The Influence of Task Specific Factors on Quantity Discrimination by Brown Capuchins (Cebus apella) and Squirrel Monkeys (Saimiri sciureus)

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The Influence of Task Specific Factors on Quantity Discrimination by Brown Capuchins (*Cebus apella*) and Squirrel Monkeys (*Saimiri sciureus*)

Alison Billas

Program in Animal Behavior - Honors Thesis
The Influence of Task Specific Factors on Quantity Discrimination by
Brown Capuchins (Cebus apella) and Squirrel Monkeys (Saimiri sciureus)

By

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A Proposal Submitted to the Honors Council
For Honors in Animal Behavior

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Approved by:

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Abstract

Previous studies have revealed that non-human primates discriminate quantities. However, their performance is highly variable both within and between species. Discrepancies in performance may be the result of a variety of factors, including species-specific cognitive differences or task specific factors such as representational format of the choice stimuli, motivation to perform that task, or tolerance for task delays. Six brown capuchin monkeys (Cebus apella) and six squirrel monkeys (Saimiri sciureus) were presented with two numerical quantities in three different conditions, replicating Schmitt and Fischer’s (2011) study with baboons and macaques. Primates were rewarded with a quantity of food corresponding in number to the quantity of the choice stimulus selected. Results revealed an influence of representational format and species on performance, however, other potential confounding variables remained that may have been affecting performance. Additional testing of the influence of the motivational value of the food reward and the time delay between choice and reward revealed a significant effect of motivation on performance. Increasing the motivation resulted in the lack of an effect of both modality and species on quantity discrimination performance. These results suggest that poor performance in quantity discrimination tasks can be potentially explained by a lack of motivation to perform.

Keywords: capuchins, squirrel monkeys, modality, counting, motivation
Introduction

Many species can discriminate quantities, including primates (Beran, 2001, Brannon & Terrace, 1998, Hauser, MacNeilage & Ware, 1996, Hauser, Carey & Hauser, 1999), dolphins (Kilian, Yaman von Fersen & Gunturkun, 2003), birds (Pepperberg & Gordon, 2005) and rodents (Panteleeva, Reznikova & Vygonailova, 2013). However, it is unclear whether the mechanisms non-human species use to make these discriminations mirror those employed by other animals or by humans. The existence of a single mechanism that governs the representation of numerical values across human and non-human animals would suggest that numerical representation is a primitive, non-verbal, evolutionarily selected ability. Rhesus macaques (*Macaca mulatta*) and college students showed qualitatively and quantitatively similar results in a quantity discrimination test, providing evidence in favor of a single mechanism underlying numerical competence (Cantlon & Brannon, 2006). Macaques and humans discriminated quantities up to 30 with the same level of accuracy, and showed decreased accuracy and increased response latency as the ratio between the two numerical quantities increased.

Both the capuchins and squirrel monkeys at Bucknell University have previously shown evidence of numerical ordering abilities (Judge; Smith et al.). Animals ordered quantities of shapes on a touch screen and then transferred this ability to novel stimuli. Initially, only one of three capuchin subjects showed true numerical ordering abilities (ranking ascending quantities) when taking into account the confounding variable of using surface area as a means to arrange quantities. Continued testing and reinforcement of correctly ordered numerical quantities resulted in all three capuchins correctly ordering the quantities presented without relying on the cue of surface area (Judge, Evans & Vyas, 2005). The one squirrel monkey tested on this task
performed significantly better than chance when discriminating quantities equal in size and surface area, but required more than 3,500 training trials to achieve this performance level above chance (Smith, Piel & Candland, 2003). Because the capuchins and squirrel monkey completed nearly identical experiments, their performance could be compared. The squirrel monkey performed above chance on only two of the six stimulus sets, whereas the capuchin subjects performed above chance on five or six sets. Additionally, the capuchins’ overall accuracy for ordering novel stimulus sets (47%, 44%, and 27% for the three subjects) was considerably higher than the squirrel monkey’s accuracy (16%; Judge et al., 2005, Smith et al., 2003). These comparisons may possibly reflect a species difference of performance in quantity discrimination ability, suggesting that capuchins are more successful in using quantity as a cue.

