Signature:

________________________________ _______________
Janice M. Hassett Date

Computerized Learning Tasks in a Social Group of Rhesus Monkeys:

Social Demographics and Timing

By

Janice M. Hassett
Doctor of Philosophy

Psychology

Kim Wallen
Advisor

Jocelyne Bachevalier
Committee Member

Stephan Hamann
Committee Member

Robert Hampton
Committee Member

Stella Lourenco
Committee Member

Accepted:

Lisa A. Tedesco, Ph.D.
Dean of the James T. Laney School of Graduate Studies

Date

Computerized Learning Tasks in a Social Group of Rhesus Monkeys:

Social Demographics and Timing

By

Janice M. Hassett
B.A., Carleton College, 2003
M.A., Emory University, 2005

Advisor: Kim Wallen, Ph.D.

An abstract of
a dissertation submitted to the Faculty of the
James T. Laney School of Graduate Studies of Emory University
in partial fulfillment of the requirements for the degree of
Doctor of Philosophy
in Psychology
2011

Abstract

Computerized Learning Tasks in a Social Group of Rhesus Monkeys: Social Demographics and Timing

By Janice M. Hassett

To understand learning fully, we must examine learning in its most natural form: in complex physical and social contexts, and under the control of the learner.
We developed a computerized testing or “kiosk” system that allowed voluntary self-regulated participation in learning tasks by over 100 members of a rhesus monkey social group. We examined social demographic influences on participation and the relationship between self-regulated participation and performance. Age, social rank, and sex were the three primary demographic factors of interest and predictions were based on previous studies of learning in monkey groups and on social demographic effects on object manipulation, attraction to novelty, competitive access to food, and general behavior. Effects of age were consistent with predictions, with young monkeys showing earlier engagement with the kiosk and higher rates of participation, even compared to young adult subjects. These effects emphasize the importance of understanding differences in motivation between subject groups tested in any context. Social rank effects, as predicted, were apparent only in initial access and participation rates, dissipating as the study progressed, and presumably as subjects learned that they were not competing for access to easily depleted food rewards. Contrary to predictions, no sex differences were observed in participation. The second set of hypotheses focused on timing of participation and its relationship to task acquisition and performance, and predictions drew from literature on self-efficacy, preference for control, and incubation effects in problem-solving. Most learning studies do not examine the actual time course of task acquisition, but we expected that timing of participation in our context might reveal interesting effects. Participation was positively related to performance, such that subjects participated more when performance was high, and less when performance was low. In addition, a subset of subjects that required fewer trials to acquire a task appeared to benefit from taking longer breaks between trials. These findings suggest patterns of learning that might not be revealed by more restricted learning contexts, and emphasize the importance of more flexible environments that allow for natural temporal shifts in learning engagement. The importance of all findings for our understanding of learning motivation is discussed.

Computerized Learning Tasks in a Social Group of Rhesus Monkeys:

Social Demographics and Timing

By

Janice M. Hassett
B.A., Carleton College, 2003
M.A., Emory University, 2005

Advisor: Kim Wallen, Ph.D.

A dissertation submitted to the Faculty of the
James T. Laney School of Graduate Studies of Emory University
in partial fulfillment of the requirements for the degree of
Doctor of Philosophy
in Psychology
2011

Acknowledgments

I thank my committee, Jocelyne Bachevalier, Stella Lourenco, Stephan Hamann, Robert Hampton, and Kim Wallen for their contributions throughout the life of this dissertation. I especially thank Kim for so many years of support, thoughtful discussion, for his advice and feedback, for countless lab lunches, dinners, and celebrations, and for numerous travel and professional development opportunities. Most of all, I thank him for the persistent optimism that, despite the obstacles faced in the course of this project, I could make it happen. I thank the rest of the Psychology Department for their support, especially Robyn Fivush, Lynne Nygaard, Steve Nowicki, Marshall Duke, Paula Mitchell, Emily Stills, and Sheila Rotter. They always expressed sincere interest in how I was doing, and talking to any of them put a smile on my face.

I thank Virginia Shadron in the Graduate School for her unwavering and spirited confidence in me and for our many meetings and discussions in pursuit of understanding graduate student needs. I hope these discussions can continue.

The implementation of a computerized testing system for use by over 100 monkeys was in no way a solo endeavor, and many individuals contributed to this team effort over the years. I thank Kristi Geraci at Neurobehavioral Systems for her persistence and patience in the creation of the kiosk "program". I thank Julie Martin-Malivel and Andrew Fischer for their work on earlier versions of the kiosk. I thank Jen Pokorny and Ben Basile for suggestions for shaping and training procedures, and for programming assistance. I thank Michael Zeiler for his suggestions for analysis. I thank all the Field Station staff, including veterinary and colony management staff, for accommodating our needs for RFID implants and checks. I also thank the shop, including Frank Mueller, Steve Lomonof, Chad Fulcher, and Shannon Cook, for their humor and patience in our requests for tools, parts, and labor. I thank Mark Sharpless, Julie Moran, Rosetta Clark, and Mark Wilson for their willingness to assist in any way possible.

In the Wallen Lab, I had the privilege of being part of what I will always consider a family. These were not only the smartest, but also among the most helpful, compassionate, and fun individuals I have ever worked with, including: Julia Zehr, Michelle Tomaszycki, Becca Herman, Molly Embree, Franklynn Graves, Jessica Raper, Henry Lange, Heather Rupp, Karen Pazol, Katie Northcutt, Anne Glenn, Jennie Crosby, Josh Murphy, Rhiannon Brey, Shannon Stephens, Kate Liebesny, Amy Henry, Greg Henry, Trina Villarreal, Christen Merte, Becca Roberts, Patrick McFarland, Casie Lyon, Dani Sanchez, and Sara Dicker. Molly Embree provided sound advice and the consistent reminder that life after the Ph.D. would be much better. Amy Henry was an expert lab manager and became a steadfast and loyal friend, and I will not forget all we went through together. Greg Henry became our hardware and software expert, and I am certain that his seamless knowledge prevented many obstacles. Without the data extraction wisdom of Becca Herman, I might still be buried in a sea of data. Both Becca and Franklynn Graves provided much-needed feedback on sections of the dissertation. Sara Dicker made a suggestion that led to greatly improved analysis. Shannon Stephens shared in many adventures, cheering me on and helping me laugh even when my sense of humor was nowhere to be found. Trina Villarreal and Christine Marsteller helped me stay grounded, both at work and with music and good eats around Atlanta. Dani Sanchez and Becca Roberts were great listeners and always made lunch time a happy break. Beyond their important roles in the lab and their assistance with my dissertation, all these individuals became friends, and I thank them for all that we have shared over the years. It truly is a fabulous group.

Outside the lab, I thank Christy Wilson-Mendenhall and Amy Hildreth. Christy always knew what to say in the emails and texts that saw me through the very last day of writing and on to the defense. Amy is one of the most empathic listeners I have ever known, and I cherished our conversations, her amazement at my stories, and her steadfast encouragement.

I thank my parents, Jim and Peg Hassett, for their love and support and for the many opportunities they created for me. They always wanted me to do what made me happy, and I know their encouragement couldn't have always been easy, especially when the pursuit of happiness involved moving across the country and missing out on so many holidays and family events. I thank John Hassett and Kelsey Keyes and Phil, Miranda, Griffin, and Iona Hassett for believing in me and for providing great perspective on what really matters.

Many other family and friends cheered me on over the years, even when they weren't always sure what exactly I was doing. I thank them all for their faith in me.

Finally, I thank my fiancée, Charlie Vick, for being a steady foundation and a great source of love, humor, and perspective. Charlie always reminded me that I was smart, capable, and compassionate, and that I could go on to do whatever I wanted, even if the path would not always be clear. I cannot wait to walk that winding path with him by my side.

This research was supported in part by an NSF Graduate Research Fellowship, NIH grant R01-MH50268 (Kim Wallen), the Center for Behavioral Neuroscience of the NSF under agreement No. IBN-9876754, and by NCRR grant RR-00165 to the Yerkes National Primate Research Center which is fully accredited by the Association for Assessment and Accreditation of Laboratory Animal Care International.

Table of Contents

Results

List of Tables of Figures

General Introduction

Research of learning processes in humans often takes place in relatively sparse spaces. Free of social and physical stimuli, the individual is left with one task on which to focus, and the possibility of distraction is, at least theoretically, reduced. While such careful control is in many ways important for removing the excess influence of moderating variables, these variables themselves can be of great interest. Learning, after all, generally occurs in environments rich with social and physical stimuli, regardless of the specific context. In these environments, it is easy to shift attention, and only social norms, rules, and internal motivations work to keep attention focused on one activity for extended periods of time. While norms may be somewhat successful in maintaining the external appearances of focused attention, they work against the more natural inclinations of the learner as cognitive engagement, affect, and motivation shift continuously and in ways which are not easy to measure (Lepper, Corpus, & Iyengar, 2005). Unfortunately, it is only when a student is truly motivated and engaged in learning that they succeed academically (Skinner, Kindermann, & Furrer, 2009). Mere physical presence in the learning environment is not enough.

The great majority of studies of primate learning, like studies in humans and other animals, have also taken place in sparse spaces. Without peers and family to play with or groom, without space for climbing and exploring, without rich visual stimulation, and with food incentives, focus on an experimental task is presumably easier to maintain. While this may seem ideal experimentally, we know very little about what the social primate would rather be doing and how this might affect performance. If we gave it a choice between working on a learning task and basking in the sun with its family, would it ever choose to work? Indeed, a strikingly sparse context could itself be a powerful influence on the behavior and motivations of the individual. Consider the controversy surrounding the prominent role of the undergraduate participant in psychological studies around the world. While much of the controversy surrounds the homogeneity of this population, another concern is the motivation of the participant who is required to "volunteer" as part of a requirement for course credit (Tomporowski, Simpson, & Hager, 1993). Eager to return to their friends, their cell phone texts, and the sunny patch of lawn outside, the undergraduate volunteer haphazardly completes a test of spatial cognition and hastily fills out a questionnaire about their experience of the test, and is out the door before the experimenter even has the chance to ask if they have any questions. Every researcher knows that the ideal participants are true volunteers, motivated more by intrinsic interest than by the incentives offered.

In nonhuman primate learning and cognitive testing, the problem of consistency in motivation is well known. The solution applied, while variable in its specifics, is often to manipulate the hunger or thirst of the animal prior to the start of a testing session, to ensure a high level of motivation to satiate these internal states by completing trials for food or liquid rewards (Prescott et al., 2010). In some research, manipulations take the form of a period of food deprivation – animals are fed at one point and tested at a later point. In a systematic investigation, the latency between feeding and the testing session was not related to object discrimination learning in rhesus monkeys – whether subjects were tested one hour, 23 hours, or 47 hours after feeding, their performance did not vary (Meyer, 1951). More recently, manipulations of food restrictions have shown that rhesus monkeys perform more poorly on a battery of cognitive tests when they have not been food-restricted (Taffe, 2004). In this study, food restriction took the form of a continuously restricted percentage (85%) of maintenance feeding levels, which may be a more effective motivator than short-term food "deprivation." Taffe (2004) suggests that such manipulations are necessary for consistent behavioral performance in nonhuman primates. The difference between delayed testing after feeding versus a reduced percentage of maintenance feeding may be important – also, in Meyer's (1951) study, food rewards consisted of peanuts and raisins, while Taffe's (2004) food rewards consisted primarily of flavored pellets. However, many studies do not use food restriction, and some even use visual social stimuli as rewards rather than food rewards (Andrews, Bhat, & Rosenblum, 1995; Andrews & Rosenblum, 2002). Even when subjects are not food-deprived, traditional testing environments offer further restrictions which likely influence motivations: subjects are often deprived of social stimulation, of space for gross physical movement, and of play objects or other visual and tactile stimuli. Interestingly, there seems to be little discussion of how such manipulations of motivation relate to motivated learning in humans. In the human learning literature, there is research on how external and internal motivations differentially affect learning (Hayenga & Corpus, 2010; Lepper et al., 2005; Steinmayr & Spinath, 2009), but this is a distinction that is not often made in nonhuman primate learning research.

While those who conduct research with humans can administer measures of self-reported motivation to control for differences in outcomes, such self-reports are not an option for those studying nonhuman animals. A testing environment designed for voluntary participation would allow subjects to participate only when they are motivated to do so. While animals would still likely work because they are motivated to obtain rewards, the consequence of not working in a volunteer context would not result in the inability to satisfy an internal drive or need.

Many primate species live in very large and hierarchical social groups. Removal of the social nonhuman primate from its normal social context can cause stress and lead to changes in behavior and performance. In one study, adult male rhesus monkeys completed fewer trials and performed more poorly on cognitive tests when tested in a room by themselves compared to when they were tested at the same time and in the same room, in separate cages out of visual contact (Washburn & Rumbaugh, 1991). The change in behavior and performance is likely more dramatic for subjects accustomed to a large social group. Furthermore, the social environment from which the animal comes potentially influences their behavior, even if other social actors from that environment are not present (Drea, 1998a; Fitchett, Collins, Barnard, & Cassaday, 2005). In this sense, all cognition and learning is actually “social,” whether the questions themselves are social or not.

The validity of models of learning developed in highly controlled experimental settings and isolated social contexts has long concerned those focused on human learning, who have found that learning principles developed from animal models seemed not to apply completely to the behavior of their subjects (Hall, 1968). Bandura and Walters, well known for studies of children’s social learning wrote that “generally speaking it has been assumed, rather than demonstrated, that reinforcement principles apply within complex social settings and that they govern the social behavior of human beings in precisely the same manner as they regulate the responses of human and animal subjects in highly structured nonsocial laboratory experiments” (Bandura & Walters, 1963, p. 109).

To better understand learning in a complex environment, subjects should be housed and tested in a rich physical and social context in which they could participate voluntarily. Voluntary participation here means that participants can stop participating at any point, leave the physical space of the testing environment and have viable alternative activities available. Thus, individuals choose not only whether to participate, but they also choose when and for how long to participate.

Since rhesus monkeys are one of the most common primate models for research into a variety of endpoints, including cognition, developing methods for shaping and testing large numbers of animals on learning tasks is of great interest. Moreover, development of a method that can be used within the natural social contexts of a variety of species, without human handling of subjects, and which measures propensities towards spontaneous acquisition and learning would allow the development of new approaches and questions for the study of learning and cognition. Before specific manipulations can be conducted, we must determine first whether it is possible for most members of rhesus monkey social groups to interact with an automated testing system. Potential influences of the social environment on participation, and of patterns of participation on performance, should be closely examined.

In this study, we created an automated touch screen testing system or “kiosk” which could be voluntarily accessed by members of a large rhesus macaque social group, automatically identifying individuals and allowing them to engage with and disengage from the system while remaining in their normal social environment. An automated training and shaping paradigm was developed to allow individuals to advance to a harder task once criterion had been achieved on a simpler task. Thus, all individuals participated at their own rate. Initially, animals were shaped to touch the screen and images on the screen, and trials could be completed correctly and rewarded or not completed (aborted). Once touch interactions were established, animals advanced to tasks in which responses could be either correct (rewarded) or incorrect (unrewarded).

Testing of the monkey volunteer within such a context raises new questions, as at least two major aspects of this model of testing are relatively new to primate learning. First, the ability to conduct testing of individuals within their normal social context allows the following kinds of questions: Do animals participate at similar rates? Do social factors, including sex, age, and rank within the group influence participation rates or performance? Second, the voluntary aspect of participation allows for an examination of how participation relates to spontaneous acquisition: How does participation change over time and as tasks change? Can participation be maintained over long periods of time, or does interest eventually wane? Does subject participation relate to performance? Are subjects that participate at the fastest rate always the best learners? Such questions are the focus of this dissertation.

Learning in complex social settings

Behavior is inextricably linked to social context, as our place within a society has a strong influence on how we behave. For rhesus monkeys, “place” in society is determined by social dominance within the hierarchy. Rhesus hierarchies are matrilineal and the roles of males and females differ over the course of development (Lindburg, 1971). While females spend their lives in their natal group (Sade, 1967), males migrate from the social group around the time of puberty, eventually joining other social groups (Boelkins & Wilson, 1972; Colvin, 1986; Drickamer & Vessey, 1973). As early as one year of age, males and females within the social group spend their time differently, with females showing greater integration within the matrilineal structure and males segregating more with same-age male peers (Hassett, Rupp, & Wallen, 2010; Lovejoy & Wallen, 1988). Adult males have their own social status and are peripheral to the matrilineal hierarchy (Southwick, Beg, & Siddiqi, 1965). Thus, age and sex as well as social status are important factors that can influence behavior.

