Can squirrel monkeys (*Saimiri sciureus*) plan for the future? Studies of temporal myopia in food choice

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In seven experiments, 2 squirrel monkeys were given choices between arrays of food that varied in the quantity offered. In Experiments 1–5, the monkeys were offered choices between quantities of the same food that varied in a 2:1 ratio. The squirrel monkeys failed to show the temporal myopia effect or a decrease in preference for the larger quantity as the absolute number of food items offered increased. Even when given choices of 8 versus 16 peanuts and 10 versus 20 peanuts, both monkeys significantly preferred the larger quantity. An examination of the monkeys' rates of consumption indicated that 20 peanuts were consumed over a 1- to 2-h period, with eating bouts separated by periods of nonconsumption. In Experiments 6A, 6B, and 7, food was either pilfered or replenished 15 min after an initial choice, so that choice of the smaller quantity led to more total food in the long run. These manipulations caused both monkeys to reduce choice of the larger quantity, relative to baseline choice. The results suggest that squirrel monkeys anticipated the future consequences of their choices.

The theoretical question of whether animals are capable of *cognitive time travel* has received considerable attention of late. Humans cognitively time travel either backward from the present moment by remembering memories of personal episodes (episodic memory) or forward from the present moment by anticipating and planning for future events. In a review of relevant literature from animal research, Roberts (2002) concluded that most of the data favored the hypothesis that animals were *stuck in time*, or did not cognitively time travel. Suddendorf and Corballis (1997) reached a similar conclusion about nonhuman primates (NHPs).

On the other hand, recent studies of memory for cached food in scrub jays have led to the conclusion that these birds can cognitively time travel (Clayton & Dickinson, 1998, 1999; Clayton, Yu, & Dickinson, 2001). Scrub jays were allowed to cache a preferred but perishable food (worms) and a less preferred but nonperishable food (peanuts) in different spatial locations. When tested for food recovery after 4 h, when the worms were still edible, the jays first visited the worm cache sites. When tested for food recovery after 128 h, when the worms had decayed, the jays first visited the peanut cache sites. These findings were interpreted to mean that the scrub jays remembered *when* they had cached worms, thus showing episodic-like memory. Some evidence for forward cognitive time travel

also has been reported for scrub jays. Emery and Clayton (2001) found that scrub jays who had cached food re-cached the food in new locations if they had been observed caching by another scrub jay. This behavior was found only in scrub jays that themselves had previously pilfered the caches of other scrub jays. Emery and Clayton suggested that having been a pilferer, a scrub jay could now anticipate that the observer scrub jay would pilfer its cache. To prevent this occurrence, it re-cached its food.

These studies and reviews have sparked further research on the question of cognitive time travel in NHPs and non-primate species. Roberts and Roberts (2002) failed to find evidence of either episodic memory or anticipation of a future event in a test of rats' spatial memory on the radial maze. Bird, Roberts, Abroms, Kit, and Crupi (2003, Experiment 6) examined rats' recovery of cached food that did and did not degrade after a fixed time period; unlike the scrub jays, the rats showed no preference for non-degraded food sites over degraded food sites. In an investigation of episodic memory in an ape, Schwartz, Colon, Sanchez, Rodriguez, and Evans (2002) found that a gorilla could remember both *what* and *who* information over a long retention interval. When fed a particular food by a particular experimenter, the gorilla could correctly choose cards 24 h later that identified the type of food and the identity of the experimenter. Schwartz et al. argued that these findings satisfy some of the criteria for episodic-like memory in animals.

In a recent series of experiments bearing on the question of cognitive time travel in animals, Silberberg, Widholm, Bresler, Fujita, and Anderson (1998) used a natural-choice procedure to study food choice in two species of Old World

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monkeys (*Macaca fascicularis* and *Macaca fuscata*) and in a chimpanzee (*Pan troglodytes*). An interesting observation that they called the *temporal myopia effect* was discovered when NHPs were given choices between different quantities of the same food. For example, the chimpanzee was given a choice between one and two peanuts on some trials and between four and eight peanuts on other trials. When the choice was between one and two peanuts, the chimpanzee chose two peanuts on about 75% of the trials. When the choice was between four and eight peanuts, however, the chimpanzee chose each alternative on 50% of the trials. In other words, a preference for the larger alternative disappeared as the number of food items offered increased. Silberberg et al. (1998) suggested that the NHPs began to show indifference between these choices when the smaller quantity reached or exceeded an amount that met an animal's current need. Because the animal could not anticipate a future need for excess food not consumed immediately, it chose only on the basis of whether each alternative met its current need. Thus, four peanuts were just as valuable to the chimpanzee as eight peanuts.

Other findings from food choice experiments with NHPs raise questions about these findings. Rumbaugh, Savage-Rumbaugh, and Hegel (1987) carried out a test of food summation in chimpanzees that required the animals to choose between two trays that each contained two food wells filled with different numbers of chocolates. In one test, 2 chimpanzees chose between trays containing sums of chocolates in a 3:4 ratio; on some trials, the numbers of chocolates on the two trays were three versus four, and, on other trials, the numbers of chocolates were six versus eight. One chimpanzee chose both four over three and eight over six on 95% of the trials. The other chimpanzee chose four over three on 90% of the trials and eight over six on 89% of the trials. In a recent study, Beran and Beran (2004) allowed chimpanzees to view an experimenter place bananas in each of two opaque containers, with the bananas placed in the containers one at a time in an order that guaranteed that one container would have a greater total number than the other. When the number of bananas was one versus two, 4 chimpanzees chose the container with the larger number on 77.5% of the trials. When the number of bananas was two versus four, the same chimpanzees chose the container with four bananas on 88.75% of the trials. In a second experiment in which the choice of 5 versus 10 halves of a banana was used, the same chimpanzees chose the container with the larger number on 91.25% of the trials. Another set of experiments that may be seen as favoring the temporal myopia effect was reported by Hauser, Carey, and Hauser (2000). Semi-free-ranging rhesus monkeys (*Macaca mulatta*) observed testers place different numbers of apple slices in two opaque containers and then chose between the containers. When the choice was between two versus one apple slices, 93.3% of the monkeys chose the container with two apple slices. When the choice was between containers with eight versus four apple slices, however, only 53.3% of the monkeys chose the container with eight apple slices. Although Hauser

et al. favored an interpretation of these findings in terms of counting limitations in monkeys first encountering a number-of-food-items discrimination, the results agree nicely with the findings of Silberberg et al. (1998) that favor a temporal myopia effect.