While other species are capable of discriminating quantities, this ability may be heavily impacted by factors unrelated to the quantities themselves, such as the modality of the stimuli presented, motivation to complete the task, and the delay between choice and reward. A study by Schmitt and Fischer (2011) revealed that the representational format of the to-be-discriminated quantities influenced performance in Old World primates. Olive baboons (Papio anubis) and long-tailed macaques (Macaca fasicularis) received a quantity of food equal to the quantity of items they chose in a two-choice quantity discrimination task. The primates selected between two food, pebbles or food replaced quantities. Food represented both a highly salient choice and reward stimulus that the monkeys pointed to and received immediately, while pebbles were a choice stimulus leading to an immediate food reward of the same magnitude, hidden underneath the plate presenting the pebbles. In the food replaced condition, the monkeys selected a quantity of food, but similar to the pebbles condition received the identical food type and amount hidden underneath the plate. This condition contained elements of both the food and
pebbles conditions. As in the food condition, food was initially present to the primates but similar to the pebbles condition, the food reward was initially hidden. Monkeys performed well when choosing between quantities of tokens that stood in for food, but performed poorly when choosing directly between quantities of food. Schmitt and Fischer (2011) suggested this poor performance in the food condition was due to either a lack of impulse inhibition (the presence of a highly salient food impairs judgment) or the inability to understand the representation of a stimulus (i.e. food) as both the choice and the reward.

Other studies have confirmed that stimulus format, as well as task specific factors, such as delay and motivation, can impact performance. A study by Addessi, Crescimbene and Visalberghi (2007) addressed the influences of stimulus format and delay on capuchins’ performance in a food and token quantity discrimination experiment. As in Schmitt and Fischer (2011), animals made a choice between two different quantities of food items or two different quantities of tokens that were then exchanged for a corresponding quantity of food. In contrast to Schmitt and Fischer’s findings in Old World Primates, capuchins performed significantly better when discriminating between quantities of food items than between quantities of tokens. Addessi et al. (2007) had two alternative hypotheses for the poor performance in the token condition. The tokens, which stood in for the received quantities of food, may have required a higher cognitive demand that impaired performance compared to choices between food items themselves. This cognitive demand may have resulted from the complexity of understanding that the inedible pebbles could be exchanged for an edible food reward. Alternatively, the comparatively long delay between selecting a token quantity and exchanging it for a food reward may have resulted in either increased memory demands or decreased motivation to perform.
Therefore, it is unclear whether modality, delay, or motivation had the strongest influence on the performance.

An experiment by Schrier and Harlow (1956) investigated the impact of motivation on performance in a discrimination-learning task. Eight java monkeys (*Macaca fascicularis*) were tested in an object discrimination task that tested their ability to discriminate between two colors. In the task both the reward size and the difficulty of the task varied. The food reward varied between one, two, or four food pellets, representing an increase in motivation as the size of the reward increased. The difficulty of the task varied with the size of the stimuli presented to the monkeys, with a larger surface area of color providing more information and thus easier discrimination. Results revealed that increased food reward (two and four food pellets relative to one pellet) led to a significantly higher performance in the discrimination-learning task. This effect was evident across all levels of difficulty, indicating that motivation positively affected performance in both the simple and difficult discrimination tasks. This suggests that poor performance can sometimes be explained by a lack of motivation to complete the task.

Most studies aimed at determining the factors affecting numerical cognition have focused on just one variable, and do not differentiate between the many small factors that can affect performance, making it impossible to determine the mechanisms underlying quantity discrimination. For example, while modality affects performance for both Old and New World monkeys, these groups appear to be affected differently. Old World primates performed significantly better when tokens served as the choice stimulus (Schmitt & Fischer, 2011), while capuchins, a New World primate species, showed significantly worse performance when tokens served as the choice stimulus (Addessi et al., 2007). This may be due to a taxonomic difference in quantity discrimination ability between Old and New World primates. However, the
difference in performance between the species could alternatively be due to differences in tolerance for other factors such as the higher cognitive demand of using tokens to represent a food reward, delay in receiving the food reward or motivation associated with choosing between food items rather than tokens.

In the following set of experiments I will independently test the effects of representational format, motivation, and delay on performance in a quantity discrimination task across capuchin and squirrel monkeys to determine if there are genuine species differences in numerical ability or simply differential responses to specific task parameter differences. If there are genuine species differences in quantity discrimination performance, I predict that both the capuchins and squirrel monkeys will perform worst in the Pebbles Condition, following a performance pattern most similar to the capuchins in the Adessi et al. (2007) experiment. If performance is influenced by task specific parameters, I predict that experimental manipulations such as increasing motivation or decreasing the length of delay will improve performance regardless of modality and species.