Studies of learning in restricted social contexts have shown that male and female rhesus monkeys of all ages are capable of learning simple tasks (Fobes & King, 1982). Thus, the focus in this study is less on capacity to learn than on motivation to participate and on social factors which may influence the likelihood of participation, and in turn, of performance. Even in restricted testing contexts, there are likely large differences in motivation to participate, and it is possible that differences in performance are a result not of capacity to learn but of this underlying motivation, an effect which could be obscured by the testing environment. For example, laboratory studies of effects of aging on cognition have found that older monkeys perform more poorly on tasks (Herndon, Moss, Rosene, & Killiany, 1997; Moore, Killiany, Herndon, Rosene, & Moss, 2006). However, it is possible that older animals lack the same motivation to participate as younger animals – thus, when they do participate, they perform more poorly.

Laboratory studies have not been able to address the role of social status on learning. However, some studies of learning have moved outside the laboratory and into the social milieu to determine effects of more complex social environments. Most studies of discrimination learning take place with a single monkey at a time, but a few studies have developed paradigms that allow for testing of a social group all at once, with measures that capture the learning process of the group as a whole. Among the very first studies of learning in primates housed in a social group was completed in marmoset monkeys (Menzel & Juno, 1982). In this study, animals were exposed to a successive discrimination task, in which some objects were initially presented with food (on or inside the objects), and other objects were presented without food. With trials occurring once per day, the researchers found that the marmosets, as a group, were more often observed in proximity to the food object than to the nonfood object on successive presentations, and that this effect was significant on the second presentation of the objects. Thus, rather than requiring multiple successive trials to learn the discrimination, a phenomenon often referred to as learning set formation or “learning to learn” (Harlow, 1949), Menzel and Juno (1982) suggested that the marmosets showed one-trial learning.

The findings reported by Menzel and Juno were controversial, as laboratory studies in primates, beginning with Harry Harlow (Harlow, 1949), had repeatedly demonstrated learning set formation, and it was the foundation for broad psychological theories of learning (Schrier, 1984). A primary problem with Menzel and Juno’s study was that it was not set up as a problem of simultaneous discrimination with reversals of the rewarded stimulus, and thus it was possible that the claimed “one-trial learning” was simply an example of associative learning (Schrier, 1984). An additional problem was that the variable of interest was the number of animals observed in proximity, and not a more precise measure reflecting individual accuracy in the discrimination.

Lepoivre and Pallaud (1986) demonstrated that even in a study of simultaneous discrimination, the specific variable of interest is critical in the interpretation of findings. Their study was conducted in a group of 5 male and 6 female young adult baboons living in a large enclosure (Lepoivre & Pallaud, 1986). Within the enclosure substrate, 32 holes were created, each at regular intervals and with 16 holes in each of two adjoining 4m x 4m zones. The baboons were first shaped to learn that wheat could be found buried in holes marked with red flags, and in successive trials the wheat was buried more deeply. In the next stage, red flags indicated locations with wheat and white flags indicated empty locations, and two reversals of this were also presented. This study demonstrated that the measure of performance mattered: the group learned to discriminate stocked from nonstocked zones in just one session ("one-trial" learning), but improvement in actual food retrieval from stocked zones was more gradual. The authors suggested that the first measure was prone to greater social influence than the actual digging behavior required to retrieve food (Lepoivre & Pallaud, 1986). Applied to the findings of Menzel and Juno (1982), it appears that when measures more comparable to those used in a traditional laboratory setting are used, learning set formation, rather than one-trial learning, is observed.

Another set of studies developed a color discrimination learning task that was used with an even larger social group of primates – in these, up to 74 members of an age-graded rhesus monkey social group (Drea, 1998b; Drea & Wallen, 1999). The design of the task allowed scoring and analysis of learning for all individuals, as well as for subgroups within the social group, described later. Similar to Lepoivre & Pallaud's (1986) discrimination learning tests with baboons, the testing area consisted of two experimental zones. In each zone, 4 colored metal boxes hung on the fence, with green boxes in one zone and orange in the other. The group was initially habituated to search for food in all boxes, with peanuts buried in increasing depths of sand within the boxes.

With one 30min trial per day, the group was retrieving 90% of the 160 hidden peanuts at the end of 16 trials. Animals were then exposed to an initial discrimination, in which green boxes were baited with 15 buried peanuts and 10 buried stones, and orange boxes baited with 25 buried stones only. They received 2-3 20min trials daily, and met criterion within 25 trials. Finally, the animals were exposed to 3 reversals of contingency, which were learned in 24, 23, and 19 trials, respectively (Drea, 1998b). Analyses of the initial discrimination trials revealed that in early trials, the two highest-ranking quartiles of the group showed higher levels of overall activity in the zones, but all group members distributed their time equally between the two zones. In the final trials of the initial discrimination, however, only the highest-ranking quartile of the group spent more time in the stocked zone compared to the non-stocked zone. This pattern continued in the reversals, with the second-ranking quartile also showing more time in the stocked zone in the final reversal condition (Drea, 1998b).

In a followup to Drea and Wallen's (1998b) initial study, a new group of rhesus monkeys acquired discriminations as a group and when divided into dominant and subordinate subgroups, and they were also tested on discriminations with the contexts reversed, so that the discrimination learned when separated was tested with the whole group present, and the discrimination learned within the whole group was tested separately with the dominant and subordinant group halves. This manipulation revealed that subordinate animals learned in both contexts, but failed to perform in the presence of dominant animals (Drea & Wallen, 1999). Subordinate animals, when separated from dominant animals, would learn the discrimination but then fail to perform it when tested with the dominant members. They would also fail to demonstrate learning of a discrimination when combined with dominant group members, but then perform the same discrimination when tested separately from the dominant members (Drea & Wallen, 1999).

In their initial study, Drea and Wallen (1998b) also reported age effects, with adults participating at lower rates overall and failing to learn initial discriminations or reversals. Only subadults showed consistent performance and successfully learned the discrimination and reversals. Juvenile animals entered the stocked zone more on the final reversal, and infants showed preferences for the stocked zone, but not stocked boxes, on the initial discrimination and on reversals (Drea & Wallen, 1999).

These group discrimination learning studies were among the first to demonstrate that learning problems typically presented to individuals in restricted settings could be translated to a group testing environment. Moreover, Drea and Wallen's (1998b, 1999) findings suggested the importance of examining learning and performance as they are influenced by social factors. However, there were also some limitations in the assessment of individual performance in these studies. Analyses focused on early behavior in the trials to access individual behavior, but there is a high probability that individuals in the group can learn from observing other actors within the group, since the behaviors of individuals in the task is readily observable by all other group members. The relative ease of transmission of learning is of course of interest for many researchers, but for some kinds of research, the influence may hinder our understanding of how the individual learns. Thus, testing methods are needed within the social group which allow for greater assessment of individual learning and reduced potential for simply "copying" the behavior of social group members.

In response to the need for more individual-specific assessment within the social group, research groups have taken advantage of advances in radio-frequency identification (RFID) technology to develop automated computerized testing systems which use RFID antennae and readers to identify individuals with RFID chips implanted in their arms (Andrews, 1994). In a study of 8 socially housed and experimentally naive male and female bonnet macaques between 24 and 26 months of age, an automated computerized testing system was used to test basic joy-stick task acquisition (Andrews & Rosenblum, 1994). In a paradigm where correct responses required increasingly specific joystick movements and with access to four identical testing systems, all 8 subjects completed hundreds of trials each day. Social status was not described or reported in this study, thus it is unknown whether these same-age peers had established any sort of social hierarchy or whether such a hierarchy influenced patterns of participation or performance.

More recently, automated computerized touch screen testing methods have been used to test performance in 9 22-year-old socially housed Guinea baboons, each with an extensive experimental history using joysticks and computers (Fagot & Paleressompoulle, 2009). The 9 individuals composed three small social groups, one with 4 males, one with 3 females, and another with 2 males. Individual identification of animals was achieved using RFID chips implanted in each wrist of every animal, and an RFID antenna detected the signals emitted by the chips, transmitting them to a reader and computer program when the animals reached through an armhole to interact with the system. With one computerized testing system in each group, all baboons except one low-ranking female interacted with the system at high rates, for a total of over 700,000 completed trials over the course of 7 months, though the distribution of these trials is not clear, as many completed trials were simple “standby” trials (forced-choice discrimination between two colored squares in which red was always the positive stimulus) which were provided to animals that completed testing trials faster than other individuals. Two of the males completed a motor control task in which the difficulty of the task could be increased or decreased using interactive keys. Six baboons completed relational match-to-sample tests to a criterion of 80% correct in two consecutive sessions (Fagot & Paleressompoulle, 2009).

Fagot and Paleressempoulle (2009) also used a similar cognitive testing system with two adult rhesus monkeys and their daughter, all three individuals being naïve to computerized screens before testing began. In this study, the monkeys were initially trained on a discrimination task in which a positive and negative stimulus appeared and animals received a food reward for touches to the positive stimulus. Several reversals of the positive and negative stimulus occurred over the course of testing. When the adult male was given a dose of ketamine anesthesia immediately prior to a two-hour period in which the testing system was available, the young female rhesus monkey learned more pairs in the discrimination compared to a later control condition in which the adult male received a sham injection. The authors suggest that this finding shows a social status effect, since the adult male was considered higher ranking than the young female. With just three animals in this unusual social configuration, however, this finding is difficult to interpret.

Most recently, a similar automated testing system was used in a group of 26 socially-housed Guinea baboons, naïve to computerized testing before the start of the study (Fagot & Bonte, 2010). Ten identical testing systems were made simultaneously available to the 26 animals, and all individuals were able to interact with any system at any time. These systems were housed indoors and accessed by the baboons through a door that connected the outside living area to a small testing chamber in which a baboon could sit with access to two arm holes and a viewing port (Fagot & Bonte, 2010). Excluding two adult females who became sick and were removed from the group during the study and four infants unable to reach the screen, almost all of the baboons interacted with the system at very high rates, with a total of a million trials completed over 85 days, including trials of discrimination learning and match-to-sample. Fifteen individuals completed more than 25,000 trials (Fagot & Bonte, 2010). Due to the nature of the software used in this study, all individuals had to be tested on the same level at any given time. Thus, individuals who were faster to reach criterion were simply held at that level until all individuals were ready to be advanced. This meant that thousands of the trials completed were simply events in which rewards were dispensed when an individual reached through an armhole, touched the screen, or touched a single square on the screen.

The studies described above vary considerably on a continuum of the study of learning within a complex social context. On one end, in the studies by Drea and Wallen (1998b, 1999) and by Lepoivre and Pallaud (1986), there is a high probability of social influence on individual performance, as all members of the group can readily observe and copy the behavior of any individual as they orient towards or retrieve food from an appropriate goal (Drea & Wallen, 1995). In these paradigms, potential competition between animals for the limited food resources offered by the testing context is high. On the other end of the continuum, the studies by Andrews and Rosenblum (1994) and by

Fagot’s group (2009, 2010) take place within social groups, but the possibility of social observation and influence of others is more limited by the design of the testing systems. Also, the large number of testing systems reduced competition for access to the food rewards. The computerized testing system used in the current study fell in the middle of this continuum – individuals could observe and learn from the performance of others, but only if they were in close proximity to an individual working at the kiosk. The food resource was available nearly continuously, but there was only one system within the large social group, allowing for a moderate level of competition for access to the system. Such a moderately competitive context might help facilitate arousal and interest in participation (Zajonc, 1965) and also maintain participation among members of the social group.

Despite the prior use of automated individual identification and computerized testing in social groups, all such studies known to date have been conducted in relatively small groups. Fagot and Bronte (2010) were able to test an age-graded social group of baboons, but with only 20 individuals, none younger than 1.9 years of age and just half of these animals younger than 5 years. In addition, the social status of individuals in the group was determined not by behavioral interactions of aggression and submission, but by an examination of food retrieval when limited quantities of food were distributed within varying areas and animals that were able to obtain food distributed within the smallest area were assigned the highest social dominance. The relationship of this measure to the overall social structure of the group is unknown, but others have cautioned against the use of such measures as a proxy for social status (Chance, 1967; Jay, 1965), as measures of dominance in “priorities to incentives” generally seem to correlate only poorly with measures obtained from observations of the directions of agonistic encounters (Bernstein, 1970).

A short-term period of data collection using an earlier prototype of our kiosk system in a different rhesus monkey social group from the current study allowed us to demonstrate that spontaneous acquisition of kiosk interaction does occur (Hassett, Martin-Malivel, Lange, Fischer, & Wallen, 2007), but in this early pilot work the animals were not systematically advanced through more difficult training and on to tasks in which they could make “incorrect” choices. In addition, the short time frame (maximum of 9 days) of continuous data collection did not allow us to determine changes in participation over time, or whether animals would maintain a minimum level of interaction as tasks got harder. However, even these few days of testing revealed differences in participation by age and rank in this 74 member social group. Subjects were required to touch an image on the screen to receive a reward and any individual was allowed to complete no more than 50 trials per day. Juvenile monkeys (ages 1-4) participated on a significantly higher percentage of days compared to subadults and adults. Subadults (ages 5-6) accessed the kiosk on a significantly higher percentage of days compared to adults (ages 7 and older). Juveniles also completed more trials per day compared to adults. The highest ranking third of the group showed task completion on the greatest percentage of days compared to both the middle and lowest thirds of the group (Hassett et al., 2007). No sex differences in either access or trial completion were observed over this short-term data collection period.

The current study substantially extends research on learning in individuals housed in a social group. First, it included many more subjects than previous computerized testing studies, with data for over 100 rhesus monkeys, all with known social histories and matrilineal social ranks within the group hierarchy. Second, the kiosk system was designed to allow animals to progress at their own pace – when a subject met criterion on a task, they moved on to the next task, regardless of the performance of other subjects. Finally, the data collection period was longer, to our knowledge, than any study reported, allowing examination of changes over time.

Given the size and demographic diversity of this social group, we were able to examine social demographic contributions to participation, including age, social rank, and sex. These influences on participation constitute the first manuscript of this dissertation. The second manuscript results from what started as exploratory examination of individual learning curves for acquisition of one simple task. Based on observed patterns of acquisition, hypotheses were developed regarding relationships between participation and performance, and between task acquisition and participation rate. Since self-regulated learning has rarely been studied in either humans or nonhuman animals, these analyses raise new questions and approaches for our understanding of learning. The first three hypotheses that follow in this introduction constitute the material for the first manuscript, and the last two hypotheses constitute the material for the second manuscript.

The computerized testing system and novelty

Since cognitive testing within a social group is uncommon and has not been completed previously for long durations in a large, age-graded social group with a known social dominance hierarchy, the development of hypotheses on demographic variation in participation drew from other literatures. One potentially useful literature was on attention to novel objects and foods by primates in the field and in captivity. Nonhuman primates show a strong attraction to novelty and, more than nonprimate species, show a great depth of visual orientation and physical manipulation of novel objects, even when objects are somewhat feared (Glickman & Sroges, 1966). Compared to other novel items that are encountered by a primate social group, the kiosk developed for this study was somewhat unusual, and a discussion of what made it so is necessary, as the background that follows is based on aspects of this novelty.

Most novel objects that the rhesus monkeys in this study had encountered were either objects which they could pick up, manipulate, chew on, and move around, or objects on which they could sit, sleep, or climb. With the exception of the perch installed for viewing and reaching the touch screen, the kiosk system was none of these things. Much of the structure related to the kiosk was in place long before kiosk testing began. Thus, the physical aspects of the kiosk – a large sheet of transparent polycarbonate resin replacing the normal fencing, a perch, an armhole allowing access to a touch screen, a pellet cup, and several large boxes just outside the fence line - were not novel at the start of testing. However, other aspects of it were novel. Prior to the start of testing, reaching through the armhole did not result in the presentation of anything on the touch screen. Touching the screen did not result in any sounds, changes on the screen, or food rewards. These aspects were novel at the start of testing and thus the kiosk as a whole was likely treated as a novel object, despite its physical familiarity. In addition, it was a novel object that presented the animals with a novel food, banana-flavored pellets. The availability of new, previously nonvisible food had never been associated with the actions of an animal – either a human was present when new food became available, or the animals entered an area to discover the presence of new food. Enrichment devices sometimes required that the animals manipulate an object to obtain food, but in these situations the food was readily detectable by sight or smell and the action required related more directly to obtaining the food. Thus, for the first time, the animals encountered a novel object which dispensed a small amount of palatable food on the basis of an unrelated manipulation of the object.

Because presumably at some point the kiosk as object and as food source became familiar, responses to familiar objects and foods were also considered. Based on the available literature on novel and familiar object orientation and manipulation and on feeding and access to resources within the social group, hypotheses are presented in the following sections on how participation with the cognitive testing system was expected to be affected by social rank, age, and sex.

Age

As described earlier, social roles and behaviors in rhesus monkeys change with age. Infants stay with their mothers almost constantly in the first weeks, but soon venture further, forming small play groups with other infants (Hinde, Rowell, & Spencer-Booth, 1964). Yearlings show much greater independence (Berman, 1982). Juvenile females enter puberty between 2.5 and 3.5 years of age (Resko, Goy, Robinson, & Norman, 1982). Males enter puberty later – around 3.5-4.5 years of age (Bernstein, Ruehlmann, Judge, Lindquist, & Weed, 1991). In combination with these changes in social roles, lifespan developmental changes result in shifts in how monkeys spend their time and explore their environment.