It seems clear from this review that there is disagreement in the data from tests with Old World monkeys and chimpanzees regarding the temporal myopia effect and, thus, regarding whether these animals can anticipate future consequences of their food choices. We report here investigations of the temporal myopia effect in 2 squirrel monkeys (*Saimiri sciureus*). An important factor in the ability to anticipate future consequences of food choices may be a brain that has developed the cognitive ability to map out the locations of food in both space and time. One hypothesis about the factors driving the development of the primate brain and intelligence is that ecological demands promote the selection of larger brains (Milton, 1988). In the case of primates, it has been suggested that species that are arboreal, largely frugivorous, and must search for patchily distributed food over a large range would develop larger brains (Clutton-Brock & Harvey, 1977, 1980). These characteristics are largely true of the macaques and chimpanzees tested in temporal myopia experiments. Among New World primates, squirrel monkeys are a good candidate for tests of cognitive time travel because this species meets all of these characteristics (Thorington, 1968) and, in addition, has been shown to have a relatively high cephalization index or large brain size relative to its body size (Jerison, 1973; Russell, 1979). The goal of this work was to extend the study of temporal anticipation in NHPs and, particularly, to carry out a comparative study with New World monkeys to find out whether they would show the same effects as those Silberberg et al. (1998) found with Old World monkeys and a chimpanzee or whether their behavior would be more like that in the studies reviewed in which NHPs chose the larger number of food items even when the absolute quantity was relatively large. Choice tests between different foods were carried out initially to determine food preferences. A number of experiments then were performed in which monkeys chose between food arrays that varied in quantity.

EXPERIMENT 1

This experiment and all of the following experiments addressed the question of temporal myopia versus anticipation of the future in squirrel monkeys. In Experiment 1, the monkeys were tested on a variety of choices designed to affirm their food preferences and to test for temporal myopia effects with both preferred and nonpreferred foods. These choices then involved tests in which the ratio between larger and smaller quantities was maintained at 2:1 but the quantities offered varied.

Method

Subjects. Jake and Elwood, 2 adult squirrel monkeys (*Saimiri sciureus*), served as subjects in this and all the subsequent experi-

ments. Although both monkeys had participated in a variety of cognitive behavioral experiments, none of these had involved choices between different arrays of food. They were housed separately for feeding purposes but were frequently released into a play cage where they could interact. The monkeys were maintained on a 12:12-h light:dark cycle. They had unrestricted access to water. In addition to the food they received during testing, they were fed a variety of foods 2 h or more after testing, including fresh fruits and vegetables.

Apparatus. The monkeys were transported from their housing room to a testing room, where they were placed in an enclosed chamber. The testing chamber was a $50.8 \times 49.53 \times 52.0$ cm box with one side and ceiling made of clear Plexiglas. Two sides were opaque, with one containing a 22.86×22.86 cm sliding door for placing a monkey in the apparatus. The fourth wall contained a 31.75×11.43 cm viewing window made of Plexiglas and two slots where trays containing food could be slid into the box. Each tray contained a food well that was 3.81 cm in diameter and 1.27 cm deep.

Procedure. A monkey was transferred from the housing room in a carrying cage and was placed in the testing apparatus. At the beginning of a trial, the two food arrays were placed on separate sliding trays that were visible through the observation window in the testing apparatus. The trial commenced when the monkey was looking at the food choices. The experimenter then slid the two trays into the apparatus simultaneously. As soon as the monkey made a selection, the nonselected tray was removed from the apparatus before the monkey could grasp the food on the tray. The monkey then was allowed to eat the food on the tray it had selected. The experimenter then withdrew the selected tray and prepared the trays for the foods to be offered on the next trial. The next trial began when the monkey was again attending to the two possible choices visible through the observation window. Upon completion of the session's trials, the monkey was returned to its home cage. The monkeys were fed their normal daily meal 2 h after testing.

Both monkeys' preferences for five foods were tested, which included mealworms, peanuts, zucchini, green beans, and monkey chow. Each monkey was given a choice between each possible com-

bination of two foods once per day for 15 days. Over all trials with a given food, Jake's preferences were mealworm (93%), peanuts (78%), zucchini (47%), beans (18%), and monkey chow (13%). Elwood's preferences were mealworm (100%), beans (65%), peanuts (50%), zucchini (33%), and monkey chow (2%).

For each monkey, two foods were selected within its mid-range of preferences. Within these pairs, zucchini was the preferred (P) food and beans were the nonpreferred food (NP) for Jake, and beans were the preferred (P) food and peanuts were the nonpreferred (NP) food for Elwood.

The monkeys were tested on eight trials per day for 20 days, with each trial containing a choice between two food arrays that varied in the number of food items offered. The eight trial types were the following: (1) 1 P versus 2 P, (2) 1 NP versus 2 NP, (3) 2 P versus 4 P, (4) 2 NP versus 4 NP, (5) 1 P versus 2 NP, (6) 1 NP versus 2 P, (7) 2 P versus 4 NP, and (8) 2 NP versus 4 P. The eight types of trials were presented in different random orders between days, and the left-right positions of the choices were balanced over trials for each type of trial.