**Methods**

**Subjects**

Subjects were six brown capuchins (*Cebus apella*; 4 females; mean age 7.1 ± 3.8 years) and six squirrel monkeys (*Saimiri sciureus*; 6 females; mean age 9.8 ± 2.7 years) housed at Bucknell University. All monkeys were born and raised in stable captive groups. The capuchin monkeys were from a social colony consisting of 20 monkeys and the squirrel monkeys were from a social colony consisting of 10 monkeys. The monkeys were housed in a USDA approved facility. All monkeys had prior experience with cognitive tasks but no prior experience with quantity discrimination.
Housing

The capuchins were housed in a large indoor enclosure consisting of nine interconnecting compartments averaging 2.0 x 1.8 x 2.4 m each, spanning three rooms. The enclosure consisted of a mixture of plastic paneling and stainless steel caging with linoleum floors covered in wood chips. Each compartment was furnished with several perches and climbing structures that the capuchins could rest on during testing. In addition, the stainless steel cage wire was spaced far enough apart (2.54 x 5.08 cm) for the capuchins to reach out and interact with the researcher. Subjects were tested in their home cage and maintained visual and auditory contact with their social group. During testing, each subject was physically isolated from the group by temporarily closing off doors and blocking off overhead walkways.

The squirrel monkeys were housed in an indoor/outdoor enclosure. The indoor enclosure was approximately 5.3 m x 5.8 m x 2.3 m and was constructed of plastic paneling and stainless steel wire caging with linoleum floors covered in wood chips. This enclosure was subdivided into three compartments roughly equal in size that were interconnected by doorways that could be closed during testing to separate individual subjects. The outdoor enclosure was a corncrib 12 m high and 5 m in diameter that was connected to the indoor enclosure via a steel wire tunnel. When the weather was warm enough, the squirrel monkeys could freely move amongst the indoor and outdoor enclosures, but were always tested indoors. Similar to the capuchins, each compartment was furnished with perches and climbing structures that the squirrel monkeys could rest on while testing, and the animals were physically separated in their home cage for testing, maintaining visual and auditory contact with their social group. Food and water were available ad libitum for both species.
Apparatus

Testing apparatuses varied slightly for the capuchins and squirrel monkeys due to differences in enclosure space. For both the capuchins and squirrel monkeys, the apparatus had a flat table-like surface on which two identical opaque Tupperware containers (13.97 x 13.97 cm, 6.4 cm deep) were placed, each of which were completely covered by two identical opaque flat plates (13.97 x 13.97 cm) so that the monkeys could not see the contents inside of the Tupperware container. The choice stimuli, pebbles (black rounded beads, ~ 1.0 cm in diameter) or pieces of grapes, were placed on top of these flat plates and were visible to the primates. The pebbles were a novel stimulus for both the capuchins and squirrel monkeys. Each grape was cut into approximately eight pieces; therefore, all quantities of food reinforcers and choice stimuli refer to 1/8th of a grape.

For each trial for the capuchins, the testing apparatus was pushed directly up against the cage so that the monkeys could easily reach it while resting on a perch. The testing apparatus was a large, table-like structure made of plastic, approximately 0.86 x 0.35 x 1.42 m. This apparatus had an occluder barrier that could easily be removed when the capuchins had to make their choice and be placed back on so the capuchins could not see the quantities being prepared. This barrier matched the measurements of the apparatus, approximately 0.86 m across and 0.35 m high. For the squirrel monkeys, the same flat plastic table-like structure (0.86 m x 0.35 m) was mounted directly to the cage at a height accessible to the squirrel monkeys while resting on a perch. The occluder barrier used for the squirrel monkeys was a small cardboard box, approximately 0.45 x 0.11 x 0.30 m.
Procedure

General Procedure

A total of eight conditions were completed over the course of this experiment that varied in modality of the stimulus presented, motivation level and length of delay. Each condition consisted of 40 total trials broken into four blocks of ten trials. For each trial, the occluder barrier was placed between the subject and the choice stimuli as the quantities were being prepared. At the start of each trial, the occluder barrier was raised and the monkey was prompted to make their choice by the phrase, “Which one [insert name of primate].” Monkeys received the number of food rewards corresponding to the number of choice stimuli on the plate that they selected, regardless of whether it was the smaller or larger quantity. The researcher collected the food reward and directly handed it to the primates through the caging. For all trials, the side containing the larger quantity was semi-randomized to avoid left and right side biases. All training and testing sessions consisted of 10 trials. All trials were video recorded. All procedures were approved by the Bucknell IACUC.