In Glickman and Sroges' (1966) analysis of orientation towards novel objects across a range of species, interaction with novel objects was more often observed in subadult monkeys than in adult monkeys. Macaque species also frequently manipulate non-novel objects in the environment – in adults, this is often associated with foraging for food (Novak et al., 1993). Field observations of a close relative of the rhesus macaque, the Japanese macaque, revealed 111 total instances of manipulation of non-novel objects in the environment, 81 by 1-year-old macaques, 24 by 2-year-old macaques, and the remaining six manipulations split evenly between 3-4-year-olds and adults (Menzel, 1966). When novel objects were introduced, observations revealed that most adults treated the objects with "studied indifference," and again younger animals were more likely to interact with the objects, with 1-year-olds showing some form of orientation towards a novel object 90% of the time that they passed it, and adults showing some form of orientation only about 30% of the time (Menzel, 1966). Others have reported similar age effects in Japanese macaques, with younger animals more readily taking food from humans (Stephenson, 1973) and retrieving food buried in piles by experimenters (Tsumori, 1966). Similar findings have been reported for vervet monkeys in captivity and in the field (Fairbanks, 1993), with juveniles more likely to approach novel or strange objects in the environment more quickly than their adult counterparts. Captive socially housed juvenile baboons also engage in greater manipulation of novel objects compared to adult female, but not adult male baboons (Joubert & Vauclair, 1986).

In addition to observed differences in attention to novelty and object manipulation by age, differences in general activity levels also change over the course of development. Higher levels of play are observed in younger animals, and play becomes less common over the course of development (Ehardt & Bernstein, 1987; Rowell, 1974), with reduced activity in adolescent individuals (Fagen, 1993), and adults showing very low levels of highly active play, instead engaging in higher rates of grooming, infant care, feeding, and sleeping.

Age effects have been reported in three primate group testing studies. Drea and Wallen (1998b) reported that adult rhesus monkeys showed the lowest levels of participation in the group visual discriminations. Our pilot study with rhesus monkeys also found that adult subjects participated less, even in a short-term study with simple image touch trials (Hassett et al., 2007). Last, Fagot and Bonte (2010) reported a significant negative correlation between age and participation in baboons, with more participation from younger animals.

Hypothesis 1: Age effects for kiosk participation

At the start of testing, the kiosk as an interactive object was novel to all animals in the social group. Young animals were expected to be drawn to this novelty and to show faster initial access to the kiosk as well as acquisition of kiosk interaction. While the kiosk did not provide an active form of physical play, interactions with it may have been somewhat analogous to other forms of object play, and the greater activity of younger animals may have increased the likelihood that they found themselves in close proximity to the kiosk. It was expected expected that younger animals would be faster to orient to the kiosk and to reach through the armhole and touch the screen compared to older animals. Subjects two and younger were expected to show the fastest kiosk orientation as a group. The slowest orientation towards the kiosk was expected in animals 5 years of age and older, with the possibility that the oldest animals in the group would show a very low level of orientation towards the kiosk.

For younger animals, it was expected that as tasks changed on the kiosk, some aspect of novelty would be maintained, whereas for the older subjects, these more subtle novelties may not have been enough to maintain motivation for continued participation, especially as tasks become harder. We expected that these older subjects would more often show drastically reduced rates of participation when tasks became harder. It is important to note that we did not wish to make any hypotheses related to the ability of these animals to complete relatively simple learning tasks on the kiosk, but simply that we expected that compared to younger subjects, their overall motivation to participate would be lower. Interestingly, while we expected the highest levels of participation in animals younger than 5, 5-year-old animals are often part of the youngest age group studied in aging studies involving rhesus monkeys (Herndon et al., 1997; Lacreuse, Espinosa, & Herndon, 2006; Moore et al., 2006) and in any context are considered "young adults". Nonetheless, we expected that our very different system of voluntary participation in a naturalistic social group will lead to these age effects as described.

Social status

The ranking of individuals in a primate social hierarchy is determined by researchers through observations of dyadic interactions involving aggressive and submissive behaviors (Altmann, 1962). Ranking the "winners" of these interactions with the smallest number of reversals and keeping all members of a matriline together produces the observed hierarchy (Drea, 1998b). The social realities of high ranking and low ranking individuals can differ dramatically (Bartlett & Meier, 1971) and relative dominance within a rhesus monkey social hierarchy determines how individuals respond not only to other individuals, but also to the shared physical environment (Jay, 1965).

Systematic studies in captive rhesus monkeys have shown that high-ranking individuals will gain access to food or water more quickly, be displaced less often, and eat more of a food than low-ranking individuals (Belzung & Anderson, 1986; Deutsch & Lee, 1991; DeWaal, 1986). Dispersion of food over a larger area can reduce these effects (Belzung & Anderson, 1986), and food size may be an important factor in food competition, with larger foods leading to higher rates of aggressive interactions (Chancellor & Isbell, 2008). Belzung and Anderson (1986) also demonstrated that when foods are highly desirable, low-ranking rhesus monkeys will gain access and eat more of these foods compared to when foods are less desirable. High-ranking animals still gain access first and eat more, but the effect is reduced. Thus, when motivation is high, low-ranking monkeys are more willing to risk being the recipients of aggression.

In the rhesus monkey group discrimination learning study described previously (Drea & Wallen, 1999), direct manipulations of social context revealed that low-ranking animals were just as capable of learning a visual discrimination as high-ranking animals. In this study, acquisition of the discrimination was demonstrated in part by retrieval of a highly valued food reward, the quantity of which was limited and in a concentrated location – peanuts buried in sand within a few adjacent boxes, each with one arm hole. Thus, individuals were competing directly for a food reward of limited availability, which may have contributed to the inhibition of performance in the lower-ranking animals.

The social hierarchy of rhesus monkeys may be maintained more through the subordinate behavior of the lowest-ranking animals than through the dominant behavior of the highest-ranking (Rowell, 1974). In a variety of species including rhesus monkeys, the approach-retreat behaviors of subordinate animals correlated more strongly with rank than did the agonistic behaviors initiated by dominant animals. Thus, Rowell (1974) described the social hierarchy as a “subordinance hierarchy” in which the most subordinate animals practice such extreme caution in their behavior and in their reactions to dominant individuals that they actually elicit dominant behavior from their higher-ranking counterparts. Drea and Wallen (1999) also reported that “playing dumb” in more subordinate individuals appeared to be a result not of aggression on the part of dominant animals, but of a voluntary inhibition of behavior on the part of the low ranking animals. Others have reported more relaxed responsiveness to consistently available food by dominant rhesus monkeys compared to their subordinate counterparts (Bartlett & Meier, 1971; Pelaez, Gil-Burmann, & Sanchez, 2000). In part, the “relaxed” responsiveness of dominant animals is likely a reflection of the “unrelaxed” cautious responsiveness of subordinate counterparts within a social group.

At least in primates, there is far more research focused on social rank and access to food resources than on access or approach to novel objects or environments. Studies in other species have suggested that subordinate individuals are more likely to explore novel environments as a way to compensate for their relative lack of access to resources or space already known by dominant members (Katzir, 1982). There is little research on social rank and approach to novel objects within the familiar environment, a question of greater relevance for this study. In our pilot study, dominant animals completed more trials over the course of nine days of testing (Hassett et al., 2007), suggesting that rank effects were likely for the current study.

Hypothesis 2: Social rank effects for kiosk participation

Rhesus monkey social rank clearly influences the access to limited food resources, but it was not clear how it would influence access to a novel food resource that also required a novel method of interaction. When the kiosk and the banana-flavored pellet reward were novel, it was expected that social rank would be of considerable importance. High-ranking animals were expected to be the first animals to gain access to the kiosk, due to low-ranking individuals inhibiting any initial motivation to participate. However, it was also anticipated that any effects of rank would diminish over time, as the kiosk continued to be available consistently and the animals would learn that they were not competing over a food or enrichment resource with limited availability. Specifically, rank effects were expected to be most prominent in the first few days of testing. As tasks got harder, rank effects would not persist. While Drea and Wallen (1999) reported low-ranking rhesus monkeys “playing dumb” in the presence of others, we expected that the nature of relatively constant availability of food rewards would result in an absence of such an effect in this study. Successful performance did not come at a cost to other individuals – if all individuals performed well, all received rewards.

Sex

As already described, the development of male and female rhesus monkeys within the social group differs substantially. As a consequence of these behavioral sex differences, we anticipated that there would be some sex differences in kiosk participation at the kiosk, though these analyses were in many ways quite exploratory.

Juvenile rhesus monkey males, as young as 1 year of age, tend to separate from the rest of the social group, segregating by both age and sex, while young females show less segregation, spending more time near adults and infants, engaged in grooming and huddling behaviors (Ehardt & Bernstein, 1987; Hassett et al., 2010; Lovejoy & Wallen, 1988). This sex difference appears to persist throughout juvenile development (Bernstein, 1993). Young females also more often attend to and mimic the behavior of their mothers compared to young males (Mondragon-Ceballos, Chiappa, Mayagoitia, & Lee, 2010). Female macaques have been reported to engage in higher levels of object exploration and manipulation compared to male macaques, and in turn, greater social facilitation for object manipulation has been observed in females (Novak et al., 1993; Stephenson, 1973). In other species in which females remain in the group for life and males disperse, such as rats, females demonstrate greater attention to novelty the immediate environment (Lynn & Brown, 2009).

Hypothesis 3: Sex differences in kiosk participation

Predictions of sex differences were made only for juveniles because there were only two adult males in the social group, so too little data were available to test adult sex differences. Juvenile sex differences in interaction with the kiosk were predicted in two different directions. First, because female macaques have been reported to engage in greater object manipulation and exploration of novelty, it was predicted that juvenile females would be faster to complete initial trials at the kiosk. However, as the kiosk became less novel, it was expected that females would spend less time at it, instead seeking to engage in those behaviors which kept them integrated with their families and the social group. Juvenile males, on the other hand, already spend more time separated from the social group and with same-age male peers. Thus, they may have had a greater amount of time available overall to engage with tasks at the kiosk. It was therefore predicted that juvenile males would show higher rates of participation over the extended period of testing.

Self-regulated participation and performance

In most regards, the monkey volunteer has greater flexibility than the human volunteer in a traditional experimental study setting. Because they control the patterns of their participation and the system is available to them almost all of the time, their learning occurs spontaneously and at a truly self-paced rate. There is very little research on this sort of learning, despite the fact that this is how most learning actually occurs. Formal institutions are increasingly observing such approaches towards learning and working, with policies for flex-time in the workplace (Shockley & Allen, 2010) and with increasing emphasis in higher education on distance learning and virtual classrooms (Artino & Stephens, 2009). Such environments allow learning to take place asynchronously and allow the learner great control over their engagement in, or disengagement from, learning (Nistor & Neubauer, 2010; Noe, Tews, & Dachner, 2010). In these contexts, as in more traditional contexts, factors influencing psychological engagement are of great interest (Noe et al., 2010). Certainly it can be argued that varying levels of engagement, or rates of participation, influence performance and that performance in turn influences engagement, but this is a little studied topic. In fact, traditional models of animal learning have historically focused on what reinforcement schedules will promote the greatest rate of participation (Skinner, 1963), with an implicit assumption that what is good for the researcher is also good for the learner – the learner sometimes being viewed as no more than a “response generator” (Washburn, Rumbaugh, & Putney, 1994).

Allowing an individual the freedom to engage in an activity at a self-determined rate results in different patterns of participation and different consequences than when the individual does not have such autonomy. When mating behavior of rats is examined in a small cage with one male and one female and both able to move freely, mating occurs at more frequent intervals compared to conditions in which the male is tethered to the cage and the female can get away. When the female is allowed to participate in mating at her own pace, a different pattern, and a pattern more conducive to fertility is produced (Madlafousek & Hlinak, 1977; Martinez & Paredes, 2001; Paredes & Vazquez, 1999). A similar effect has been demonstrated in the mating behavior of rhesus monkeys. When a male and a female rhesus monkey are paired in a cage together, mating may occur on any day, regardless of the female’s cycle (Goy, 1979). However, when the monkeys are moved to a naturalistic social context with a greater number of adult females than adult males, females are much more likely to mate with males in correspondence with peak estrogen levels near the time of ovulation (Wallen, Winston, Gaventa, Davis-Dasilva, & Collins, 1984; Wilson, Gordon, & Collins, 1982).

The importance of autonomy and choice applies beyond reproductive contexts. Many species, including rats, pigeons, and human children have been shown to prefer performing a simple operant to obtain rewards to having rewards made freely available, in some cases even when rewards could be obtained at a faster rate in the “free” condition – a phenomenon described as “contrafreeloading” (Inglis, Forkman, & Lazarus, 1997; Neuringer, 1969; Singh, 1970). Inglis and colleagues (1997) suggest that when an option to exert control over the environment is made available, it is adaptive to choose to exert such control, as it is a method for gathering more information and exploring and learning about the surrounding environment. Choice is one avenue which allows for the perception of control over both positive and negative types of stimuli (Leotti, Iyengar, & Ochsner, 2010). Both humans and animals in experimental paradigms have demonstrated a preference for a choice over a non-choice when faced with the same reward outcomes (Bown, Read, & Summers, 2003; Catania & Sagvolden, 1980; Leotti et al., 2010; Suzuki, 1997, 1999). In humans, intrinsic motivation increases when choices are available (Patall, Cooper, & Robinson, 2008) and there are also data that indicate that performance endpoints can be affected by choice: adult male rhesus monkeys given a choice of computer tasks during testing sessions showed better performance than when they were given no choice over which task they would be working on (Washburn, Hopkins, & Rumbaugh, 1991).

In human self-determination theory, a distinction is made between different levels of choice and control, and one of those distinctions lies between autonomous regulation – “doing what one finds interesting or important and would be inclined to do more freely” – and controlled regulation – “feeling pressured, coerced, or seduced into action” (Moller, Deci, & Ryan, 2006, p. 1025). This is a distinction that is useful for consideration of testing learning in individuals living in a social group compared to testing learning of individuals in a small cage. The greater freedom allowed by autonomous regulation has been linked to greater subjective vitality, persistence, effort, and intrinsic motivation in humans (Moller et al., 2006). If monkeys engaged with the kiosk in our voluntary social context, they would be doing so not because they were placed in an environment with a lack of appealing alternatives and a need to obtain food, but because they were freely inclined to engage with it, despite the available activities of their everyday lives from which they have to choose. In this context, participation serves as a measure of motivation, and we can determine when, in relation to factors such as performance, the learner is most motivated.

A large literature has explored relationships between motivation and performance, but almost exclusively in humans and using self-report measures to distinguish among individual differences in constructs such as self-efficacy (Niemivirta & Tapola, 2007), effort (Schmitz & Skinner, 1993; Yeo & Neal, 2004), intrinsic versus extrinsic motivation (Cordova & Lepper, 1996; Lepper et al., 2005), interest (Niemivirta & Tapola, 2007), training motivation (Orvis, Fisher, & Wasserman, 2009), goal orientation (Orvis et al., 2009; Skinner et al., 2009; Steinmayr & Spinath, 2009; Yeo & Neal, 2004), performance concern (Smiley, Coulson, Greene, & Bono), contingent self-worth (Smiley et al.), and ability self-perceptions (Steinmayr & Spinath, 2009). Perhaps most useful for the current study is the perspective offered by efficacy research: "A sense of personal efficacy in mastering challenges is apt to generate greater interest in the activity than is self-perceived inefficacy in producing competent performances" (Bandura & Schunk, 1981, p. 587). Though self-efficacy in monkeys is not something that can be measured as it is in humans, the trial-by-trial feedback that serves as a source of initial motivation and as task "instruction" can serve as a proxy for an individual's performance efficacy. In less cognitive terms, this might be thought of as an animal's sense of control over contingencies, as in the contrafreeloading literature. When given the opportunity to participate whenever they choose, participation should be expected to increase as individuals perceive improvement in their performance, or at least as there is an increased association between their actions and reward disbursement.

Hypothesis 4: Rate of participation and performance

A strong relationship between rate of participation and performance was expected, such that as performance improved, subjects would complete trials at a faster rate. It is important to understand the nature of this relationship, especially in the case of individuals who showed large drops in their participation. Continued poor performance in learning may result in negative arousal (Kluger & DeNisi, 1996) and as a consequence, avoidance of the task and the context. In a more traditional environment, subjects would remain in a small confined space despite poor performance, whereas in the context of this study, subjects could remove themselves permanently from the testing context.