Analyses. All the choice proportions obtained in this experiment and in all of the subsequent experiments were tested against chance (50%), using the binomial test. The level of significance used on all the tests was $p < .05$.

Results and Discussion

Figure 1 shows the percentage of choices of the array containing the preferred food on the four types of trials that involved choice between preferred and nonpreferred foods. Both monkeys always showed significant preference for the array that contained the preferred food, even when there was more of the nonpreferred food than of the preferred food. Thus, the monkeys' food preferences were clearly maintained throughout these tests.

Figure 1. Percentages of trials on which Elwood and Jake chose the array containing the preferred food in Experiment 1. P, preferred; NP, nonpreferred. *Significantly different from 50%.

Figure 2A shows performance on trials in which the monkeys were offered different quantities of the nonpreferred food. Interestingly, neither monkey showed a significant preference for the larger quantity, either when the choice was between one and two items or between two and four items. Figure 2B shows performance when the choice was between different quantities of the preferred food. By contrast to the nonpreferred food trials, significant preference for the larger quantity was shown in all cases except Elwood's choice for 2 P versus 4 P.

The results of this experiment are mixed in terms of their support for the temporal myopia effect. Elwood's loss of significant preference for the larger quantity when the quantities were increased is consistent with Silberberg et al.'s (1998) finding that Old World NHPs demonstrated temporal myopia. On the other hand, Jake continued to prefer the larger quantity when the overall amounts were doubled and thus failed to show any evidence of temporal myopia. It may be the case that the quantities of food uti-

lized in this experiment were not large enough to produce a temporal myopia effect with Jake.

EXPERIMENT 2

The purpose of this experiment was to further test for the temporal myopia effect by increasing the number of food items in each choice while keeping the ratio between choices at 2:1.

Method

Both monkeys were tested using the same apparatus and procedure as those in Experiment 1. Preference tests indicated that Jake had switched his preference from zucchini to beans and that Elwood continued to prefer beans to peanuts. Thus, all the tests offered the monkeys a choice between two quantities of beans. Only two types of trials were given each monkey; on one trial, the choice was one versus two beans, and on the other trial, the choice was four versus eight beans.

The last element to differ in this experiment was the number of trials per day. It could be argued that one of the shortcomings of the

Figure 2. (A) Percentages of trials on which Elwood and Jake chose the larger nonpreferred (NP) food quantity in Experiment 1. (B) Percentages of trials on which Elwood and Jake chose the larger preferred (P) food quantity in Experiment 1. *Significantly different from 50%.

previous experiment was that there was no incentive for the monkey to choose the larger quantity because, with multiple trials, more food would be forthcoming in the near future. Thus, a monkey that could anticipate the future still might not choose the larger quantity, because it could foresee no eventual shortage of food. This potential problem was rectified in Experiment 2 by giving the monkeys only one trial per day. The monkeys were tested over a total of 60 days, with each type of trial tested on 30 days and the order of tests randomized across days.

Results and Discussion

As can be seen in Figure 3, neither Jake nor Elwood demonstrated a preference for two beans over one bean. Jake significantly preferred eight beans over four beans, but Elwood did not show this preference. The results of this experiment failed to show the temporal myopia effect. Elwood failed to show a significant preference for the larger quantity on either type of trial, and Jake actually showed a reverse effect from those reported by Silberberg et al. (1998), by choosing the larger quantity significantly above chance only when the four versus eight choice was offered.

EXPERIMENT 3

As was demonstrated in Experiment 1, the preference for the larger quantity was more evident when the monkeys chose between varying quantities of a preferred food, as compared with varying quantities of a less preferred food. Thus, Experiment 3 was a replication of Experiment 2 in which an even more preferred food was used. The reward was mealworm, which the preference tests had shown was highly favored by both monkeys.

Method

Apparatus. Jake and Elwood were tested in the same apparatus as that in Experiments 1 and 2.

Procedure. Mealworms that measured about 1 cm in length were used as the food in this experiment. Choice tests between mealworm

and other foods showed that both squirrel monkeys preferred mealworm to any other food. The quantities offered were the same as those in Experiment 2. Thus, half the trials involved a choice between one versus two mealworms, and the other half of the trials involved a choice between four versus eight mealworms.

The number of trials on which each monkey was tested varied. Jake was tested for 60 days, with 30 trials on each choice. However, Elwood was stopped sooner than anticipated because he developed behavioral problems. He became very agitated when placed in the testing apparatus. Therefore, Elwood was tested only for 13 trials on the one versus two problem and only for 12 trials on the four versus eight problem.

Results and Discussion

As compared with Experiment 2, the use of mealworms made Jake's preference for the larger quantity more evident. As can be seen in Figure 4, Jake significantly preferred both two worms over one worm and eight worms over four worms. This was not the case for Elwood, who still demonstrated no preference for either the smaller or the larger quantities. Once again, the evidence does not support the temporal myopia hypothesis, since one monkey showed no significant preference on either choice and the other showed significant preference for the larger quantity on both choices.

EXPERIMENT 4

This experiment addresses two related problems evident in the previous experiments. First, the quantities of food offered the monkeys may have been sufficiently small that the monkeys could consume them all in a short space of time. One of the premises underlying the theory of temporal myopia is that animals cannot cognitively project themselves into the future. Therefore, they do not take into consideration the possibility that they may not be able to consume all of the food available and can eat leftover food at a later time. Thus, using quantities of food that can be consumed quickly may not be a good test of temporal

Figure 3. Percentages of trials on which Elwood and Jake chose the larger quantity of beans in Experiment 2. *Significantly different from 50%.

myopia. The second concern with the prior experiments is that monkeys were removed from the testing apparatus immediately after the trial was completed. As a consequence, any uneaten food that might be consumed at a later time was unavailable to them. Once again, this is not an ideal procedure for testing temporal myopia versus the possibility that monkeys can anticipate future need.