Pre-training

In order to get the monkeys accustomed to the apparatus and to “pointing” to their choice, each monkey was presented with a pre-training phase in which their choices were an empty plate and a plate with one food reward (grape piece) on it. Monkeys pointed to the plate with the food reward on it in order to receive that reinforcer. If they pointed to the plate that did not contain the food reward, they received no reinforcer and moved on to the next trial. Primates moved onto the training phase of the experiment after achieving 100% accuracy within a 10 trial session (pointing to the plate with the grape on it all 10 times in a row). Each subject completed pre-training only once.
Training

Each of the eight testing conditions in the experiment was preceded by a training phase. These training phases laid out the contingencies (type of choice stimuli, type of food reinforcer, length of delay) present in that condition. Quantity pairs of 2 with 7 and 1 with 6 were intermixed semi-randomly within 10 trial blocks (five of each quantity pair). These quantities pairs were chosen from the Schmitt and Fischer (2011) paper and were deemed to be quantities relatively easy to discriminate. The criterion to move onto testing was choosing the larger quantity eight times out of 10 trials (80% accuracy).

Testing

Testing differed from training in that primates were presented with 20 different choice pair combinations (combinations of quantities 1 through 8). Each individual received four, 10-trial sessions per condition. Each of the 20 possible quantity pairs was presented semi-randomly twice over the course of the four sessions, resulting in a total of 40 trials. Each quantity pair differed in the numerical distance between the two quantities and in the numerical ratio between the two quantities. Identical quantity pairs in the first column were not included in statistical analysis and were solely used to test for side biases (Table 1).

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Data Analysis

Correct choices were scored as the choice of the higher quantity item in the pair. Repeated measures ANOVA and paired samples t-tests were used to compare performance across different conditions within a species. One sample t-tests compared performance to a chance rate of 50% correct. All tests used an alpha level of $p \leq 0.05$.

Conditions

All subjects completed three experiments in the following order. Experiment 1 consisted of three conditions that replicated those in Schmitt and Fischer (2011): Food, Food Replaced, and Pebbles. Experiment 2 tested the impact of motivation on performance by increasing motivation (using preferred food rewards) in the Food and Pebbles Conditions. Experiment 3 tested the impact of delay on performance by varying the length of delay between choice and reward in the Food and Pebbles Conditions. Finally, I ran a learning check following completion of the experimental manipulations to assure that any improved performance over the course of the experiment was due to experimental manipulations rather than general learning over time. Each condition consisted of a training phase and a testing phase.

Experiment #1: Replication Conditions

This experiment was designed to test the impact of representational format on performance in our New World monkeys by replicating the three conditions in the Schmitt and Fischer (2011) experiment. If the differences in findings between Schmitt and Fischer (2011) and Addessi et al. (2007) are due to species differences in the impact of representational format on quantity discrimination, then the capuchins and squirrel monkeys should follow a performance pattern more similar to the capuchins in the study by Addessi et al. (2007). This would result in quantity discrimination performance being lowest in the Pebbles Condition and
equally high in the Food and Food Replaced conditions where the modality of the choice stimulus is not changed.

**Methods**

*Food Condition.* A number of grape pieces corresponding to the predetermined numerical quantity for each test pair were presented on each plate. After pointing to a quantity of grapes on a plate, the primates directly received the choice grapes off of the plate (Figure 1).

![Figure 1 Food Condition. Image displays the choice visible to the primates.](image)

*Food Replaced Condition.* At choice this condition looked identical to the Food Condition: the primates made a choice between two quantities of grapes presented on the plates. However, when the monkeys made their choice, they did not receive the grapes on the plate, but instead the plate was removed, revealing an identical quantity of grapes hidden inside the container and underneath the plate. The primates received these grapes (Figure 2).
Figure 2  Food Replaced Condition. Top image displays the choice visible to the primates. Bottom image displays the food reward given to the primates from inside the container.

Pebbles Condition. This was similar to the Food Replaced Condition except that the choice stimuli on the plates were pebbles rather than grapes. Primates pointed to one of the quantities of pebbles presented on the plate, the plate was removed, and the primates received the quantity of grapes from inside the container that corresponded to the quantity of pebbles presented on the plate (Figure 3).
Results

The capuchins performed significantly above chance in all three conditions (Food: t(5)=14.91, p<0.001; Food Replaced: t(5)=8.85, p<0.001; Pebbles: t(5)=3.80, p=0.01; Figure 4). Squirrel monkeys performed significantly above chance in the Food (t(5)=4.43, p=0.01) and the Food Replaced (t(5)=4.43, p=0.01) Conditions but not in the Pebbles Condition (t(5)=2.37, p=0.06; Figure 5).