Spontaneous acquisition and participation

While an important concern in studying acquisition in a context of voluntary participation is that participation be maintained over time, the time course of participation is itself a topic of interest, especially after observations of initial patterns of participation in early data collection for this study. Non-analytical examination of participation by different individuals revealed that participation rates varied dramatically over time. To the experimenter familiar with studies of caged animals being presented with a set number of trials per day or being tested at the same time each day, it was clear that these patterns might be of interest in their own right. The temporal patterns of the learning curves, with time plotted on the X-axis, suggested that, especially in early acquisition, some individuals appeared to complete trials at a relatively consistent rate, while others showed more variation, with long breaks between early trials.

Students of learning, whether in animals or humans, are familiar with perseverance errors in learning. Despite never receiving positive reinforcement for a particular response, individuals persist in making the same incorrect response. Generally and depending on the characteristics of the task, the difficulty lies in inhibiting the incorrect response in favor of the correct response. In the human literature on creative problem-solving, a similar issue – one of fixation – is described (Beeftink, van Eerde, & Rutte, 2008; Smith & Blankenship, 1991). Some have argued that incubation, or time away from conscious thought over the problem leads to the generation of new possible solutions, especially if the problem-solver can choose when to break away from the problem (Beeftink et al., 2008). While there is considerable controversy over whether incubation effects are real, over what forms of incubation are best, and to what specific problem-solving contexts they apply (Orlet, 2008; Sio & Ormerod, 2009), it is possible that time away from a learning problem could have a similar effect of reducing perseverance errors and leading to solution insight. However, to our knowledge, no such effect has been tested in animals, likely because of the restricted setting in which most animals are tested.

Hypothesis 5: Incubation effects for task acquisition

Animals that took fewer trials to learn a task were expected to take longer breaks from completing trials, particularly in the early stages of task acquisition – thus, in this phase of testing, more time would pass between completed trials compared to later stages and compared to subjects that required more trials to learn a task. Animals that required a greater number of trials to learn a task were expected to allow less time to pass between completed trials. A threshold for optimal breaks or incubation times was also expected – animals that showed very long delays between trials were not expected to show mastery of a task.

Summary

This study of voluntary participation and spontaneous acquisition with computerized touch-screen tasks in rhesus monkeys within a social context allowed us to examine important questions which have been little studied in any species, but which shed light on important questions for ongoing learning research. The vast majority of learning research takes place in relatively controlled and restricted conditions, and variables regarding social influences and motivation to participate are not generally measured. This study is among the first to examine individual acquisition and performance on computerized testing within a complex social context, allowing for examination of effects of social status, including relative social rank, age, and sex. It is also among the first to measure participation rates within a context of choice: individuals choose whether and when to participate, with a choice of all other activities normally available to them.

References

Altmann, S. A. (1962). A field study of the sociobiology of rhesus monkeys, *Macaca mulatta*. *Annals of the New York Academy of Sciences, 102*, 338-435.

Andrews, M. W. (1994). An automated identification system for use with computer-controlled tasks. *Behavior Research Methods Instruments & Computers, 26*(1), 32-34.

Andrews, M. W., Bhat, M. C., & Rosenblum, L. A. (1995). Acquisition and long-term patterning of joystick selection of food-pellet vs social-video reward by bonnet macaques. *Learning and Motivation, 26*(4), 370-379.

Andrews, M. W., & Rosenblum, L. A. (1994). Automated recording of individual performance and hand preference during joystick task acquisition in group-living bonnet macaques (*Macaca radiata*). *Journal of Comparative Psychology, 108*(4), 358-362.

Andrews, M. W., & Rosenblum, L. A. (2002). Response patterns of bonnet macaques following up to 75 weeks of continuous access to social-video and food rewards. *American Journal of Primatology, 57*(4), 213-218.

Artino, A. R., & Stephens, J. M. (2009). Academic motivation and self-regulation: A comparative analysis of undergraduate and graduate students learning online. *Internet and Higher Education, 12*(3-4), 146-151.

Bandura, A., & Schunk, D. H. (1981). Cultivating competence, self-efficacy, and intrinsic interest through proximal self-motivation. *Journal of Personality and Social Psychology*, *41*(3), 586-598.

Bandura, A., & Walters, R. H. (1963). *Social Learning and Personality Development*. New York: Holt, Rinehart, and Winston, Inc.

Bartlett, D. P., & Meier, G. W. (1971). Dominance status and certain operants in a communal colony of Rhesus macaques. *Primates, 12*(3-4), 209-219.

Beeftink, F., van Eerde, W., & Rutte, C. G. (2008). The Effect of Interruptions and Breaks on Insight and Impasses: Do You Need a Break Right Now? *Creativity Research Journal, 20*(4), 358-364.

Belzung, C., & Anderson, J. R. (1986). Social rank and responses to feeding competition in rhesus monkeys. *Behavioural Processes*, *12*(4), 307-316.

Berman, C. M. (1982). The Ontogeny of Social Relationships with Group Companions among Free-Ranging Infant Rhesus-Monkeys .1. Social Networks and Differentiation. *Animal Behaviour, 30*(Feb), 149-162.

Bernstein, I. S. (1970). Primate Status Hierarchies. In L. A. Rosenblum (Ed.), *Primate Behavior: Developments in Field and Laboratory Research* (Vol. 1, pp. 71-109).

Bernstein, I. S. (1993). Sex differences in adolescent rhesus monkey (*Macaca mulatta*) behavior. *American Journal of Primatology, 31*, 197-210.

Bernstein, I. S., Ruehlmann, T. E., Judge, P. G., Lindquist, T., & Weed, J. L. (1991). Testosterone changes during the period of adolescence in male rhesus monkeys. *Psychoneuroendocrinology, 31*, 118-130.

Boelkins, R. C., & Wilson, A. P. (1972). Intergroup social dynamics of the Cayo Santiago rhesus (*Macaca mulatta*) with special references to changes in group membership by males. *Primates, 13*(2), 125-140.

Bown, N., Read, D., & Summers, B. (2003). The lure of choice. *Journal of Behavioral Decision Making, 16*, 297-308.

Catania, A. C., & Sagvolden, T. (1980). Preference for choice over forced choice in pigeons. *Journal of the Experimental Analysis of Behavior, 34*, 77-86.

Chance, M. R. A. (1967). Attention structure as the basis of primate rank orders. *Man, 2*(4), 503-518.

Chancellor, R. L., & Isbell, L. A. (2008). Punishment and competition over food in captive rhesus macaques, Macaca mulatta. *Animal Behaviour, 75*, 1939-1947.

Colvin, J. D. (1986). Proximate causes of male emigration at puberty in rhesus monkeys. In R. G. Rawlins & M. J. Kessler (Eds.), *The Cayo Santiago Macaques*. Albany, NY: State University of New York Press.

Cordova, D. I., & Lepper, M. R. (1996). Intrinsic motivation and the process of learning: Beneficial effects of contextualization, personalization, and choice. *Journal of Educational Psychology, 88*(4), 715-730.

Deutsch, J. C., & Lee, P. C. (1991). Dominance and feeding competition in captive rhesus monkeys. *International Journal of Primatology*, *12*(6), 615-628.

DeWaal, F. B. M. (1986). Class structure in a rhesus monkey group: the interplay between dominance and tolerance. *Animal Behaviour, 34*, 1033-1040.

Drea, C. M. (1998a). Social context affects how rhesus monkeys explore their environment. *American Journal of Primatology, 44*(3), 205-214.

Drea, C. M. (1998b). Status, age, and sex effects on performance of discrimination tasks in group-tested rhesus monkeys (Macaca mulatta). *Journal of Comparative Psychology, 112*(2), 170-182.

Drea, C. M., & Wallen, K. (1995). Gradual Acquisition of Visual-Discrimination Tasks in a Social Group of Rhesus-Monkeys (Macaca-Mulatta). *Animal Learning & Behavior, 23*(1), 1-8.

Drea, C. M., & Wallen, K. (1999). Low-status monkeys "play dumb" when learning in mixed social groups. *Proceedings of the National Academy of Sciences of the United States of America, 96*(22), 12965-12969.

Drickamer, L. C., & Vessey, S. H. (1973). Group changing in free-ranging male rhesus monkeys. *Primates, 14*(4), 359-368.

Ehardt, C. L., & Bernstein, I. S. (1987). Patterns of affiliation among immature rhesus monkeys (*Macaca mulatta*). *American Journal of Primatology, 13*(3), 255-269.

Fagen, R. (1993). Primate juveniles and primate play. In M. E. Pereira & L. A. Fairbanks (Eds.), *Juvenile Primates: Life History, Development, and Behavior*. New York: Oxford University Press.

Fagot, J., & Bonte, E. (2010). Automated testing of cognitive performance in monkeys: Use of a battery of computerized test systems by a troop of semi-free-ranging baboons (Papio papio). *Behavior Research Methods, 42*(2), 507-516.

Fagot, J., & Paleressompoulle, D. (2009). Automatic testing of cognitive performance in baboons maintained in social groups. *Behavior Research Methods, 41*(2), 396-404.

Fairbanks, L. A. (1993). Risk-taking by juvenile vervet monkeys. *Behaviour, 124*, 57-72.

Fitchett, A. E., Collins, S. A., Barnard, C. J., & Cassaday, H. J. (2005). Subordinate male mice show long-lasting differences in spatial learning that persist when housed alone. *Neurobiology of Learning and Memory, 84*(3), 247-251.

Fobes, J. L., & King, J. E. (1982). Measuring primate learning abilities. In J. L. Fobes & J. E. King (Eds.), *Primate Behavior*. New York Academic Press.

Glickman, S. E., & Sroges, R. W. (1966). Curiosity in zoo animals. *Behaviour, 26*(1/2), 151-188.

Goy, R. W. (1979). Sexual compatibility in rhesus monkeys: Predicting sexual performance of oppositely sexed pairs of adults. *Ciba Foundation Symposium, 62*, 227-255.

Hall, K. R. L. (1968). Social learning in monkeys. In P. C. Jay (Ed.), *Primates: Studies in Adaptation and Variability*. New York: Holt, Rinehart, and Winston.

Harlow, H. F. (1949). The formation of learning sets. *Psychological Review, 56*(1), 51-65.

Hassett, J. M., Martin-Malivel, J., Lange, H., Fischer, A., & Wallen, K. (2007). *Age and rank influences on access to an automated system for cognitive testing in socially housed rhesus monkeys*. Paper presented at the Comparative Cognition Society Conference.

Hassett, J. M., Rupp, H. A., & Wallen, K. (2010). Social segregation in male, but not female yearling rhesus macaques (*Macaca mulatta*). *American Journal of Primatology, 72*, 87-92.

Hayenga, A. O., & Corpus, J. H. (2010). Profiles of intrinsic and extrinsic motivations: A person-centered approach to motivation and achievement in middle school. *Motivation and Emotion, 34*(4), 371-383.

Herndon, J. G., Moss, M. B., Rosene, D. L., & Killiany, R. J. (1997). Patterns of cognitive decline in aged rhesus monkeys. *Behavioural Brain Research, 87*(1), 25-34.

Hinde, R. A., Rowell, T. E., & Spencer-Booth, Y. (1964). Behaviour of socially living rhesus monkeys in their first 6 months. *Proceedings of the Zoological Society of London, 143*, 609-649.

Inglis, I. R., Forkman, B., & Lazarus, J. (1997). Free food or earned food? A review and fuzzy model of contrafreeloading. *Animal Behaviour, 53*, 1171-1191.

Jay, P. (1965). Field studies. In A. M. Schrier, H. F. Harlow & F. Stollnitz (Eds.), *Behavior of nonhuman primates* (Vol. 2, pp. 525-591). New York: Academic Press.

Joubert, A., & Vauclair, J. (1986). Reaction to novel objects in a troop of guinea baboons: approach and manipulation. *Behaviour, 96*(1/2), 92-104.

Katzir, G. (1982). Relationships between Social-Structure and Response to Novelty in Captive Jackdaws, Corvus-Monedula L .1. Response to Novel Space. *Behaviour, 81*, 231-264.

Kluger, A. N., & DeNisi, A. (1996). The effects of feedback interventions on performance: a historical review, a meta-analysis, and a preliminary feedback intervention theory. *Psychological Bulletin, 119*(2), 254-284.

Lacreuse, A., Espinosa, P. M., & Herndon, J. G. (2006). Relationships among cognitive function, fine motor speed and age in the rhesus monkey. *Age, 28*(3), 255-264.

Leotti, L. A., Iyengar, S. S., & Ochsner, K. N. (2010). Born to choose: the origins and value of the need for control. *Trends in Cognitive Sciences, 14*(10), 457-463.

Lepoivre, H., & Pallaud, B. (1986). Learning set formation in a group of Guinea baboons (*Papio papio*): Importance of the behavioral variable measured. *American Journal of Primatology, 10*(1), 25-36.

Lepper, M. R., Corpus, J. H., & Iyengar, S. S. (2005). Intrinsic and extrinsic motivational orientations in the classroom: Age differences and academic correlates. *Journal of Educational Psychology, 97*(2), 184-196.

Lindburg, D. G. (1971). The rhesus monkeys in North India: an ecological and behavioral study. In L. A. Rosenblum (Ed.), *Primate Behavior* (Vol. 2, pp. 1-106). New York: Academic Press.

Lovejoy, J., & Wallen, K. (1988). Sexually dimorphic behavior in group-housed rhesus-monkeys (Macaca-Mulatta) at 1 year of age. *Psychobiology, 16*(4), 348-356.

Lynn, D. A., & Brown, G. R. (2009). The Ontogeny of Exploratory Behavior in Male and Female Adolescent Rats (Rattus norvegicus). *Developmental Psychobiology, 51*(6), 513-520.

Madlafousek, J., & Hlinak, Z. (1977). Sexual behavior of female laboratory rat - inventory, patterning, and measurement. *Behaviour, 63*, 129-174.

Martinez, I., & Paredes, R. G. (2001). Only self-paced mating is rewarding in rats of both sexes. *Hormones and Behavior, 40*(4), 510-517.

Menzel, E. W., & Juno, C. (1982). Marmosets (Saguinus fuscicollis): Are learning sets learned? *Science, 217*(4561), 750-752.

Menzel, E. W. J. (1966). Responsiveness to objects in free-ranging Japanese monkeys. *Behaviour, 26*(1/2), 130-150.

Meyer, D. R. (1951). Food deprivation and discrimination reversal learning by rhesus monkeys. *Journal of Experimental Psychology 41*(1), 10-16.

Moller, A. C., Deci, E. L., & Ryan, R. M. (2006). Choice and ego-depletion: The moderating role of autonomy. *Personality and Social Psychology Bulletin, 32*(8), 1024-1036.

Mondragon-Ceballos, R., Chiappa, P., Mayagoitia, L., & Lee, P. (2010). Sex differences in learning the allocation of social grooming in infant stumptailed macaques. *Behaviour, 147*(9), 1073-1099.

Moore, T. L., Killiany, R. J., Herndon, J. G., Rosene, D. L., & Moss, M. B. (2006). Executive system dysfunction occurs as early as middle-age in the rhesus monkey. *Neurobiology of Aging, 27*, 1484-1493.

Neuringer, A. J. (1969). Animals respond for food in the presence of free food. *Science, 166*(3903), 399-401.

Niemivirta, M., & Tapola, A. (2007). Self-efficacy, interest, and task performance: Within-task changes, mutual relationships, and predictive effects. *Zeitschrift Fur Padagogische Psychologie, 21*(3-4), 241-250.

Nistor, N., & Neubauer, K. (2010). From participation to dropout: Quantitative participation patterns in online university courses. *Computers & Education, 55*(2), 663-672.

Noe, R. A., Tews, M. J., & Dachner, A. M. (2010). Learner engagement: A new perspective for enhancing our understanding of learner motivation and workplace learning. *The Academy of Management Annals, 4*, 279-315.

Novak, M. A., Musante, A., Munroe, H., Oneill, P. L., Price, C., & Suomi, S. J. (1993). Old, social housed rhesus monkeys manipulate objects. *Zoo Biology, 12*, 285-298.

Orlet, S. (2008). An expanding view on incubation. *Creativity Research Journal, 20*(3), 297-308.

Orvis, K. A., Fisher, S. L., & Wasserman, M. E. (2009). Power to the People: Using Learner Control to Improve Trainee Reactions and Learning in Web-Based Instructional Environments. *Journal of Applied Psychology, 94*(4), 960-971.

Paredes, R. G., & Vazquez, B. (1999). What do female rats like about sex? Paced mating. *Behavioural Brain Research, 105*(1), 117-127.

Patall, E. A., Cooper, H., & Robinson, J. C. (2008). The effects of choice on intrinsic motivation and related outcomes: A meta-analysis of research findings. *Psychological Bulletin, 134*(2), 270-300.

Pelaez, F., Gil-Burmann, C., & Sanchez, S. (2000). Feeding tactics in juvenile rhesus monkeys (Macaca mulatta). *American Journal of Primatology, 51*(2), 147-152.