Method

Subjects and Apparatus. Jake and Elwood continued to be tested in this experiment. To eliminate the problem of monkeys being removed from the place where uneaten food would be kept, they were no longer transported to the apparatus used in Experiments 1–3 for testing. Instead, both monkeys were tested in their home cages (76.5 cm high $\times$ 45.7 cm wide $\times$ 61.0 cm deep). The stainless steel home cages contained a 30.5 $\times$ 7.7 cm wire-mesh window on the front of the cages through which the monkeys could reach.

Procedure. The monkeys continued to be tested on one trial per day, and there continued to be only two types of trials. However, the quantity of food used and the type of food was changed from those in Experiments 1–3. In Experiment 4, peanuts were used because they do not perish over time as quickly as mealworms, beans, or zucchini. Whole peanuts, rather than pieces of peanuts, were utilized in order to increase the quantity of food available for consumption. Furthermore, the number of pieces of food was increased. The monkeys had to choose between 2 and 4 unshelled peanuts and between 8 and 16 unshelled peanuts. This increase in the amount of food items increased the likelihood that not all of the food would be consumed in one continuous feeding session. The peanuts were presented in two clear plastic drinking glasses that were 8.89 cm tall and had top and bottom diameters of 7.62 and 5.08 cm, respectively. The experimenter held the two cups at equal distances from the monkey, in front of its cage. After it had chosen one container by touching it, the food in the touched container was placed in the monkey's food bin. The experimenter who tested the monkeys was not familiar with the hypothesis being tested.

During each monkey's testing, the other monkey was taken out of the housing room in a carrying cage. This controlled for the possibility that the monkeys would influence one another's choice behavior. The second monkey was returned to its home cage after the first monkey had made its choice and was presented with the same food choice.

Results and Discussion

The findings are displayed in Figure 5. Jake significantly preferred 4 over 2 peanuts and 16 over 8 peanuts. These findings are consistent with Jake's results in the previous experiments, because he continued to demonstrate a preference for the larger quantities of food, despite the large increase in the amounts offered in this experiment. Elwood's findings, by contrast, departed from those of the previous experiments. Although Elwood did not show a significant preference for 4 peanuts over 2 peanuts, he significantly preferred 16 peanuts over 8 peanuts.

The findings from both Jake and Elwood fail to support the temporal myopia hypothesis, because both monkeys significantly preferred the larger quantity when the choice was between 8 and 16 peanuts. They suggest that Silberberg et al.'s (1998) findings with Old World macaques and a chimpanzee may differ from those found with squirrel monkeys.

EXPERIMENT 5

Although it was the experimenter's impression that the monkeys took an extended period of time to consume all of the peanuts chosen in Experiment 4, no data were taken on the time to eat the chosen array. In addition, Silberberg et al. (1998) reported no detailed data on the rates at which their monkeys and chimpanzee consumed the foods chosen in their experiments. Experiment 5 was carried out to examine the time course of food consumption and to carry out a test of temporal myopia with still larger arrays of food offered to the monkeys. In particular, the monkey's choice of quantities when it can be shown that food consumption goes far beyond the immediate period after choice provides a strong test of temporal myopia.

Method

Jake and Elwood were tested again in their home cages. The procedure was identical to that in Experiment 4, with the exception that the

Figure 4. Percentages of trials on which Elwood and Jake chose the larger quantity of meal worms in Experiment 3. *Significantly different from 50%.

Figure 5. Percentages of trials on which Elwood and Jake chose the larger quantity of peanuts in Experiment 4. *Significantly different from 50%.

monkeys were offered choices between 2 and 4 peanuts and between 10 and 20 peanuts. The experiment was carried out over 40 days, with one trial per day. A choice between 2 and 4 whole unshelled peanuts was given each monkey on 20 trials, and a choice between 10 and 20 whole unshelled peanuts was given on the other 20 trials. These types of trials occurred in a random order, and the left–right positions of the larger and the smaller quantities were balanced across trials for each type of trial.

To measure the time course of food consumption, the experimenter recorded how many peanuts were uneaten at 10-min intervals after the monkey had made its choice. These measurements were taken for choices of both 10 and 20 peanuts. In addition, observations were recorded on some days when the monkeys were given 10 or 20 peanuts without choice.

Results and Discussion

Figure 6A shows that both Jake and Elwood significantly preferred 4 peanuts over 2 peanuts and 20 peanuts over 10 peanuts. There is no indication that preference for the larger quantity was diminished with larger numbers of peanuts. In fact, Elwood showed equal preference for the larger quantity in both choices, and Jake showed a somewhat larger preference for 20 over 10 peanuts than for 4 over 2 peanuts.

In Figure 6B, the cumulative number of peanuts consumed is plotted over 10-min blocks of time from the moment (0 min) that the monkey received 10 or 20 peanuts. These curves reveal that it took Elwood, on average, 20 min to consume 10 peanuts and 110 min to consume 20 peanuts. Jake ate somewhat more slowly, taking about 30 min to consume 10 peanuts and not completely finishing 20 peanuts after 140 min. It appears that the monkeys consumed 10 peanuts in what could be considered one eating session, since they appear to have eaten these continuously. On the other hand, both monkeys appear to have stopped eating at different points while consuming 11–20 peanuts. This fact is most evident when consumption curves are examined for individual days but can still be seen in the averaged data. For example, Elwood shows a plateau

where he consumed 18 and 18.25 peanuts at 80 and 90 min, respectively. Jake shows plateaus at three different occasions. At 40 and 50 min, Jake consumed 11.25 and 11.5 peanuts, respectively. At two other pairs of successive time points, Jake consumed nothing over the 10-min intervening period: At both 100 and 110 min, Jake had consumed 16.5 peanuts, and, at both 130 and 140 min, Jake had consumed 18 peanuts. These data suggest that 20 peanuts were not consumed in a single eating session and are consistent with the idea that the monkeys took the larger quantity so that they could consume them at a later point in time. Once again, the data failed to show any evidence of the temporal myopia effect in squirrel monkeys.