A repeated measures ANOVA revealed a significant effect of condition on performance for the capuchins; (F(1, 5) = 4.97, p = 0.03). Follow up paired samples t-tests comparing performance across the three conditions revealed that the capuchins performed significantly better in the Food Condition (M=85.42, SD=2.38) than in the Food Replaced Condition (M=79.17, SD=3.29; t(5)=2.73, p=0.04) and the Pebbles Condition (M=69.27, SD=5.07; t(5)=2.94, p=0.03; Figure 4). Repeated measures ANOVA revealed no significant effect of
condition on performance for the squirrel monkeys ($F(2,6)=1.76$, $p=0.22$; Figure 5).

Figure 4  Experiment 1. Percent choice of the larger quantity in the three replication conditions of the Schmitt and Fischer (2011) experiment by the capuchins. Asterisks indicate a significant difference on a paired samples t-test ($p<.05$). Error bars represent standard errors of the mean.

Figure 5  Experiment 1. Percent choice of the larger quantity in the three replication conditions of the Schmitt and Fischer (2011) experiment by the squirrel monkeys. Error bars represent standard errors of the mean.
Discussion

Capuchins performed significantly better in the Food Condition than both the Food Replaced and Pebbles Conditions. Additionally, capuchins performed significantly above chance in all three conditions. Although performance did not significantly vary based on condition for the squirrel monkeys, their performance in the Pebbles Condition was not above chance, possibly reflecting a species difference in performance for the capuchins and squirrel monkeys. Additionally, these results suggest that the Pebbles Condition was the most challenging for both species. It is possible that the higher cognitive demand of the pebbles serving as the choice stimulus was impairing performance for both the capuchins and squirrel monkeys. However, it is also possible that the primates were not highly motivated to perform if the food reward was not visible at choice. Experiment 2 was designed to distinguish between these two potentially confounding variables: the higher cognitive demand of the pebbles stimuli or the lower motivational level resulting from the food reward being initially hidden.

Experiment #2: Motivation Conditions.

These two conditions were designed to increase the reward value of the food reinforcer to provide additional motivation to discriminate between the two quantities presented. If motivation was the key factor in the comparatively low performance by capuchins and squirrel monkeys in the Pebbles Condition in Experiment 1, then increasing the motivation in both the Food and Pebbles Condition would lead to increases in performance, regardless of modality. In particular, this increase in motivation of the food reward in the Pebbles Condition might bring the squirrel monkeys’ performance in the Motivated Pebbles Condition to above chance. However, if use of the pebbles as a choice stimuli to stand in for a food reward is too cognitively
demanding, than both species were already performing at ceiling level in the Pebbles Condition, and increasing motivation should not improve performance.

**Methods**

*Food Preference Test.* A food preference test comparing some of the favorite foods of the capuchins and squirrel monkeys was conducted to determine which food they found most rewarding. A food item was selected as the motivated food reward following a monkey choosing it 80% of the time or more in a preference test comparing the original food reward (grapes) with two additional new food choices. For four of the capuchins (Schroder, Smithson, Nye and Niko) the preferred food item was dried mangoes, while for the remaining two capuchins (Newton and Nigel) the preferred food item was cashews. For all six of the squirrel monkeys, the preferred food item was meal worms.

*Motivated Food Condition.* This was identical to the original Food condition except that the more rewarding foods were used as the choice and reward stimuli. When discussed for comparison, the original Food Condition from Experiment 1 will now be referred to as the Unmotivated Food Condition.

*Motivated Pebbles Condition.* This was identical to the original Pebbles condition except that the more rewarding foods were used as the reward stimuli. When discussed for comparison, the original Pebbles Condition from Experiment 1 will now be referred to as the Unmotivated Pebbles Condition.

**Results**

One sample t-tests revealed that both capuchins (Figure 6) and squirrel monkeys (Figure 7) performed significantly above chance in both the Motivated Food (capuchins: \( t(5)=32.87, \))
Paired samples t-tests showed that increasing motivation significantly improved performance by both the capuchins and squirrel monkeys. Capuchins performed significantly better in the Motivated Pebbles Condition (M=83.33, SD=2.72) than in the original Pebbles Condition (t(5)= -2.96, p=0.03). However, their performance in the Motivated Food Condition (M=87.50, SD=1.41) was not significantly different than their performance in the Food Condition (t(5)= 0.83, p=0.44; Figure 6). Squirrel monkeys performed significantly better in both the Motivated Food Condition (M=80.21, SD=3.29; t(5)= -3.73, p=0.01) and the Motivated Pebbles Condition (M=77.08, SD=4.97; t(5)= -4.13, p=0.01; Figure 7) than in the original Food and Pebbles Conditions.