Prescott, M. J., Brown, V. J., Flecknell, P. A., Gaffan, D., Garrod, K., Lemon, R. N., et al. (2010). Refinement of the use of food and fluid control as motivational tools for macaques used in behavioural neuroscience research Report of a Working Group of the NC3Rs. *Journal of Neuroscience Methods, 193*(2), 167-188.

Resko, J. A., Goy, R. W., Robinson, J. A., & Norman, R. L. (1982). The pubescent rhesus monkey - some characteristics of the menstrual cycle. *Biology of Reproduction, 27*(2), 354-361.

Rowell, T. E. (1974). The concept of social dominance. *Behavioral Biology, 11*, 131-154.

Sade, D. S. (1967). Determinants of dominance in a group of free-ranging rhesus monkeys. In S. A. Altmann (Ed.), *Social communication among primates* (pp. 99-113). Chicago: University of Chicago Press.

Schmitz, B., & Skinner, E. (1993). Perceived control, effort, and academic performance: interindividual, intraindividual, and multivariate time-series analyses. *Journal of Personality and Social Psychology, 64*(6), 1010-1028.

Schrier, A. M. (1984). Learning how to learn: the significance and current status of learning set formation. *Primates, 25*(1), 95-102.

Shockley, K. M., & Allen, T. D. (2010). Investigating the missing link in flexible work arrangement utilization: an individual difference perspective. *Journal of Vocational Behavior, 76,* 131-142.

Singh, D. (1970). Preference for bar pressing to obtain reward over freeloading in rats and children. *Journal of Comparative and Physiological Psychology, 73*(2), 320-327.

Sio, U. N., & Ormerod, T. C. (2009). Does Incubation Enhance Problem Solving? A Meta-Analytic Review. *Psychological Bulletin, 135*(1), 94-120.

Skinner, B. F. (1963). Operant behavior. *American Psychologist, 18*(8), 503-515.

Skinner, E. A., Kindermann, T. A., & Furrer, C. J. (2009). A Motivational Perspective on Engagement and Disaffection Conceptualization and Assessment of Children's Behavioral and Emotional Participation in Academic Activities in the Classroom. *Educational and Psychological Measurement, 69*(3), 493-525.

Smiley, P. A., Coulson, S. L., Greene, J. K., & Bono, K. L. Performance Concern, Contingent Self-worth, and Responses to Repeated Achievement Failure in Second Graders. *Social Development, 19*(4), 779-798.

Smith, S. M., & Blankenship, S. E. (1991). Incubation and the persistence of fixation in problem-solving. *American Journal of Psychology, 104*(1), 61-87.

Southwick, C. H., Beg, M. A., & Siddiqi, M. R. (1965). Rhesus monkeys in North India. In I. DeVore (Ed.), *Primate behavior: Field studies of monkeys and apes* (pp. 111-159). New York: Holt, Rinehart, and Winston, Inc.

Steinmayr, R., & Spinath, B. (2009). The importance of motivation as a predictor of school achievement. *Learning and Individual Differences, 19*(1), 80-90.

Stephenson, G. R. (1973). Biology of communication and population structure. In C. R. Carpenter (Ed.), *Behavioral Regulators of Behavior in Primates*. Cranbury, New Jersey: Associated University Presses, Inc.

Suzuki, S. (1997). Effects of number of alternatives on choice in humans. *Behavioural Processes, 39*, 205-214.

Suzuki, S. (1999). Selection of forced- and free-choice by monkeys (Macaca fascicularis). *Perceptual and Motor Skills, 88*(1), 242-250.

Taffe, M. A. (2004). Effects of parametric feeding manipulations on behavioral performance in macaques. *Physiology & Behavior, 81*(1), 59-70.

Tomporowski, P. D., Simpson, R. G., & Hager, L. (1993). Method of recruiting subjects and performance on cognitive tests. *American Journal of Psychology, 106*(4), 499-521.

Tsumori, A. (1966). Delayed response of wild Japanese monkeys by the sand-digging method (II). *Primates, 7*(3), 363-380.

Wallen, K., Winston, L., Gaventa, S., Davis-Dasilva, M., & Collins, D. C. (1984). Periovulatory changes in female sexual behavior and patterns of steroid secretion in group-living rhesus monkeys. *Hormones and Behavior, 18,* 431-450.

Washburn, D. A., Hopkins, W. D., & Rumbaugh, D. M. (1991). Perceived control in rhesus monkeys (Macaca mulatta) - enhanced video-task performance. *Journal of Experimental Psychology-Animal Behavior Processes, 17*(2), 123-129.

Washburn, D. A., & Rumbaugh, D. M. (1991). Impaired performance from brief social isolation of rhesus monkeys (Macaca mulatta): A multiple video-task assessment. *Journal of Comparative Psychology, 105*(2), 145-151.

Washburn, D. A., Rumbaugh, D. M., & Putney, R. T. (1994). Apparatus as milestones in the history of comparative psychology. *Behavior Research Methods Instruments & Computers, 26*(2), 231-235.

Wilson, M. E., Gordon, T. P., & Collins, D. C. (1982). Variation in ovarian steroids associated with the annual mating period in female rhesus monkeys (*Macaca mulatta*). *Biology of Reproduction, 27,* 530-539.

Yeo, G., & Neal, A. (2004). A multilevel analysis of effort, practice, and performance: Effects of ability, conscientiousness, and goal orientation. *Journal of Applied Psychology, 89*(2), 231-247.

Zajonc, R. B. (1965). Social facilitation: a solution is suggested for an old unresolved social psychological problem. *Science, 149,* 269-274.

Social demographic influences on voluntary participation in computerized learning tasks in a rhesus monkey social group

Janice M. Hassett

Emory University and Yerkes National Primate Research Center

Kim Wallen

Emory University and Yerkes National Primate Research Center

Abstract

Empirical studies of learning often take place in sparse spaces. However, normal learning generally occurs in environments rich with physical and social stimuli, and regardless of the formality of the learning context, learners shift regularly between engagement in and disengagement from learning. Thus, our understanding of learning translates poorly to learning in complex environments. This is particularly the case in studies of animal learning. Previous studies have shown that social demographics, especially social rank, can influence participation and performance on learning tasks in monkeys. We created a computerized kiosk system designed to allow over 100 members of a rhesus monkey social group to “volunteer,” engaging with the kiosk as they chose, with banana-flavored pellets as food rewards. Individuals were automatically identified by RFID tag implants. In this context, we were able to examine the influence of social demographics on participation, including subject age, social rank, and sex. Social rank was an important variable only in the beginning of the study, affecting initial access and trial completion rates. This effect dissipated over the course of the study, possibly as low-ranking subjects learned that food rewards were not depleted. Young monkeys engaged with the kiosk much more than adult subjects, with faster initial access and trial completion and much higher rates of participation overall, and these effects became more prominent over the course of the study. Sex differences could only be examined in juvenile subjects, but no differences in access or overall participation were found. These findings suggest that in any testing context, the motivation of adult subjects to work for food rewards may be lower than the motivation of younger subjects. Possibly, older subjects were less motivated due to the smaller relative reward in relation to body mass,

due to less exposure to control over environmental contingencies, or due to a preference for other kinds of activities. Studies of age-related changes in learning and cognition must consider differences in motivation and changes in types of motivation that occur with age in any species, including humans. A restriction of choice cannot be assumed to equalize motivation between subject groups.

Social demographic influences on voluntary participation in computerized learning tasks in a rhesus monkey social group

In the majority of social species, learning takes place in a highly social context. Even when learning occurs in isolation, it can be affected by the social history of an individual (Fitchett, Collins, Barnard, & Cassaday, 2005). Despite the "sociality" of learning, the vast majority of our understanding of learning, especially in nonhuman species, comes from studies of animals tested and often housed in relative social isolation. Their motivation to participate in testing is most often manipulated through food or water restriction, so that subjects are motivated by the drive to obtain food or liquid to meet physiological needs (Taffe, 2004). In some studies in primates, food restriction and the use of food rewards is replaced by social stimulus rewards, such as videos of other monkeys (Andrews & Rosenblum, 2002). This is also a manipulation of motivation, given the social restrictions of the subjects. Some have argued that without manipulations of motivation, it is not possible to attain consistent performance. A systematic investigation of food restriction in rhesus monkeys demonstrated that when subjects are not food restricted, performance on a broad range of neurocognitive tasks declines, compared to when subjects are at least moderately food restricted (Taffe, 2004).

If we move outside of the highly restricted physical space of laboratory cognitive testing, however, would motivation to participate in cognitive testing exist? Other studies have demonstrated the importance of autonomy and choice in both humans and nonhuman primates, and one study demonstrated that in a more traditional testing environment, rhesus monkeys perform better when allowed to choose which task they will work on (Washburn, Hopkins, & Rumbaugh, 1991). If nonhuman primates could participate in cognitive testing as volunteers, working from a more naturalistic social environment without food or water restrictions and with minimal restriction on activities of choice, would anyone choose to participate? If they did participate, would participation be influenced in any way by social factors?

In rhesus monkeys, social groups are organized in matrilineal hierarchies (Lindburg, 1971), and three primary demographic factors are central to the social structure (Bernstein & Sharpe, 1966; Chance, 1956). First, social rank determines place within the hierarchy (Rowell, 1974). Second, sex is important because of the different roles played by adult males and females, with females central to the hierarchy and passing their social status to their offspring (Sade, 1967), and males peripheral to the matrilineal hierarchy, joining the social group as adults and establishing a separate hierarchy with other adult males (Southwick, Beg, & Siddiqi, 1965). Juvenile monkeys also show sex differences in behavior and patterns of affiliation, as early as one year of age (Hassett, Rupp, & Wallen, 2010; Lovejoy & Wallen, 1988; Wallen, 1996). Finally, age is important as the behaviors and roles of both males and females change over the developmental trajectory (Berman, 1982). While both sexes inherit the mother’s social rank, only the females will remain in the natal group for the duration of their lives, while the males will leave the natal group around the time of puberty (Boelkins & Wilson, 1972; Colvin, 1986; Drickamer & Vessey, 1973). All three of these demographic factors – sex, age, and social rank – can influence interactions with others and interactions with the shared physical environment (Jay, 1965).

In this study, we created a computerized cognitive testing system or “kiosk” that allowed for nearly all members of an age-graded social group of more than 100 rhesus monkeys to be individually identified and to participate as they were motivated to do so. The kiosk was available on a nearly continuous basis over the course of 439 days.

The current study is not the first to complete cognitive testing in a primate social group. Others have successfully done such testing, using different methodologies or different kinds of social groups. Two research groups developed a group visual discrimination task, in which primate subjects learned that colors or spatial arrangements indicated where they would find food-baited holes or boxes (Drea, 1998b; Drea & Wallen, 1995, 1999; Lepoivre & Pallaud, 1986). With baited and non-baited discriminanda in different zones, learning could be measured by visits to zones, overall or by individuals, and by successful retrieval of buried foods. With this methodology, the potential for social influence is high and learning by observation is high, and Drea and Wallen demonstrated significant effects in their rhesus monkey subjects of rank on participation and performance (Drea, 1998b; Drea & Wallen, 1999), as well as significant effects of age on participation (Drea, 1998b). Lepoivre and Pallaud (1986) did not report on social demographic effects in their Guinea baboon subjects.

The importance of social influences on participation and performance in cognitive testing was clearly demonstrated in a series of these group visual discrimination studies (Drea, 1998a, 1998b; Drea & Wallen, 1999). First, they found that high-ranking monkeys participated more overall, and also that high-ranking monkeys demonstrated learning of the discrimination more often than did low-ranking monkeys (Drea, 1998b). They also found that adult members of the social group participated less than did younger animals, and that fewer adults learned the discrimination compared to subadult and juvenile animals (Drea, 1998b). However, the rank effect was demonstrated to be a result of the specific social context: in a subsequent study, high and low ranking monkeys learned the discrimination separately or all together (Drea & Wallen, 1999). When low-ranking monkeys learned the discrimination in the absence of high-ranking monkeys, they performed just as well. They also performed discriminations that had been learned in the group as a whole. Thus, low-ranking monkeys modified their performance based on the presence of high-ranking members of the social group.

A different approach to testing learning within the social group has been in studies more like that which is reported here. In these studies, RFID technology is used to activate a computerized testing system (with a joystick or touch screen interface). This allows for the individual identification of participating individuals and for the automated tracking of participation and performance, as well as for testing to occur in the absence of the experimenter (Andrews, 1994). These studies have been completed in small groups of young bonnet macaques (Andrews & Rosenblum, 1994), in small groups of older baboons (Fagot & Paleressompoulle, 2009), in a small group of rhesus macaques (Fagot & Paleressompoulle, 2009), and in an age-graded social group of 26 baboons (Fagot & Bonte, 2010). While the latter study demonstrated that such testing could be completed in a larger group, the youngest animals were about two years of age, and social rank was determined by access to desirable foods, an approach to determining social rank which should be treated with caution (Chance, 1967; Jay, 1965). Each of these studies has also used a relatively high testing system to subject ratio, with at least one testing system for every four animals within a group. Furthermore, none of these studies, with the exception of Andrews and Rosenblum (1994), has used testing systems with the capacity to advance individuals to different tasks once they meet criterion, instead requiring that all animals meet criterion or be dropped from the study before any subject can be advanced to a new level. In such a paradigm, some individuals are inevitably over-trained on certain tasks.

The current study fell between the discrimination and computerized testing methodologies. While our cognitive testing system or “kiosk” could only be used by one individual at a time, the design of the system was such that it was possible for a limited number of group members to observe another animal working, and for them to see what the focal subject saw on the touch screen. The testing systems described above were designed to limit visual access to a single animal at a time. Also in the current study, only a single testing system was used for the large social group, creating the potential for greater competition for access within the group.

An earlier pilot study using a similar cognitive testing system in a different rhesus monkey social group revealed some significant social demographic effects. This pilot study was far more limited in scope, with just 9 days of testing in a 74 member social group (Hassett, Martin-Malivel, Lange, Fischer, & Wallen, 2007). All subjects were allowed to complete 50 trials per day, with a “trial” consisting of a touch to an image on the screen. In that study, we found that juvenile animals accessed and completed all trials on a significantly greater proportion of days compared to adult animals. Also, high-ranking individuals completed trials on a greater proportion of days compared to low-ranking individuals. We did not find any sex differences in participation in this short study.

Aside from our earlier pilot study, there was little similar data on which to base hypotheses of participation by social demographics. Thus, we turned to the most similar available literature, on object manipulation and attention to novel objects in primates. Our kiosk system was novel as an interactive device for all subjects in this study, starting with the first day of data collection, when the computer and cognitive testing program were first turned on. The food rewards that it dispensed (94mg banana-flavored pellets) were also novel. Thus, this literature, in combination with our pilot study findings, seemed the most appropriate for developing hypotheses of social demographic influences on participation.

Younger animals show a stronger tendency to orient to and interact with objects of many kinds (Fairbanks, 1993; Glickman & Sroges, 1966; Joubert & Vauclair, 1986; Menzel, 1966; Stephenson, 1973; Tsumori, 1966), and thus we expected that with the kiosk system – a system which was especially novel at the start of testing, but which continued to be novel as tasks changed – younger animals would be the leading participants. We also predicted this because young primates in the social group spend a greater proportion of their time engaged in play behaviors (Ehardt & Bernstein, 1987; Fagen, 1993; Rowell, 1974), including social play and nonsocial object play. Older animals, on the other hand, spend much of their time engaged in more sedentary affiliative behaviors such as grooming, infant care, and napping with family members. We expected to find similar effects for age as we found in the pilot study. Specifically, we expected that initial access to the kiosk system would show an age effect, with younger animals accessing the kiosk before older animals. Furthermore, we expected that age effects would become more substantial over the course of the study. As tasks got harder in the current study, age would matter more, with older animals participating at slower rates compared to younger animals due to reduced interest. In regard to the specific breakdown of age effects, we predicted that fully adult animals would show the slowest rates of participation. Generally, these are individuals 7 years of age or older. We also expected that animals between ages 5 and 6 would show reduced participation compared to animals 4 years of age or younger. Since almost all of the animals over 3 years of age in the social group of this study (with the exception of two 16-year-old adult males) were female, one reason for reduced motivation with age may relate to the size of an adult female's matriline: the more offspring an adult female has, the less likely she is to be motivated to engage in cognitive tasks to obtain food rewards, engaging instead in high rates of affiliative behaviors within her family and with other members of the social group.