EXPERIMENTS 6A AND 6B

Both Jake and Elwood significantly preferred 16 over 8 peanuts in Experiment 4 and 20 over 10 peanuts in Experiment 5. An important observation made in Experiment 5 was that 20 peanuts were not consumed in one bout of eating. Both monkeys took 1–2 h to consume the peanuts, with breaks in their consumption activity during which no peanuts were eaten. This observation is in keeping with the possibility that choice was based on the anticipation that the larger quantity of peanuts would be eaten over an extended time period in the future.

These findings with squirrel monkeys, then, are consistent with the possibility that they can anticipate future need for food and contrast with Silberberg et al.'s (1998) findings with two species of macaques and a chimpanzee. Some caution should be advised, however, in leaping to the conclusion that squirrel monkeys can plan for the future. If Silberberg et al. had found initially that their monkeys and chimpanzee preferred the larger alternative to the smaller alternative equally at all food quantities, they probably would not have judged this to be evidence for

Figure 6. (A) Percentages of trials on which Elwood and Jake chose the larger quantity of peanuts in Experiment 5. (B) Cumulative curves for Elwood and Jake, showing the rate of peanut consumption over successive 10-min periods after they received 10 or 20 peanuts in Experiment 5. *Significantly different from 50%.

cognitive anticipation of the future. Rather, it might simply have appeared that the monkey's natural choice was to take the larger amount when offered a choice. Foraging opportunities in the wild dictate that fitness is best served by choosing the patch with the most food available. It was the counterintuitive aspect of Silberberg et al.'s findings that led to the explanation of indifference in choice between larger quantities as the result of temporal myopia. Although Jake and Elwood's choice of the larger amount when larger numbers of peanuts were used is consistent with cognitive anticipation of the future, it is also consistent with the possibility that their natural (evolved) preference is for larger amounts of food.

Stronger tests of forward cognitive time travel were carried out in Experiments 6A, 6B, and 7. In Experiments 6A and 6B, squirrel monkeys again chose between containers of 10 and 20 peanuts and received whichever quantity was chosen. After a baseline of preference for the larger quan-

tity had been established, a pilfering manipulation was introduced. Whenever a monkey chose the larger 20-peanut quantity, the experimenter returned to its cage 15 min later and pilfered all of the remaining peanuts. Consumption across time data demonstrated that a monkey did not consume 10 peanuts within 15 min. Thus, under the pilfering condition, a monkey actually obtained fewer peanuts in the session by choosing 20 instead of 10. However, the loss of peanuts always occurred 15 min into the future after the choice of 20 peanuts. We reasoned that if a monkey could anticipate this future loss of the greater present total, it should modify its preference toward equal or even greater choice of the 10-peanut quantity.

Method

Apparatus. The apparatus used in Experiment 6A was identical to that in the previous experiment. The apparatus was slightly modified for Experiment 6B, which consisted of the creation of a new

food bin. The food bin was 15.5 cm high $\times$ 14.5 cm wide $\times$ 9.0 cm deep, with a clear Plexiglas sliding backdoor that measured 7.4 $\times$ 9.0 cm. The remainder of the apparatus was the same as that in Experiment 6A. The food bin was altered for Experiment 6B because it was noted that the method used to take the consumption time measures and to pilfer food in Experiment 6A may have interfered with the monkeys' normal behavior. In order to count the number of uneaten peanuts and to pilfer the remaining peanuts after 15 min, the experimenter had to nudge the monkeys away from the food bins, thereby blocking the monkeys' access to the food. This raised the concern that this method may have unintentionally taught the monkeys to stay away from the food bins and may have reduced their attention to the peanuts. The possibility that this disruption may have somehow confounded the results of Experiment 6A was rectified in Experiment 6B by the construction of this new food bin.

Procedure. Both Experiments 6A and 6B consisted of a multiple-baseline design in which, prior to experimental testing, each monkey was tested on 16 baseline trials of food choice and was required to select between 10 and 20 peanuts. No pilfering took place during baseline testing. The purpose of the baseline trials was to ensure that both monkeys chose the 20 peanuts on a significant majority of trials, since the hypothesis being tested was that preference for the larger alternative may display preparation for future needs. The monkeys' baseline behavior was then compared with their behavior during the experimental trials. As in the previous experiment, the monkeys were tested on only one trial per day.

In both Experiments 6A and 6B, after the Baseline 1 period, 12 pilfering trials were conducted at the rate of 1 trial per day. Whenever a monkey chose 20 peanuts, the monkey had its peanuts pilfered 15 min after the initial choice was made. The remaining food choice procedure was the same as that in the baseline period. The left-right positions of the choices were selected at random and were balanced over trials for each monkey for both baseline and pilfering testing. The monkeys were fed their normal daily meal 2 h or more after testing was completed.

The procedure was the same as that in Experiment 5, except that the monkeys chose between 10 and 20 peanuts. Consumption time measures for baseline periods were taken by recording the number of uneaten peanuts at 10-min intervals after the monkeys had made their choice. For Experiment 6A, these measurements, which were recorded for choices of both 10 and 20 peanuts, were taken by removing each monkey's food bin, counting the remaining number of peanuts, and then placing the food bin back in the home cage. For Experiment 6B, these measurements were taken without removing the food bins, since the new food bins allowed for measurement by counting peanuts seen through transparent Plexiglas. When peanuts were pilfered, the sliding door at the back of the food bin was used. Thus, the monkey's activities were not disrupted.

The consumption time measure calculated during baseline testing was used to determine the pilfering time for the experiment. At 15 min, Jake and Elwood consumed, on average, approximately 7 to 8 peanuts and 6 to 7 peanuts, respectively, of their 20 peanuts. Therefore, 15 min was chosen as the pilfering time, since it provided the monkeys with the opportunity to learn that a choice of 10 peanuts was better if they were planning for the future. In addition, consumption rates were used to ensure that the monkeys were not eating all their peanuts in one session but, rather, were consuming them over an extended period of time.