Figure 6 Experiment 2. Comparison of performance in the Unmotivated and Motivated Food and Pebbles Conditions by the capuchins. Unmotivated data are from Experiment 1. Asterisks indicate a significant difference on a paired samples t-test (p<.05). Error bars represent standard errors of the mean.
Discussion

Consistent with findings that increasing motivation led to an increase in performance (Schrier & Harlow, 1956), these results indicate that motivation had a strong impact on performance in the quantity discrimination task by both the capuchins and squirrel monkeys. Both the capuchins and squirrel monkeys demonstrated significant improvement in the Pebbles Condition when the food reward became more motivating. The squirrel monkeys failed to perform above chance in the original Pebbles Condition, but with the added motivation their performance reached above chance level. The added motivation also resulted in a significantly better performance for the capuchins with the pebbles as the choice stimuli. These results suggest that cognitive limitations on the ability to understand the pebbles’ representation as a
non-edible choice stimulus leading to an edible food stimulus was not the reason for poor performance in the Unmotivated Pebbles Condition from Experiment 1.

The increased motivation also led to a significant improvement for the squirrel monkeys in the Motivated Food Condition relative to the original Unmotivated Food Condition. For the capuchins, however, there was no significant improvement in the Food Condition following an increase in motivation. The capuchins were already performing at a high level in the Unmotivated Food Condition, significantly better than their performances in the Food Replaced and Pebbles Conditions. Thus, it appears that they may have already reached their “ceiling effect” in food quantity discrimination tasks and further motivation would not have an effect on their performance. In contrast, the squirrel monkeys had not reached their maximum level of performance in the Unmotivated Food Condition, therefore increasing motivation led to significant improvements.

Closer analysis of the Food and Pebbles Conditions from Experiment 1 revealed that the delay in the Food condition between the monkeys making a choice and receiving the food reward was shorter than the delay in the Pebbles Condition. This was a result of the food reward being hidden under the plates in the Pebbles Condition, while the food reward was directly on top of the plates in the Food Condition. Average length of delay for each condition was calculated by looking back at ten videos of each of the conditions and timing the length of delay. On average, the delay in the Food Condition was 2.45 seconds, while the delay in the Pebbles Condition was 4.72 seconds. It is therefore possible that this difference in delay may have impacted performance. The capuchins’ significantly better performance in the original Food Condition may have been a result of the shorter time delay between choice and reward. Additionally, the squirrel monkeys’ poor performance in the original Pebbles Condition may have been a result of
the longer time delay. Given that increasing the motivational value of the food reward led to significant improvements in performance for both the capuchins and squirrel monkeys in the Motivated Pebbles Condition, it was possible that decreasing the delay in the original Pebbles Condition could lead to significant improvements in performance and increasing the delay in the original Food Condition could lead to decreases in performance. This would imply that performance in quantity discrimination tasks is influenced by both motivation and delay.

**Experiment #3: Delay Modifications.**

To test the impact of delay on performance in quantity discrimination tasks, the delay between choice and reward in the Food Condition was increased to more closely resemble the delay in the Pebbles Condition, while the delay in the Pebbles Condition was decreased to more closely resemble the delay in the Food Condition. If the length of delay was a key factor effecting performance in Experiment 1, then increasing the delay in the Food Condition should lead to decreases in performance, while decreasing the delay in the Pebbles Condition should lead to increases in performance for both the capuchins and squirrel monkeys. If length of delay is the major factor influencing quantity discrimination, then similar delay lengths should lead to similar performances, regardless of modality. However, if the poor performance in the Pebbles Condition was not due to the long delay, then decreasing the length of delay should not improve performance. This would suggest that lack of motivation is the major factor influencing the poor performance in the original Pebbles Condition.

**Methods**

*Long Delay Food Condition.* This was similar to the Food Condition from Experiment 1 except that the length of delay between food choice and reward was increased. Primates made a choice by pointing to one of the two plates, and the plate was lifted off the Tupperware container.
The experimenter reached inside the container (but retrieved nothing), then handed the primates the grapes they originally pointed to from the plate. When discussed for comparison, the original Food Condition from Experiment 1 will now be referred to as the Short Delay Food Condition. The new length of delay was on average 5.53 seconds compared to the original delay length of 2.46 seconds.

*Short Delay Pebbles Condition.* This was similar to the Pebbles Condition except that the length of delay between pebbles choice and food reward was decreased. After pointing to a quantity of pebbles on the plate, the primates immediately received the corresponding quantity of grapes. The grapes were pre-counted and held in the experimenter’s hands underneath the testing apparatus, invisible to the monkeys. When discussed for comparison, the original Pebbles Condition from Experiment 1 will now be referred to as the Long Delay Pebbles Condition. The new length of delay was on average 0.89 seconds compared to the original delay length of 4.72 seconds.