We also predicted that participation would show effects by social rank, but that these effects would be reduced over the course of the study. Most rank effects that have been studied in primates and particularly in macaques have consistently shown that when access to a desirable food or object is limited, high-ranking individuals will gain access to them first (Belzung & Anderson, 1986; Chancellor & Isbell, 2008; Deutsch & Lee, 1991; DeWaal, 1986; Drea, 1998a, 1998b; Drea & Wallen, 1999). More than an effect of overt assertion of dominance by high-ranking individuals, these access effects seem to result largely from voluntary inhibition of behavior by lower-ranking individuals. When access is less limited, such as with normally available food or food that can be accessed predictably, dominant group members sometimes take on a more relaxed approach compared to subordinate animals (Bartlett & Meier, 1971; Pelaez, Gil-Burmann, &

Sanchez, 2000). When the access to a resource does not come in form of competition over a limited quantity, then access is more equal across social ranks. In the case of the kiosk system, it may have taken time for the animals to learn that the kiosk was nearly continuously available and during that time we expected that rank effects would disappear and that, due to the lack of competition for resources, there would be no differences in either participation or performance on learning tasks.

Although we did not observe sex differences in participation or performance in our initial pilot study, a review of the literature suggested the possibility of sex differences in initial access to the kiosk and in overall rates of participation. First, female macaques are more often observed to manipulate both familiar and novel objects, and greater social facilitation of object manipulation has been observed in female macaques (Novak et al., 1993; Stephenson, 1973). From an early age, female macaques are more integrated with the social group (Ehardt & Bernstein, 1987; Lovejoy & Wallen, 1988), and females more often mimic the behaviors of their mothers compared to juvenile males (Mondragon-Ceballos, Chiappa, Mayagoitia, & Lee, 2010). Juvenile males are more often separated from the social group, forming small groups of same-age male peers (Hassett et al., 2010; Lovejoy & Wallen, 1988). Thus, we predicted that, given the greater orientation of female macaques towards object manipulation and social facilitation, juvenile females would initially access the kiosk faster than juvenile males. In terms of overall participation, however, we expected that juvenile males would show higher overall rates of participation, due to their greater separation from the social group.

Our hypotheses focused primarily on participation, rather than on performance. Due to the fact that the tasks examined in this study were primarily tasks designed to shape interactions with the kiosk system in preparation for later, more advanced testing, we did not make predictions of performance and did not expect social demographic differences in performance, especially due to the continual availability of the kiosk. The consequences of differences in participation, and, presumably, of differences in motivation, should be considered in relation to their relevance for testing in any environment.

Methods

Subjects

The rhesus monkey social group in this study was housed at the Yerkes National Primate Center Field Research Station in a large indoor-outdoor compound (30m x 30m) with attached heated and air conditioned indoor quarters. Water was continuously available. The group was fed monkey chow (LabDiet 5037 chow, Purina Mills, St. Louis, MO) twice daily, around 8:00am and 4:00pm on each day, supplemented once per day with fruits and vegetables. All research was conducted under an approved Institutional Animal Use and Care protocol, in accordance with the *NIH Guide for the Care and Use of Laboratory Animals*, and in accordance with legal requirements of the United States. At the start of this study, all subjects in the social group were naïve to computerized testing of any kind.

Subjects in the social group ranged in age from newborn to 18 years of age. Matrilineal rankings within the group were determined by research staff through observations and documentation of agonistic interactions between dyads, with a focus on the matriarchs of each family. From these observations a linear hierarchy was constructed. Matriarchs that never showed subordinate behavior to others were the highest ranking, or alpha. Matriarchs that showed subordinate behaviors to all others were the lowest ranking, and the position of middle-ranking matriarchs was determined by relative prevalence of subordinate behavior to other middle-ranked matriarchs, with the smallest number of reversals. Every monkey within a given matriline was assigned the same social rank.

The majority of subjects living in this group had received RFID implants in their arms (described below) and were allowed kiosk access (access of individuals was controlled electronically by linking their RFID numbers with the kiosk program) from the first day it became available on February 17, 2010. On this day, 88 animals had access to the kiosk. In these social groups, it is routine for animals to be removed from the group for veterinary care, with durations of removal ranging from one day to several months. Thus, additional potential subjects were returned to the group over time. In the first two months of its operation, the kiosk was available to 95 members of the social group. A few individuals living within the group did not have access to the kiosk for an extended period. This included a cohort of animals born in 2009 who were part of a separate study and excluded because of needs of that study. These individuals had RFID tags, but they were not recognized by the kiosk program, preventing these individuals from attempting the tasks described below. In addition, infants under 6 months of age were too young to receive the RFID microchips and thus were excluded at the start of the study.

The kiosk program was made available to the previously excluded 1-year-old subjects in August 2010. At the time, 7 of these individuals were housed in the social group, but 5 of these individuals were permanently removed from the group less than 20 days after they were given initial access (described in detail below). Seven additional members of this cohort returned to the social group and were given kiosk access between October 2010 and April 2011. In November 2010 and January 2011, microchips were implanted and the kiosk made available to a total of 17 monkeys born in spring and summer of 2010. In total, 126 animals had access to the kiosk for at least some period of time. Four individuals never interacted with the kiosk, but these individuals were in the social group for an average of only 20 days.

Changes in the social group and numbers of animals

Beginning in 2009, the social group began exhibiting high levels of social upheaval and a large number of juveniles born in 2009 were removed to temporary housing outside of the social group. In August 2010, a decision was made to split the group, and the top five ranking matrilines were moved to a different compound at the field station. In January 2011, there was an overthrow of the new alpha female, resulting in permanent removal of the top four ranking matrilines. After this split, the animals that remained for kiosk testing were the seven matrilines originally ranked as 10-16. After August 2010, the juveniles that had been removed from the social group were gradually returned. At the conclusion of data collection reported here, 5/1/2011, 51 animals within the social group had access to the kiosk. Table 1 shows the breakdown by sex, age, and social rank as the group was in February 2010 and how it changed over the course of this study. The two adult males in the group, both 16 years of age, are not included in this table since their social ranks were not a part of the matrilineal rankings. The four subjects that never participated are also not included.

🟩 Families in the group until August 2010 (group split)
🟦 Families in the group until January, 2011 (group overthrow)
▨ Families in the group through the entire study

	Animals given kiosk access in February-April 2010						**Kiosk access in November 2010**		**Kiosk access in August 2010**		**Kiosk access in January 2011**		
Social rank before August, 2010	Ages 1-2, M	Ages 1-2, F	Ages 3-4, M	Ages 3-4, F	Ages 5-6, F	Ages 7+, F	Age <1yr, M	Age <1yr, F	Age 1, M	Age 1, F	Age <1yr, M	Age <1yr, F	**total**
1	1	1	0	1	1	4	0	0	0	0	0	0	**8**
2	0	2	0	3	2	2	0	0	1	1	0	0	**11**
3	2	0	0	1	0	1	0	0	0	0	0	0	**4**
4	3	1	1	4	3	4	0	0	1	2	0	0	**19**
5	0	0	0	0	0	1	0	0	0	0	0	0	**1**
6	0	0	0	1	0	1	0	0	0	1	0	0	**3**
7	0	1	0	1	0	1	0	0	0	0	0	0	**3**
8	0	0	0	0	0	1	0	0	0	0	0	0	**1**
9	0	0	0	2	0	1	0	0	1	0	0	0	**4**
10	0	0	0	1	1	3	1	1	1	1	0	0	**9**
11	1	0	0	1	1	2	1	1	0	0	0	0	**7**
12	1	0	0	3	1	2	1	0	0	1	0	0	**9**
13	0	0	0	0	1	1	0	1	1	1	0	0	**5**
14	0	0	1	5	2	5	1	3	0	1	1	1	**20**
15	0	0	0	2	1	1	0	1	0	0	1	1	**7**
16	0	1	0	2	1	3	1	0	0	1	0	0	**9**
total	**8**	**6**	**2**	**27**	**14**	**33**	**5**	**7**	**5**	**9**	**2**	**2**	

Table 1: Composition of the social group, listed by matrilineal social rank at the start of the study, sex, age, and time of kiosk access. A social rank of "1" is the highest rank. The two adult males in the social group are not included, and the 4 members that lived in the social group for brief periods but did not participate are also not included. Also highlighted are the social ranks of the matrilines that were removed from the group in August 2010 and January 2011.

RFID implant procedures

RFID microchips (12.5mm, 134.2 kHz ISO, Destron Fearing, St. Paul, Minnesota) were implanted in potential subjects using sterile 12 gauge needles with disposable single-use plunger-style implanters (Biomark, Boise, Idaho). Implants were completed by trained research personnel while animals were under ketamine general anesthesia, injected IM or IV at 10mg/kg. All subjects received a subdermal implant of an RFID tag in each forearm. All individuals were checked annually for functional RFID tags in both arms, and new tags were implanted if older tags were not working or no longer present. For individuals born after the start of cognitive testing with the kiosk, implants were made around the time that the infants turned 6 months of age.

Apparatus

The “kiosk” system was mounted in a corner just outside of the perimeter fence of the monkey compound. Figure 1 presents an overhead perspective diagram of the compound and kiosk position, along with an image of the social group with the kiosk in context.

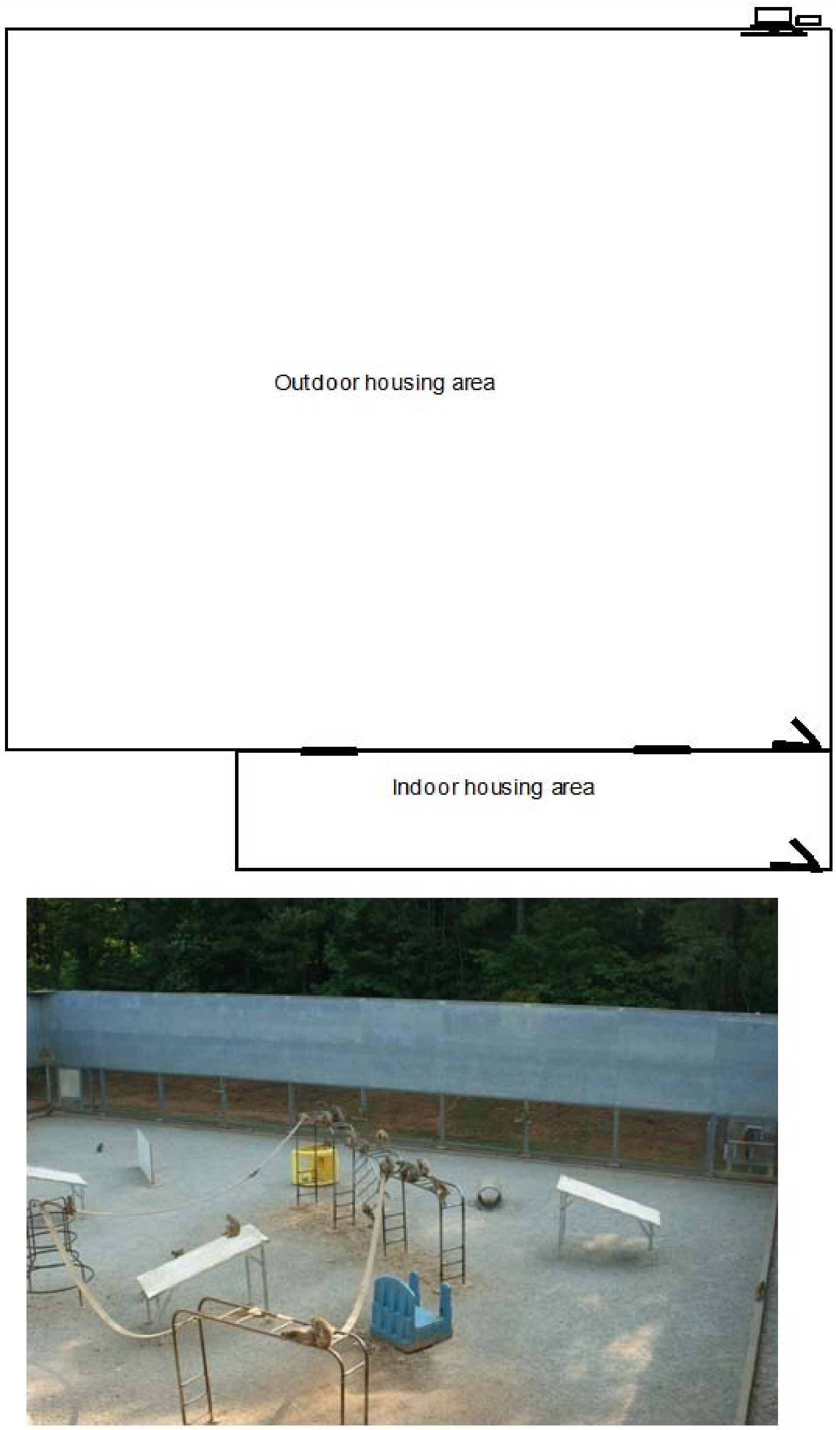


Figure 1: Overhead perspective diagram and photo of the social group in which the kiosk was installed. In the diagram, the kiosk is indicated in the upper-right corner of the image. In the photo, it is on the right end of the compound.

The monkeys were separated from most of the physical components of the kiosk system by a large window of 1.3cm-thick clear polycarbonate resin, allowing them a clear view of the kiosk components and the surrounding space. On the inside of the monkey compound, a 140cm x 8cm metal perch mounted 15cm from the window allowed multiple monkeys to sit in front of or in the vicinity of the kiosk. A cloverleaf-shaped armhole, cut in a panel of polycarbonate resin with a maximum opening of 5cm (14cm diameter), was centered in front of the touch screen and encircled by an RFID antenna (described below) and allowed access to all parts of the screen, which was positioned approximately 15cm from the window. The kiosk consisted of a NEMA4 15” capacitive touch screen monitor (Vartech Systems Inc., Baton Rouge, Lousiana), mounted in a cutout of a large NEMA4 weather-proof enclosure. The touch screen was connected by a VGA cable for video and serial-to-USB converter for “mouse” input to a small low-power netbook running the Windows XP Professional operating system. An automated pellet dispenser (Med Associates Inc., Georgia, Vermont) was connected to a programmable logic controller (PLC) to allow serial input and output connections via a serial-to-USB converter connection to the netbook. A modified iMax Black Label RFID reader (Datamars Inc., Youngstown, OH) and custom-built antenna was also connected to the netbook via a serial-to-USB converter. The iMax Black Label readers were modified with circuitry to enable the reader to identify a chip approximately every 300ms. The three USB converters allowed connections to the netbook, while also allowing input and output signals to work as in a traditional serial connection. Each of these connections was mapped to its own COM port using the Windows Device Manager on the kiosk netbook. In addition to these central components, a small thermostat and thermo-electric cooling units were housed in the same weather-proof box as the netbook and touchscreen, as well as a generic loud-speaker for audio feedback.

An additional smaller weather-proof enclosure housed the pellet dispenser and RFID reader electronics. Connections to the PLC and the netbook in the main compartment were made using flexible conduit and multi-conductor cabling. The RFID reader was connected to its antenna via shielded two-wire cable in flexible conduit, which was mounted in a circle shape (16cm diameter) inside polycarbonate resin and positioned over the armhole through which the animals reached to touch the touch screen. The pellet dispenser was attached to a length of clear plastic food and beverage tubing, which terminated on a connection to a metal pellet cup (Med Associates Inc., Georgia, Vermont). The pellet cup was located to the right of the touchscreen, 16 cm from the right edge of the armhole, and 10cm above the perch. A final weather-proof accessory box housed active ethernet connections, with connections to the main compartment via conduit. Figure 2 shows photographs of many of the kiosk components described here.

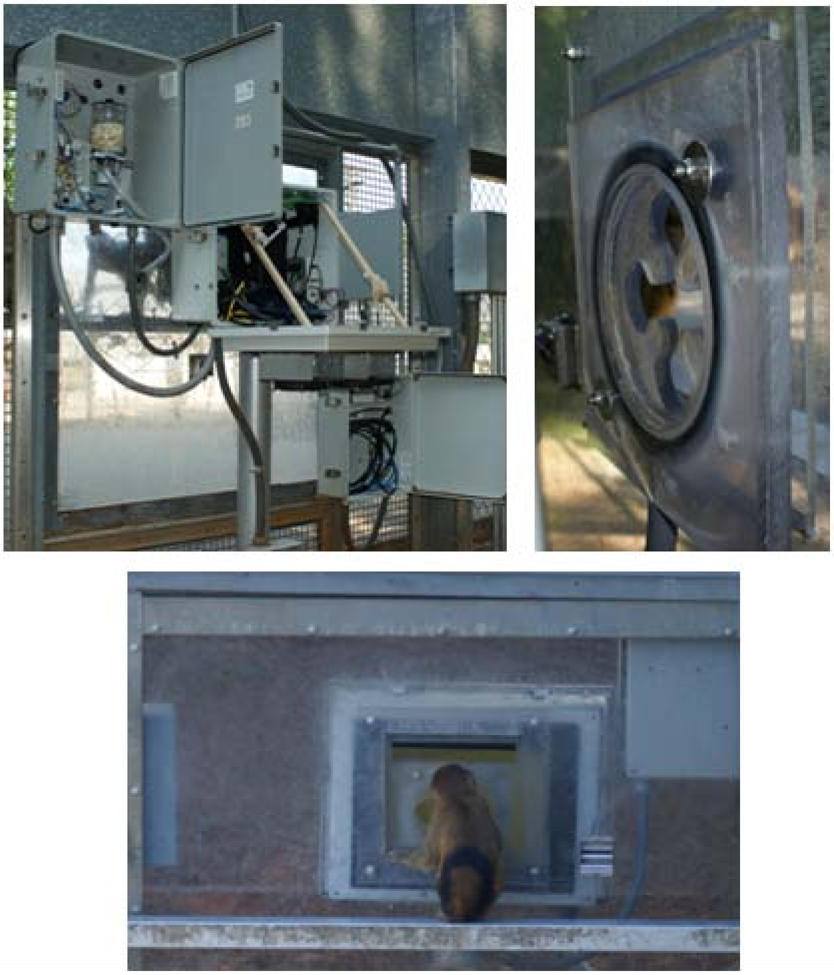


Figure 2: Kiosk components. Top left: viewed from just outside the monkey social group, all weatherproof boxes housing kiosk components, including the pellet dispenser and reader, touch screen and netbook, and related components. Top right: armhole encircled by the RFID antenna (black). Bottom: the kiosk from the monkey's perspective inside the compound.

