *unknown* condition. Thus, when initially seeing food or not seeing food could not serve as a cue for which response to make, chimpanzees still effectively monitored their memories for what information they had, and what information might still be needed, as they moved through space and attempted to earn rewards. These results also indicated a sophisticated form of cognitive control that underlies flexible and adaptive information-seeking behavior in chimpanzees.

Implications and Outstanding Questions

The question of whether chimpanzees have cognitive control in the form of self-control and metacognition should be answered in the affirmative. The more appropriate question moving forward is to what degree chimpanzees and other animals demonstrate such control and under what circumstances. Answering this question will highlight the nature of cognitive control in other species and will be informative about the evolution of such control in humans. It also will illustrate how different contexts might support stronger or weaker cognitive control in humans.

Controlled (vs. automatic) processing also is characterized by conscious awareness in humans. Given the cognitive control that is evident in at least the great apes, and perhaps other species, questions naturally emerge regarding the nature of animal consciousness. Other difficult questions also remain. For example, Baumeister (2008) has argued that self-control and intelligent, controlled decision making are two important phenomena in a psychological approach to studying free will. If this is true for humans, is it also true for chimpanzees and other animals, or are these phenomena relevant only when they are evident (sometimes) in human behavior? If memory monitoring and directed information-seeking are evident in nonhuman animals, does this indicate only intrapersonal cognitive control (i.e., the implicit control of only one's own knowledge), or might some species also show suprapersonal cognitive control (i.e., the control of multiple agents' behavior through cooperation, information exchange, and weighing different confidence levels; Shea et al., 2014)? At present, these may be intractable questions, for which new empirical methods and clear operational definitions are required to spur progress, but they are also exciting questions to consider as we come to understand more about cognitive control and its extent and limits in other species.

Recommended Reading

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Crystal, J. D., & Foote, A. L. (2011). Evaluating information-seeking approaches to metacognition. *Current Zoology*, *57*, 531–542. An article that discusses important issues in assessing information-seeking tasks that are used with nonhuman animals.

Metcalfe, J., & Mischel, W. (1999). A hot/cool-system analysis of delay of gratification: Dynamics of willpower. *Psychological Review*, *106*, 3–19. This article discusses delay of gratification and cognitive-control processes in more detail than the current article.

Mischel, W. (2014). *The Marshmallow Test*. New York: Little, Brown. A clearly written and comprehensive review for readers who wish to expand their knowledge on delay of gratification in humans.

Smith, J. D., Couchman, J. J., & Beran, M. J. (2012). The highs and lows of theoretical interpretation in animal-metacognition research. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *367*, 1297–1309. An article that discusses interpretive issues in animal metacognition research in more detail than the current article.

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Declaration of Conflicting Interests

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