**Results**

One sample t-tests revealed that the capuchins (Figure 8) and the squirrel monkeys (Figure 9) performed significantly above chance in both the Long Delay Food (capuchins: t(5)=20.56, p=0.00; squirrel monkeys: t(5)= 2.79, p=0.039) and in the Short Delay Pebbles (capuchins: t(5)=4.6, p=0.001; squirrel monkeys: t(5)=5.12, p=0.004) Conditions.

A paired samples t-test revealed that the capuchins performed significantly better in the Short Delay Food Condition from Experiment 1 than in the Long Delay Food Condition (M=77.08, SD=1.32; t(5)=6.33, p=0.001). However, there was no significant difference in performance between the Short Delay Pebbles Condition (M=72.40, SD=4.87) and the Long Delay Pebbles Condition from Experiment 1 (t(5)=0.397, p=0.078; Figure 8). For the squirrel
monkeys, paired samples t-rest revealed that their performance did not significantly differ based on delay in either the Food (M=65.10, SD=5.44; t(5)=0.15, p=0.89) or Pebbles (M=61.98, SD=2.34; t(5)=0.31, p=0.77; Figure 9) Conditions.

![Figure 8](image)

**Figure 8** Experiment 3. Comparison of performance in the Long Delay and Short Delay Food and Pebbles Conditions by the capuchins. Short Delay Food and Long Delay Pebbles data are from Experiment 1. Asterisk indicates a significant difference on a paired samples t-test (p<.05). Error bars represent standard errors of the mean.
Discussion

Results revealed that the length of delay could not fully account for differences in performance across conditions in Experiment 1. Increasing the delay in the Long Delay Food Condition resulted in a significant decrease in performance for the capuchins. However, there was no effect of delay length on performance in the Pebbles Condition for the capuchins, or in either condition for the squirrel monkeys. In particular, these results suggest that the long delay was not the major factor impairing performance in the Pebbles Condition. The Motivated Pebbles Condition revealed that even with the long delay, both the capuchins and squirrel monkeys were capable of discriminating quantities at a high performance level. If a long delay was impairing performance, this would have been manifested in significantly worse performances in both long delay conditions, regardless of modality, which was not observed here.
Delay still appears to be playing some role in performance as decreasing the delay between pebbles choice and food reward resulted in the squirrel monkeys’ performing significantly above chance in the Short Delay Pebbles Condition. In the Long Delay Pebbles Condition from Experiment 1, the squirrel monkeys did not perform above chance. Given this result, and the decreased performance of the capuchins in the Long Delay Food Condition, it appears that delay may have some impact on performance, but because the effects were not consistent across the Food and Pebbles Conditions, this suggests that delay is not the major factor affecting the performance of the capuchins and squirrel monkeys in quantity discrimination tasks.

**Experiment #4: Pebbles 2 Condition.**

This was identical to the original Pebbles Condition from Experiment 1. It was re-run at the end of the experiment to rule out that improvements in performance across the seven prior conditions within the three experiments tested were attributable to learning.

**Results**

Paired samples t-test revealed that performance in the Pebbles 2 Condition by both the capuchins and the squirrel monkeys did not differ significantly from their performances in the original Pebbles Condition from Experiment 1 (capuchins: \(M=77.60, SD=3.90; t(5)=1.54, p=0.18\); squirrel monkeys: \(M=70.83, SD=4.75; t(5)=2.00, p=0.10\)).

**Discussion**

This Pebbles 2 Condition was run at the end of the series of experiments, following the completion of the replication conditions and the motivation and delay manipulations (7 conditions total). The intent of this experiment was to test whether the improvements in performance seen in Experiments 2 and 3 were attributable to learning or were the result of the
experimental manipulations. Results revealed that for both the capuchins and squirrel monkeys, performance in the Pebbles 2 Condition did not significantly differ from performance in the original Pebbles Condition. This provides evidence to support the hypothesis that experimental manipulations were affecting performance rather than learning over time.