Materials

In addition to the materials described above as part of the kiosk apparatus, 94mg banana-flavored food pellets were used as rewards. The pellet mixture in the feeder consisted of about 80% grain-based and 20% of a purified pellet dextrose and sucrose-based formula (Bio-serv, Frenchtown, New Jersey).

Training plan and software design

The kiosk program was programmed using Presentation software (NeuroBehavioral Systems, Inc., Albany, CA). When the program was running and a subject reached through the armhole encircled by the RFID antenna, the antenna detected either of the subject's two unique 15-digit RFID numbers, depending upon which arm was used, which was transmitted via the RFID reader to the kiosk program. The program retrieved the information required to present the appropriate trial of the appropriate task for the identified subject. To ensure accurate identification, two readings of the same 15-digit RFID number were required to start a trial. If an animal had met the maximum number of trials allowed for that day, the program briefly presented a large green "X" on a black screen, and then returned to the login screen to wait for an RFID code. With this design, it was possible for animals to come and go from the system and for each individual to advance through training at their own pace.

Initial Training: On the first day that the kiosk was made available, the experimenter placed a small amount of peanut butter on the four corners of the touch screen. After the initial peanut butter placement, no rewards other than the banana flavor pellets were offered near the kiosk on this day or on any subsequent days of testing. The same initial shaping procedures were set for all animals with access to the kiosk. Figure 3 shows all of these stages of shaping.

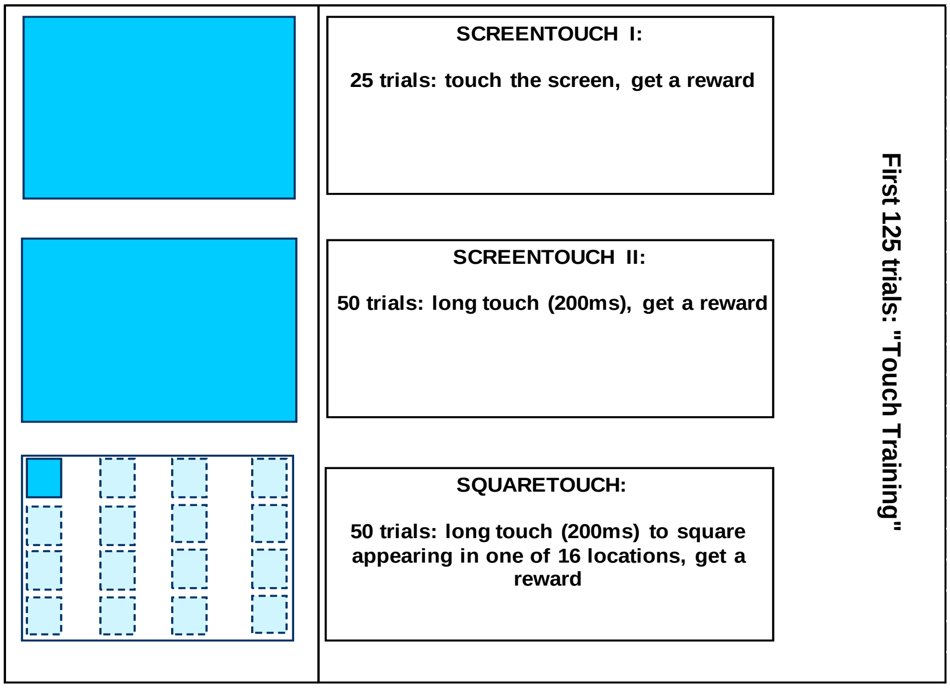


Figure 3: The three stages of touch training.

In the first stage, Screentouch I, the input of an individual's RFID tag resulted in the screen being filled with a solid bright blue color. Once the blue screen was displayed, a touch anywhere on the screen by the same animal, using either hand, resulted in one pellet being dispensed, the screen turning bright yellow for 500ms, and a high-tone sound ("Woohoo!"). If the most recently read RFID tag did not match the identity of the animal that started the trial, any touch ended the trial, turning the screen brown (4000ms) accompanied by an unpleasant tone ("Haha"). Such trials were recorded as "cheater" trials. If instead there was no touch of the screen within 20,000ms, the trial was aborted and the screen turned purple for 3000ms. The screen then turned gray until another RFID tag was read. Touches to the screen during the inter-trial interval resulted in a red screen that lasted as long as the touch was held, and the inter-trial interval timer was reset with each touch. These same procedures for correct, aborted, and cheater trials were used throughout training and testing.

Subjects completing 25 trials of Screentouch I advanced to Screentouch II in which the screen was still bright blue, but only touches at least 200msec long resulted in a reward event. If a touch of 200msec or longer was not registered within 20,000ms, the trial was aborted. Any touch, regardless of duration, by a different individual, if identified by the RFID antenna and reader, resulted in a “cheater” trial. For the remainder of training and testing all touches had to be at least 200msec long.

After completing 50 trials of Screentouch II, subjects advanced to the next shaping stage, “Squaretouch,” in which a blue square appeared in one of 16 locations. The square appeared in one of four sizes: 85 x 89 pixels, 101x 106 pixels, 160 x 168 pixels, or 203 x 214 pixels. Touching the square for at least 200msec resulted in a “correct” trial and the reward events (pellet, yellow screen,“woo-hoo!”). Shorter touches to the square or any other touches to the screen led to no change in the trial. All animals were set to complete 50 Squaretouch trials.

“Touch Training” consisted of the 125 trials described above (25 Screentouch I, 50 Screentouch II, and 50 Squaretouch). All subsequent training and testing trials involved the possibility of incorrect responses and thus required that individuals reach a particular criterion before advancing to the next stage. Thus, the number of trials required for completion of each subsequent stage varied depending on the number of trials needed to reach criterion.

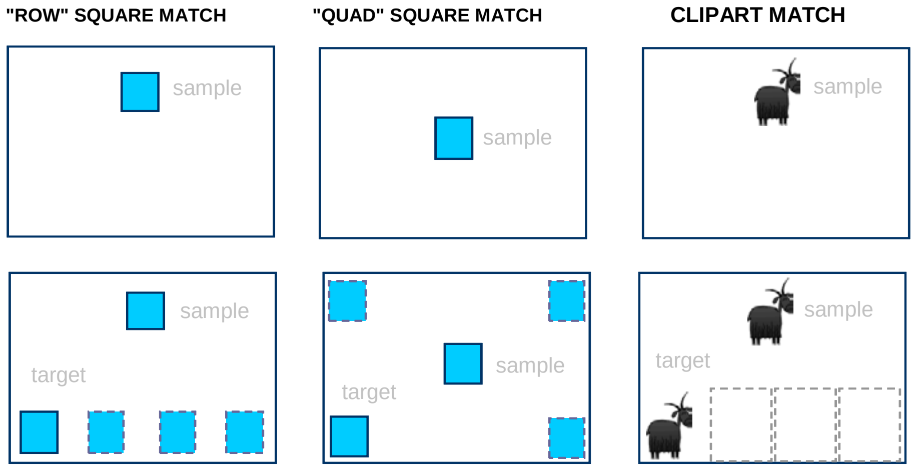
For all testing beyond Touch Training, there were two sequential trial phases: the “sample” phase, and the “choice” phase. The sample phase always included only one image in the same position on the screen. The choice phase always included the image from the sample phase, still in the same position, and a “target” image – the image that matched the sample. In some levels of training (described below), the choice phase also included “distractor” images – images that did not match the sample. From the sample phase, a trial could be terminated if a cheater was detected or if no touch to the sample was made within 20,000ms. If a “legal” touch was made the choice phase was presented. Touches during this phase resulted in trials designated as “correct”, “incorrect”, “cheater”, or “aborted” if no legal touches were made to stimuli on the screen within 20,000ms of the trial’s start.

Subjects advanced from Touch Training to a task which was designed to prepare them for match-to-sample tasks. Initially, all subjects were placed on a task referred to as “Square Match”. A trial began with the sample phase of testing, and a blue square of one of the 4 sizes used in Squaretouch appeared on the screen. A touch of at least 200ms to this square resulted in presentation of the “choice phase”, which included the same blue square in the same position (the “sample”) and an identical blue square (the “target”) in one of four positions. During this phase, a 200ms or longer touch to the sample square resulted in an incorrect trial, in which the trial terminated with a low tone (“Doh!”) sound, no pellet reward was received, and the screen turned dark blue for the duration of a 4000ms inter-trial interval. A 200ms or longer touch to the target square resulted in a correct trial. Shorter touches to either square or anywhere else on the screen did not change the trial status. If no touches of appropriate duration were made to either the sample or the target after 20,000ms, the trial was aborted.

Initially, this task had two forms, and animals were assigned to a form after they completed Touch Training, with counterbalancing for age and rank. In the “row” form, the sample image always appeared at the top center of the screen, and the target image appeared in one of four positions along the width of the bottom of the screen. In the “quad” form, the sample image always appeared centered on the screen, and the target image appeared in one of the four corners of the screen. Eventually, the quad form of the Square Match task was dropped and all subjects used the “row” form. At the time of this change, six subjects were working on but had not completed the “quad” Square Match task. They were re-assigned to the “row” form of the task. None of these individuals had completed more than 10 trials at the time of the switch.

For any incorrect trial, the animal was entered into “correction trials”. These trials repeated the incorrectly answered trial, with target images appearing in the same location as they had for the first presentation of the trial. Correction trials were presented until a correct response was made or until 3 correction trials had been presented. Correct responses on correction trials resulted in the same yellow screen and “correct” tone, but no pellet was dispensed. Events associated with incorrect correction trials were the same as for incorrect first presentation trials.

Starting in December 2010, animals completing Touch Training did not receive the “Square Match” task but instead were placed on a “Clipart Match” task directly after completion of Touch Training. The sample and choice phases of Clipart Match were the same as in Square Match, except that instead of blue squares, black and white clip art images were used. All clipart images were 200 pixels wide, but varied in height from about 100 to 330 pixels. With 1000 clipart images in the set and none repeated until all images had been used, the Clipart Match training familiarized the animals with a wide range of images earlier in their training. Animals that had received Square Match training did not see clipart in their own trials until they passed Square Match and advanced to the first level of Match-to-Sample training. The two forms of the Square Match task and the Clipart Match task are referred to collectively as the “Match Task”. See Figure 4 for examples of each form of Match Task training, and Table 2 for the distribution of the 3 forms of the Match Task by age group.



MATCH TASK TRAINING (with squares or clipart):

long touch (200 ms) to square or clipart appearing at top center of screen **(the "sample")**

A matching image appears in one of 4 locations **(the "target")**

Long touch to the target: correct
Long touch to the sample: incorrect
Touches anywhere else: trial continues until correct or incorrect response or 20,000 ms passes (aborted)

Trials continue until the animal meets criterion for advancement or demotion

Figure 4: The three forms of the "Match Task".

	initial Match Task			
age category	**"quad" Square Match**	**"row" Square Match**	**Clipart Match**	Total
<1yr	0	0	15	15
1-2yrs	8	9	6	23
3-4yrs	9	15	0	24
5-6yrs	4	5	0	9
7+yrs	2	4	1	7

Table 2: Match Task assignments, n's by age group.

A visual schematic of the progression of a trial, and a flowchart with the basic operations of the Presentation program written to run all trials is included in the Appendix.

Match Task training continued for all individuals until criterion was achieved. In the Match Task and for all levels of training beyond it, subjects could move to a new task because they had completed a set proportion of trials correctly and were advanced to a more difficult task. They could also move to a different task because they had completed a set proportion of trials incorrectly (demotion). Criterion for advancement to the next task was completion of 80 correct trials out of any 100 consecutive trials. Criterion for demotion was initially set at 200 incorrect out of any consecutive 1000 trials, but in September 2010 was changed to 100 incorrect out of any consecutive 500 trials. After the completion of each trial, the program checked whether either advancement or demotion criteria had been met. If 80 trials were answered correctly before completing 100 consecutive trials, the subject advanced. Likewise if 100 trials were answered incorrectly prior to completing 500 consecutive trials, the subject was demoted. When criteria for advancement or demotion were met, the program automatically generated the stimulus list for the next task, and, when the subject's RFID code was identified again, the first trial of this new task was presented. Demotion from the Match Task was rare, and only occurred in subjects who completed the tasks after demotion criteria were changed. Thus, in these cases, the Match Task was simply repeated.

Animals that met the criterion for advancement from the Match Task were assigned to the first level of match-to-sample (MTS). At this stage, the sample and target image appeared with one different image, referred to as the distractor. Trials proceeded as they had for the Match Task, with the same consequence for touching the sample or the distractor during the choice portion of a trial. A new combination of sample and distractor was presented with each trial. Meeting the criterion for advancement resulted in a new level of MTS, with one additional distractor. This continued until the criterion for advancement was met with a total of three distractors present. Demotion from the first level of MTS resulted in the presentation of Clipart Match in the case of the Square Match completers. Advancing from Clipart Match resulted in repeating the first level of MTS. In all other cases and in subsequent demotions from the first level of MTS for Square Match completers, subjects were presented with a task in which the number of distractors remained the same as for the failed level, but the luminosity of the distractors was reduced to 30%, with the effect that the target image was much brighter than the distractors. Advancing from these levels resulted in repeating the previously failed level of MTS. Failure of these levels, which rarely occurred, resulted in repeating the same task. Throughout all MTS stages, all clipart images appeared in black and white only.

Successful completion of MTS with three distractors resulted in advancement to the “Line MTS” in which black lines of different angles were used as stimuli. This was for testing the monkey’s ability to complete a line matching task of spatial perception (Benton, Varney, & Hamsher, 1978; Collaer & Nelson, 2002; Collaer, Reimers, &

Manning, 2007; Hamilton, 1983). The minimum angle difference between any two lines was 18°, and the maximum angle difference within a trial was 90°. If pictured as a fan of lines between 0° and 180°, only lines from one half of the fan were placed together in a trial, to avoid presenting mirror-image lines. Subjects correctly answered a trial when they touched the target line that matched the angle of the sample line. Progression through these levels was set to proceed in the same manner as for MTS stages, beginning with Line MTS with one distractor. Initial demotion from this level was to a "Line Match" task with no distractors, and subsequent demotions were to one low luminosity distractor. Advancement from one distractor at full luminosity resulted in addition of a second distractor, as in the MTS task. Examples of the MTS stages with clipart and lines are shown in Figure 5.