Results and Discussion

The data presented in Figure 7A show the percentage of trials on which Jake and Elwood chose the larger quantity of peanuts (i.e., 20 peanuts) in Experiment 6A. During Baseline 1, both Jake and Elwood significantly preferred 20 peanuts over 10 peanuts, choosing 20 peanuts on 81.3% and 75.0% of the trials, respectively. During the

pilfer stage of Experiment 6A, Elwood continued to significantly prefer 20 peanuts. In fact, the percentage of trials on which Elwood chose the larger quantity remained unchanged at 75.0%. Jake showed a drop in his preference for 20 peanuts in the pilfer stage, choosing them at the chance level of 50.0% of the trials. Preference for the larger quantity of peanuts was restored during Baseline 2, with both Jake and Elwood choosing 20 peanuts on a significant majority of trials (81.3% and 87.5% of the trials, respectively).

In Figure 7B (Experiment 6B), Baseline 1 is the same as Baseline 2 in Figure 7A. During the pilfer stage, Jake and Elwood's choice of 20 peanuts dropped to 58.3% and 66.7% of the trials, respectively, and did not differ significantly from 50%. The results from Baseline 2 of this experiment indicate that both Jake and Elwood chose 20 peanuts on 81.3% of the trials; therefore, their preference for the larger quantity returned when pilfering no longer occurred.

The trends in the rate of consumption data for 10 and 20 peanuts over time during the baseline and pilfer phases of both Experiments 6A and 6B were similar to those observed in Experiment 5. The data suggest that the monkeys consumed 10 peanuts in one eating bout; in contrast, 20 peanuts were consumed over an extended period of time consisting of multiple eating bouts. These results are consistent with the idea that choice of the larger amount of peanuts was made so that the monkeys could consume them at some point in the future.

In Experiments 6A and 6B, both Jake and Elwood displayed peanut-hoarding behavior by removing peanuts from their food bins and hoarding them on the bottoms of their cages (see Table 1). These observations suggest the possibility that the monkeys hoarded the peanuts in anticipation of future pilfering, since both monkeys displayed this peanut-hoarding behavior only during experimental trials. No observation of peanut hoarding by either monkey was made during baseline trials.

The results from Experiment 6A suggest that Jake learned to anticipate that 20 peanuts would be pilfered and altered his behavior accordingly. The drop in preference for 20 peanuts from the baseline to the pilfer phases suggests that Jake learned that the smaller quantity was the better choice and selected the smaller quantity in an attempt to plan for the future. Elwood, on the other hand, was not significantly affected by the pilfering experience. It was noted that the method used to take the consumption time measure may have interfered with the monkeys' normal behavior. In order to count the number of uneaten peanuts and to pilfer peanuts, the experimenter had to nudge the monkeys away from the food bins during the experiment, thereby blocking the monkeys' access to the food. It is possible that this method may have unintentionally caused the monkeys to stay away from the food bins and may have reduced their attention to the peanuts. However, this disruption was removed from the procedure of Experiment 6B, and the results from this experiment support the conclusion that the squirrel monkeys may be ca-

Figure 7. (A) Percentages of trials on which Elwood and Jake chose the larger quantity of peanuts (20) during Baseline 1, pilfering, and Baseline 2 in Experiment 6A. (B) Percentages of trials on which Elwood and Jake chose the larger quantity of peanuts (20) during Baseline 1, pilfering, and Baseline 2 in Experiment 6B. *Significantly different from 50%.

pable of forward cognitive time travel. The drop in preference for 20 peanuts indicates that both monkeys had the ability to anticipate and plan at least 15 min into the future.

EXPERIMENT 7

The purpose of the present experiment was to further test for forward cognitive time travel abilities in squirrel monkeys by performing an experimental manipulation in the direction opposite from the one used in Experiments 6A and 6B. The initial choice between food items was reduced to four peanuts versus two peanuts. Instead of choice of the larger number triggering a pilfering manipulation, choice of the smaller number triggered a replenishment manipulation. After a monkey chose two peanuts,

the experimenter returned 15 min later and added eight more peanuts. Thus, choice of the smaller quantity led to a greater overall number of peanuts than choice of the larger quantity did.

Method

Procedure. Both monkeys were tested using the same procedure described in Experiment 6B, with only two differences. First, each trial now contained a choice between 2 and 4 peanuts. Second, no pilfering occurred during the baseline or the replenishment phases. An initial period of baseline choice (Baseline 1) between 2 and 4 peanuts was given to ensure that preference for 4 peanuts was present in both monkeys prior to the start of the experimental trials. In the replenishment phase of testing, choices of 2 peanuts led to replenishment with 8 more peanuts 15 min after the initial choice, resulting in a total of 10 peanuts for the monkey to consume. This occurred only when a choice of 2 peanuts was made and occurred only in the

Table 1
Number of Peanuts Hoarded on the Bottoms of the
Cages by Jake and Elwood on Various Trials During
Experiments 6A and 6B

Trial	Number of Peanuts Hoarded			
	Experiment 6A		Experiment 6B	
	Jake	Elwood	Jake	Elwood
2	0	0	4	3
3	0	4.5	0	5
6	0	0	3	0
7	3	0	0	0
8	2	3	0	4
12	0	0	0	6
Total	5	7.5	7	18

replenishment phase of testing. A choice of 4 peanuts resulted in a total of 4 peanuts. On average it took Elwood 2 min to eat 2 peanuts and 8 min to eat 4 peanuts. Jake took, on average, 2 min to consume 2 peanuts and 12 min to consume 4 peanuts. Therefore, when a choice of 4 peanuts was made, all the peanuts were consumed before 15 min. Fifteen minutes was chosen as the replenishment time for peanuts for Experiment 7 since it provided the monkeys with the opportunity to learn that a choice of 2 peanuts was better if they were planning for the future. A choice of 4 peanuts would result in complete consumption of the peanuts prior to 15 min, whereas a choice of 2 peanuts would result in additional peanuts 15 min after the initial choice was made.