**General Discussion**

Overall, the results of this series of experiments revealed that both the capuchin and squirrel monkeys are capable of discriminating quantities, as evidenced by their consistently above chance performances. This provides substantiation to the growing library of data on a wide range of species that possess numerical abilities, including dolphins, birds, rodents and several other species of both the Old and New World primates (Kilian, Yaman von Fersen & Gunturkun, 2003, Pepperberg & Gordon, 2005, Panteleeva et al., 2013, Beran, 2001, Brannon & Terrace, 1998, Hauser et al., 1996, Hauser et al., 1999). This evidence also corroborates the previous findings at Bucknell University, which revealed numerical ordering abilities in both the capuchins and squirrel monkeys (Judge et al., 2005, Smith et al., 2003). Finally, the data presented here provide support that performance in quantity discrimination tasks is not ubiquitous, but rather can be dependent on factors other than the quantities themselves. The ability to discriminate quantities is dependent on task specific parameters and performance cannot always be generalized across conditions or experiments.

Initial results of the replication conditions in Experiment 1 revealed an effect of modality on performance, and suggested that there was a species difference in quantity discrimination ability. However, the results were the opposite of the results found by Schmitt & Fischer (2011) in Old World Monkeys. The capuchins and squirrel monkeys performed the worst in the Pebbles Condition, whereas the olive baboons and long tailed macaques performed the best. This led to
the hypothesis that the pebbles were too cognitively demanding for the New World Monkeys or that they were not highly motivated to perform when the food reward was not initially present and clearly visible to them. Additionally, the squirrel monkeys performed below chance in the Pebbles Condition while the capuchins performed above chance, suggesting that there may be a species-specific difference in numerical ability, and that maybe the squirrel monkeys are not capable of discriminating quantities when the quantities are represented by pebbles.

Following the findings of the Schrier and Harlow’s (1956) experiment with the java monkeys, I increased motivation to complete the task by increasing the value of the food reward. Results revealed a strong impact of motivation on performance. The results of the increase in motivation provided evidence against a species-specific difference in numerical ability, as both the capuchins and squirrel monkeys discriminated quantities in the Motivated Food and Motivated Pebbles Conditions above chance level. Additionally, increased motivation led to significant improvement in the Motivated Pebbles Condition relative to the original Unmotivated Pebbles Condition, with performance level reaching that in the Motivated Food Condition. These results indicated that the use of pebbles to represent a food quantity did not impair performance if a more valued food reward was used. One potential explanation for the improvement in performance following increased motivation is that the more highly valued food reward motivated the monkeys to more closely attend to the choice stimuli.

The numerical experiment by Addessi et al. (2007) suggested that the capuchins’ poor performance in discriminating quantities in the token condition may have been due to either the higher cognitive demand of the tokens or the length of delay between making a choice and receiving the food reward. Given that the Motivation Conditions in Experiment 2 revealed that using pebbles as a choice stimulus was not too cognitively demanding, we tested for the impact
of delay on performance. Shortening the delay in the Pebbles Condition to correspond to the length of the delay in the Food Condition from Experiment 1 did not lead to significant improvements in performance in the Short Delay Pebbles Condition for either New World species. Therefore, these results suggest that delay was not the primary factor impacting performance in the quantity discrimination tasks. Consequently, the differences in performance revealed between Schmitt and Fischer (2011) and Addessi et al. (2007) do not appear to be a direct result of the increased delay in the token condition of the Addessi et al. (2007) paper. These results suggest that the impaired performance of the Addessi’s capuchins in the token condition can best be explained by a lack of motivation.

Overall, results obtained in the present study most closely match those found by Schrier and Harlow (1956) in their experiment with the java monkeys. Increasing motivation led to significant improvements in performance, regardless of modality. In addition, high performance levels were observed by both species in the Motivated Pebbles Condition, even when the length of delay between choice and reward was much longer than the length of delay in the Motivated Food Condition. Increasing the value of the food reward led to similarly high performance levels for both the capuchins and the squirrel monkeys. This was in contrast to the previous results obtained at Bucknell, which revealed that the capuchins’ overall accuracy in ordering quantities was considerably higher than the squirrel monkeys’ ordering abilities. These results led to the suggestion that the capuchins are more successful in using quantities as a cue, relative to the squirrel monkeys (Judge et al., 2005, Smith et al., 2003). The results of the present experiment, in contrast, suggest that the squirrel monkeys are capable of discriminating quantities on a level that rivals the capuchins, but only if they are motivated to do so. These results are an important reminder that some species differences in cognitive ability can be explained by simpler
differences in tolerance to experimental factors. The present results aid in explaining why work in comparative cognition is difficult by revealing that performance in tasks cannot always be generalized across conditions.

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References


Smith, Brian R., Piel, Alexander K., & Candland, Douglas K. Numerity of a socially housed hamadryas baboon (Papio hamadryas) and a socially housed squirrel monkey (Saimiri sciureus). Journal of Comparative Psychology, 117(2), 217-225.
http://dx.doi.org/10.1037/0735-7036.117.2.217