After Baseline 1 was completed, each monkey was given four forced choice trials. The monkeys were presented with choices of two and four peanuts, following the same procedure as that used in Experiment 6B. Although both choices were in view of the monkeys, only one choice was within reach (i.e., the forced choice). The choice of peanuts that were within reach was randomized across the 4 days, with 2 days of each choice being forced. The left-right positions of the choices in the forced choice trials were randomized. On trials in which the forced choice was two peanuts, the experimenter returned 15 min later to add eight peanuts to the food hopper. When the forced choice was four peanuts, no additional peanuts were given. These forced trials were given to familiarize the monkeys with the replenishment manipulation that was used during the free-choice experimental trials. It was designed to avoid the possibility that monkeys would choose only four peanuts and, thus, not experience replenishment.

The replenishment phase of testing followed the forced choice trials and was followed by another baseline phase (Baseline 2). To summarize, the monkeys were tested on one trial per day for 16 days in Baseline 1, one trial per day for 4 forced choice days, one trial per day for 12 days during the replenishment phase, and one trial per day for 16 days for Baseline 2. The left-right positions of the choices were randomized between trials and were balanced for each monkey for both baseline and replenishment testing.

Results and Discussion

The proportion of trials on which the larger quantity of peanuts (i.e., four peanuts) was chosen is shown for Baseline 1, replenishment, and Baseline 2 in Figure 8. The results from Baseline 1 show that both Jake and Elwood significantly preferred four peanuts over two peanuts; both chose four peanuts on 87.5% of the trials. Replenishment of peanuts when an initial choice of two peanuts was made caused preference for four peanuts to drop significantly below the chance level of 50%. Jake chose four peanuts on

only 33.3% of the trials, and Elwood chose four peanuts on only 25.0% of the trials. Preference for the larger quantity of peanuts was recaptured during the Baseline 2 period, with both Jake and Elwood choosing four peanuts on a significant majority of trials (81.3% and 75.0% of the trials, respectively).

Only one observation of peanut hoarding by Elwood took place during Experiment 7, in which he hoarded six peanuts on the bottom of his cage. Jake was noted to hoard peanuts twice during Experiment 7. On the first occasion, Jake hoarded one peanut, and on the second occasion he hoarded two peanuts on the cage floor. All of these peanut-hoarding observations occurred during the experimental replenishment phase.

The results from this experiment further support the conclusion that squirrel monkeys may be capable of forward cognitive time travel. The drop in preference for four peanuts from baseline to the replenishment trials suggests that both monkeys were able to anticipate the forthcoming replenishment of two peanuts with eight peanuts and were able to alter their choice behavior accordingly so as to maximize the amount of food they would have in the future.

GENERAL DISCUSSION

Silberberg et al. (1998) found that two species of Old World monkeys and a chimpanzee preferred a larger number of food items over a smaller number when the amounts offered were small, but not when the amounts offered were large. They called this a *temporal myopia effect* and suggested that it arose because NHPs could not anticipate a future need for food beyond that of the moment. The present Experiments 1–3 provided little evidence for the temporal myopia effect in squirrel monkeys. Only in Experiment 1 did Elwood show a significant preference for two over one food item, but indifference was shown between two and four items. Elwood then failed to show a significant preference for the larger number with both smaller and larger quantities of food in both Experiments 2 and 3. Jake consistently showed a significant preference for the larger number when a choice between larger quantities was offered and either preferred the larger number or showed indifference when a choice between smaller quantities was offered.

Some shortcomings of those experiments were rectified in Experiments 4 and 5. The testing conditions for temporal myopia were improved by testing the monkeys on one trial per day in their home cages, using a nonperishable food (peanuts) and offering choices between larger quantities. Under these conditions, no further food could be obtained on subsequent trials, and all the food chosen would be available to the monkey over an extended time period past the time of choice. Under these conditions, both monkeys showed evidence that weighed heavily against the temporal myopia effect. They clearly preferred the larger number of food items over the smaller number of food items when the quantities offered were large. Thus, both Jake and Elwood significantly preferred 16

Figure 8. Percentages of trials on which Elwood and Jake chose the larger quantity of peanuts (four) during Baseline 1, replenishment, and Baseline 2 in Experiment 7. *Significantly different from 50%.

over 8 peanuts in Experiment 4 and 20 over 10 peanuts in Experiment 5. An important observation made in Experiment 5 was that 20 peanuts were not consumed in one bout of eating. Both monkeys took 1–2 h to consume the peanuts, with breaks in their consumption during which no peanuts were eaten. This observation is in keeping with the possibility that choice was based on the anticipation that the larger quantity of peanuts would be eaten over an extended time period in the future.

The finding that Jake and Elwood chose the larger number of food items when large quantities were offered is inconsistent with Silberberg et al.'s (1998) findings but is consistent with other findings that chimpanzees maintain a strong preference for the larger number of food items when larger quantities are offered (Beran & Beran, 2004; Rumbaugh et al., 1987). Although the maintenance of a preference for the larger quantity regardless of total amount offered in NHPs argues against temporal myopia and in favor of anticipation of future need for food, it might also be explained as a genetically programmed foraging strategy to maximize energy gain. In other words, consistent preference for larger quantities of food is not particularly strong evidence for cognitive time travel into the future.

Experiments 6A, 6B, and 7 then were performed as stronger tests of forward cognitive time travel in squirrel monkeys. They addressed the question of whether the monkeys' normal preference for the larger quantity could be reduced when that choice led to less total food in the long run than choice of the smaller quantity did. Importantly, the monkey could understand the implication of its choice only if it could anticipate future depletion (Experiments 6A and 6B) or replenishment (Experiment 7) of the amount currently chosen. When food was pilfered 15 min after a choice of 20 peanuts, Jake in Experiment 6A and both Jake and Elwood in Experiment 6B showed a decline

in preference for 20 peanuts to a level that did not differ significantly from chance. Furthermore, when 20 peanuts had been chosen, both monkeys were observed to hoard peanuts on the floor of their cages during experimental pilfering sessions, but not during baseline nonpilfering sessions. When a choice of 2 peanuts instead of 4 peanuts led to an additional 8 peanuts 15 min later in Experiment 7, both Jake and Elwood showed a significantly lower than chance choice of 4 peanuts.

The finding that the effects seen in Experiment 7 were stronger than those seen in Experiments 6A and 6B may be understandable in terms of the total amounts gained by choice of the smaller quantity. When the monkeys chose 20 peanuts, they usually consumed 7–8 peanuts within 15 min. Thus, the total gained by choosing 10 over 20 peanuts was 2 or 3 peanuts when the remaining 12 or 13 peanuts were pilfered in Experiments 6A and 6B. When choice of 2 peanuts was replenished with 8 peanuts in Experiment 7, however, the total gained by choosing 2 instead of 4 peanuts was $10 - 4 = 6$ peanuts.

It is interesting to compare these findings with squirrel monkeys with those from other experiments with NHPs that bear some similarity to these studies. In a self-control experiment, a subject may choose between responses that lead to a small immediate reward or a larger delayed reward. A typical choice in such experiments is 2-sec access to reward after a 0.1-sec delay versus 6-sec access to reward after a 6-sec delay. Experiments with rats and pigeons show consistent preference for the immediate (0.1-sec delay) but smaller reward (Logue & Mazur, 1981; Mazur & Logue, 1978; Tobin, Chelonis, & Logue, 1993). By contrast, humans show self-control behavior by choosing the delayed but larger reward (Logue, 1988). Tobin, Logue, Chelonis, Ackerman, and May (1996) tested cynomolgus monkeys (*Macaca fascicularis*) and found that they behaved like humans by consistently choosing

the delayed alternative. This macaque species then behaved in a fashion that suggested it could anticipate at least a briefly delayed consequence.

In experiments with chimpanzees, a selector animal was allowed to choose between two arrays of candies varying in amount from one to six. Whichever amount the selector animal chose was given to an observer animal, and the selector animal received the other (nonchosen) quantity. Although the chimpanzees were tested over many trials, they consistently chose the larger amount and, thus, received the smaller amount. Their preference for the larger number was overcome only when they chose between Arabic number symbols instead of real candies (Boysen & Berntson, 1995; Boysen, Berntson, Hannan, & Cacioppo, 1996).

The experiments above are interesting to contrast with the present findings. Only monkeys, among the animals tested in the self-control paradigm, have been found to show self-control, albeit only for a few seconds. The chimpanzees tested by Boysen and her colleagues could show self-control when tested with number symbols, but not when tested with actual food quantities. Two squirrel monkeys, Jake and Elwood, on the other hand, showed excellent self-control in Experiments 6A, 6B, and 7 by choosing the greater of two immediately available quantities of peanuts below baseline levels when the delayed consequence of their choice was 15 min into the future.

The fact that Jake and Elwood failed to show temporal myopia by consistently preferring the larger quantity of food but were able to reduce or reverse that preference when choice of the smaller amount led to a favorable consequence 15 min later suggests that these squirrel monkeys could anticipate a future event. Why the macaque monkeys and chimpanzee studied by Silberberg et al. (1998) showed temporal myopia and Jake and Elwood did not is not clear. Some factors that would seem to make *Saimiri* a good candidate for the possible discovery of future planning are their natural ecology and their brain-to-body ratio. Squirrel monkeys forage over a large range of patchily distributed food resources, which may have placed an evolutionary demand on the species for spatial and temporal mapping and, therefore, a larger brain. Their relatively high cephalization index supports this possibility. On the other hand, these comments are generally true of the macaques and chimpanzee studied by Silberberg et al. Another possible difference is in test sophistication. Jake and Elwood have been tested on a variety of cognitive tasks over a number of years. These include foraging in artificial trees, learning to prefer number symbols associated with greater rewards, and using landmarks to find food within a spatial environment. Perhaps these monkeys developed a sensitivity to future events through this extended testing. In itself, it would be quite remarkable that monkeys could learn a sense of time or future planning on the basis of lab experiences. Such an effect would suggest that a latent ability for cognitive time travel might exist in many NHPs.

Future research may be directed toward testing the limits of future planning in squirrel monkeys. Can a positive consequence be delayed longer than 15 min and still have

an impact on earlier behavior? Note that Jake and Elwood's choice behavior and the subsequent consequences in Experiments 6A, 6B, and 7 always had to do with the acquisition and consumption of peanuts. Some observations of chimpanzees in the wild have suggested future planning, because they carry stones to nut-cracking sites and prepare and carry sticks for termite fishing to termite mounds (Boesch & Boesch, 1984; Lawick-Goodall, 1971). The Bischof-Kohler hypothesis (Roberts, 2002; Suddendorf & Corballis, 1997) suggests that this future planning is limited to situations in which the motivation at the time of tool preparation matches that for which the tool will be used. No evidence of planning for a future reward that is not currently desired has been found. Is the future planning suggested by Jake and Elwood's behavior limited in the way indicated by the Bischof-Kohler hypothesis? An interesting question is whether these squirrel monkeys' choice of food quantities would be affected by a delayed consequence that involved a different food or, perhaps more interesting, a delayed opportunity to perform some desired activity that did not involve food at all. Experiments of this nature may help us better understand whether anticipation of future events in NHPs is limited or has a breadth that perhaps approaches human future planning.

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