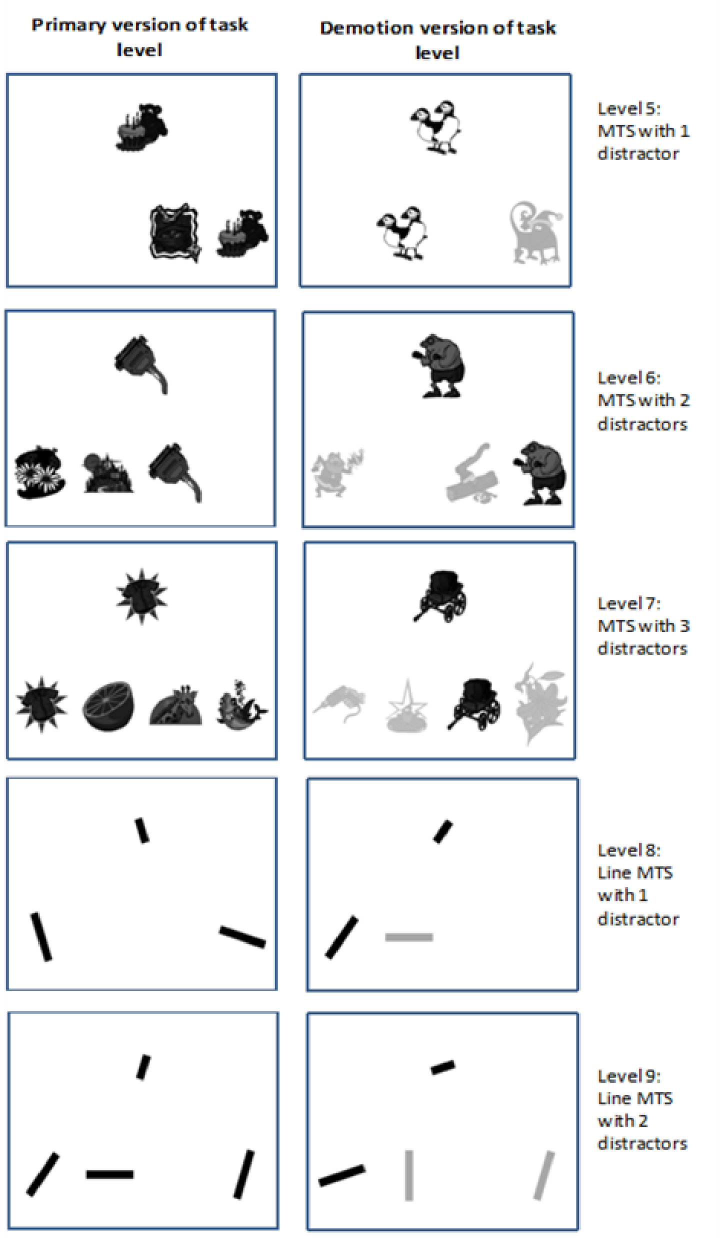


Figure 5: Match to Sample (MTS) task progression. In the column on the left are examples of the tasks which, when criterion were met, allowed advancement to the next level, starting with the primary version of the task in the next level. If criterion for demotion were met, the subject was placed on the task in the right-hand column. Successful completion of the demotion level led to repeating the primary version of the task for a given level.

If the pellet dispenser jammed or was empty during the course of a trial, the screen turned black and the program would not continue. This was rare, generally occurring less than once per month.

Kiosk maintenance

Use of a remote access program allowed secured access to the kiosk over its ethernet connection. The remote access connection was used on a daily basis as well to stop the program (usually at times when the animals were not working, particularly after dark), remotely restart the netbook, retrieve and back up files, and restart the Presentation program.

Data collection and extraction

Data generated from the program were recorded in a tab delimited text format log file, with a new file generated for each day. This file contained one row of data for each completed trial, whether it was correct, incorrect, aborted, cheater, or a correction trial. Because the kiosk was available on a nearly continuous basis but not a completely continuous basis, and, moreover, many members of the social group were removed from the group either temporarily or permanently, periods of unavailability were generated on a subject-by-subject basis for data on cumulative times on tasks and on elapsed times between trials. Corrections to elapsed time data took 3 forms: night-time was not counted (with seasonal adjustments made to which hours were included), days when the kiosk was off or otherwise confirmed as nonoperational were not counted, and days when an individual was out of the group and unable to use the kiosk were not counted. As an example, if a monkey completed a trial on 4/23/2010 at 8:00pm, and the next trial on 4/24/2010 at 8:00am, rather than counting the elapsed time between trials as 12 hours, the elapsed time was corrected to avoid counting the hours between 11:00pm and 5:30am. All time data reported in the results have been corrected for these forms of unavailability.

All analyses were completed using SPSS.

Handling of skewed data

For any given statistical analysis, the dependent variables of interest were subjected to an analysis of skew using the One-sample Kolmogorov-Smirnov (K-S) test. If the result of this test showed significant skew in a variable, indicating a violation of the assumption of normality required by parametric statistics, the data were submitted to a natural log transformation: ln (x+1). If skew remained after this transformation, nonparametric tests were used with the nontransformed data. If the dependent variable of interest was noncontinuous, then nonparametric tests were used. For ANOVA analyses, Least Significant Difference (LSD) post-hoc tests were used for pairwise comparisons of means between groups. For nonparametric Kruskal-Wallis tests, the Least Significant Difference in Ranks test was used as a post-hoc test for pairwise comparisons of mean ranks. Reported means and standard errors in the following text, tables, and graphs are nontransformed data for ease of interpretation. Calculations of Cohen's *d* effect sizes, however, were calculated using transformed data when probability statistics used transformed data.

Results

Overall descriptive data

Data were collected between 2/17/2010 and 5/1/2011, with the kiosk available to the animals on a near-continuous basis. There were 14 days in the data collection period for which the kiosk was not at all available to the monkeys due to maintenance needs.

There were an additional 34 days on which no trials were completed, most of these related to weather conditions, such as extreme cold, heat, precipitation, or severe weather. During the study period, 101,227 (first-presentation) trials were collected by 122 total animals. The distribution of these trials among all individuals ranged from 2 trials to 9,869 trials completed by one individual (*M*=828, *Mdn*=140). Table 3 shows the distribution of animals by the highest level of training achieved.

Highest level completed	**level number**	**n**	**mean total trials completed**	***SEM***
Screentouch I	1	3	29.33	3.38
Screentouch II	2	20	95.55	2.91
Squaretouch	3	43	150.53	5.72
Match Task	4	29	896.28	165.31
clipart MTS, 1 distractor	5	1	3701	
clipart MTS, 2 distractor	6	1	8936	
clipart MTS, 3 distractor	7	7	5478.43	724.93
line MTS, 1 distractor	8	2	7737.5	2131.5

Table 3: Distribution of subjects by the highest level of training passed. Subjects that did not complete Screentouch I are not included. The mean total number of trials completed reflects the total across all completed tasks.

The earliest completed trial occurred at 6:06am, and the latest completed trial occurred at 11:33pm. Throughout the data collection period, trials were not evenly distributed throughout the day (Figure 6a), and seasonal variation in the preferred time of day also occurred (Figure 6b and 6c), with peak times at the start and end of the day in warmer months, and in the middle of the day in cooler months.

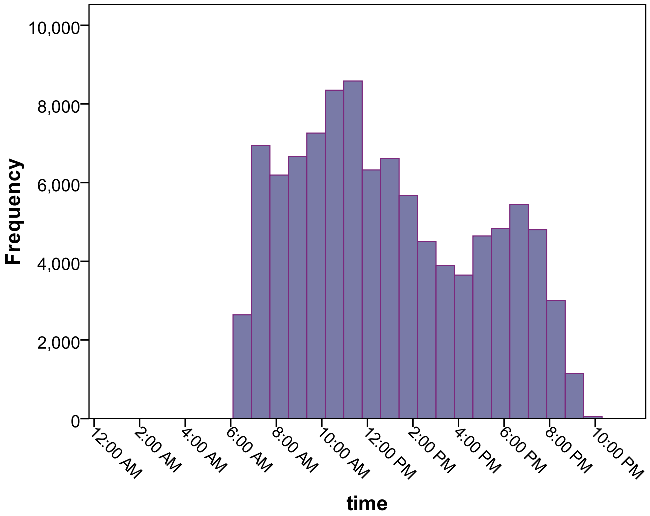


Figure 6a: Histogram with the frequency by hour of the day for all first-presentation trials over the entire course of data collection. The pattern of trial completion suggests peak participation in the morning hours, reduced participation in the afternoon, and an increase in participation later in the day.

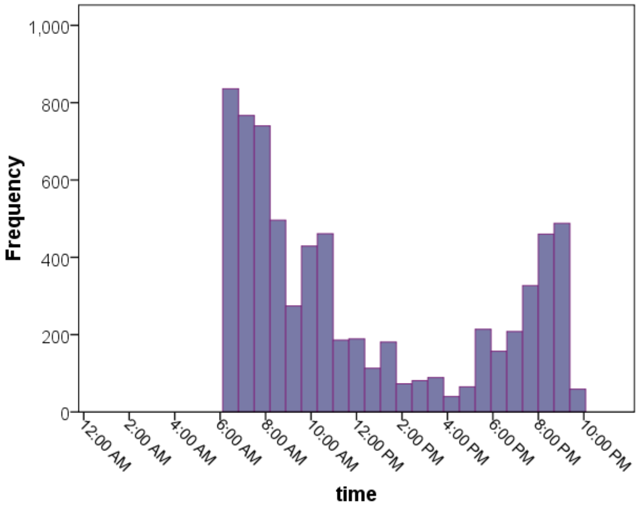


Figure 6b: Histogram with frequency by hour of the day for all first-presentation trials completed between 6/17/10 and 8/16/10. The average daily high temperature during this period was 96ºF, and the average low temperature was 74ºF. It is clear that morning and

evening times were highly favored, with little participation in the middle of the day, when temperatures were highest.

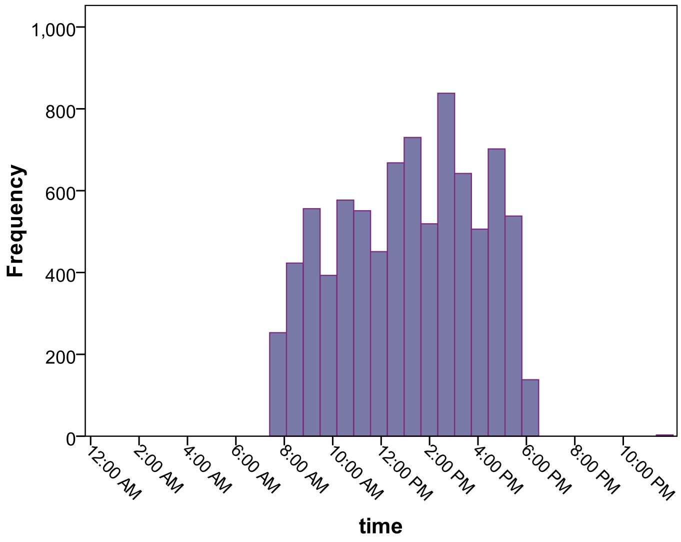


Figure 6c: Histogram with frequency by hour of the day for all first-presentation trials completed between 12/16/10 and 2/17/11. The average daily high temperature during this period was 48ºF, and the average low temperature was 30ºF. In contrast to Figure 6b, most trials were completed in the middle of the day, when temperatures were warmest, and few trials were completed early or late in the day.

There was considerable variability in the number of trials completed overall in a day, and in the number of trials completed by any one subject in a given day. However, across the study, the total number of daily trials increased, even as the total number of subjects available for testing decreased. This may have resulted from providing access to additional young subjects at different points during the study. Total completed trials and total number of subjects available for testing for each day is shown in Figure 7.

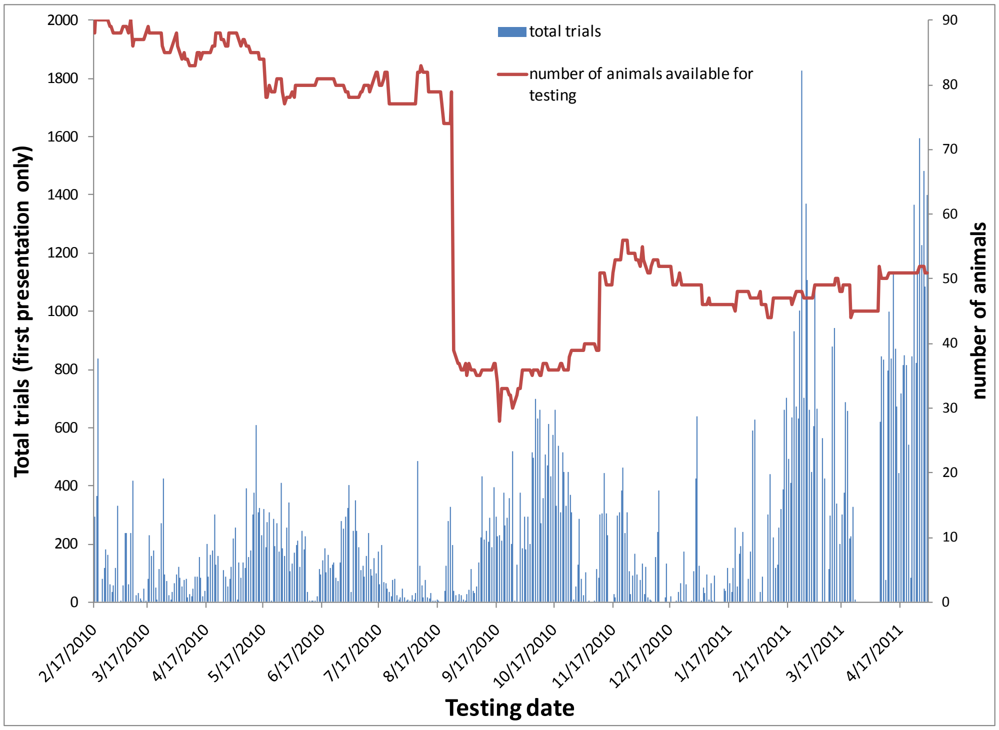


Figure 7: Total trials completed per day (in blue), and number of subjects available for testing per day (in red). Though overall, fewer animals were available for testing at the end of the study, an increase in trials completed per day was observed for many days.

Age

The distribution of animals by age group is shown in Table 4. An animal's age in years was calculated by determining what age it would turn in 2010. Thus, an animal born in 2009 would be classified as 1 year of age, even if they were born in June. Since rhesus monkeys at this site are generally born between March and September, this provided a reasonable average of any given animal's age for the duration of kiosk testing. The total number of days available over the testing period differed significantly by age group $F(4, 116) = 20.23$, $p<.001$, with animals under 2 years showing the smallest number of days in the group compared to all other age groups. Animals 7 years and older were in the group significantly more days than any other age group. Animals ages 3-4 and 5-6 did not differ significantly from each other.

	Age group				
	<1yr	**1-2yr**	**3-4yr**	**5-6yr**	**7+yr**
n	16	28	29	14	35
Mean days in group ± SEM	115.81 ± 8.61	108.96 ± 13.54	199.9 ± 17.90	217.07 ± 27.25	283.71 ± 15.87

Table 4: Number of subjects and average number of days in the group (with kiosk access possible), by age group.

Age and time to first kiosk access and first completed trial

Older animals were slower in their initial access of the kiosk. The calculation of time to first kiosk access (reaching into or through the armhole encircled by the RFID antenna, thus activating a trial) was made from the time that the kiosk program was first started in the afternoon of the first day. For this reason, first access data was analyzed only for animals present in the social group on the first day of kiosk testing. There was a significant effect of age group on time to initial access, Kruskal-Wallis $H(3) = 15.24$, $p=.002$. Post-hoc tests revealed that animals 7 years and older took significantly more time to access the kiosk compared to 1-2-year-old and 3-4 year-old animals (Figure 8). A significant positive Spearman correlation was also found for age and time to first access, $r_s(86)=.45$, $p<.001$ (Figure 9).

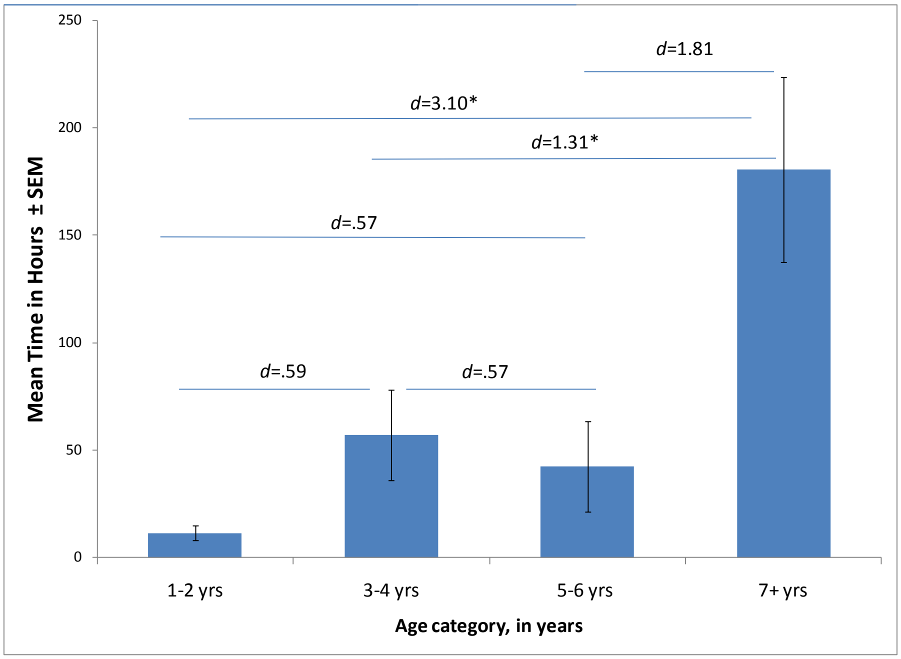


Figure 8: Average time to first access the kiosk in hours, by age group. Effect sizes are reported for all comparisons, * indicates *p*<.05 in post-hoc tests.

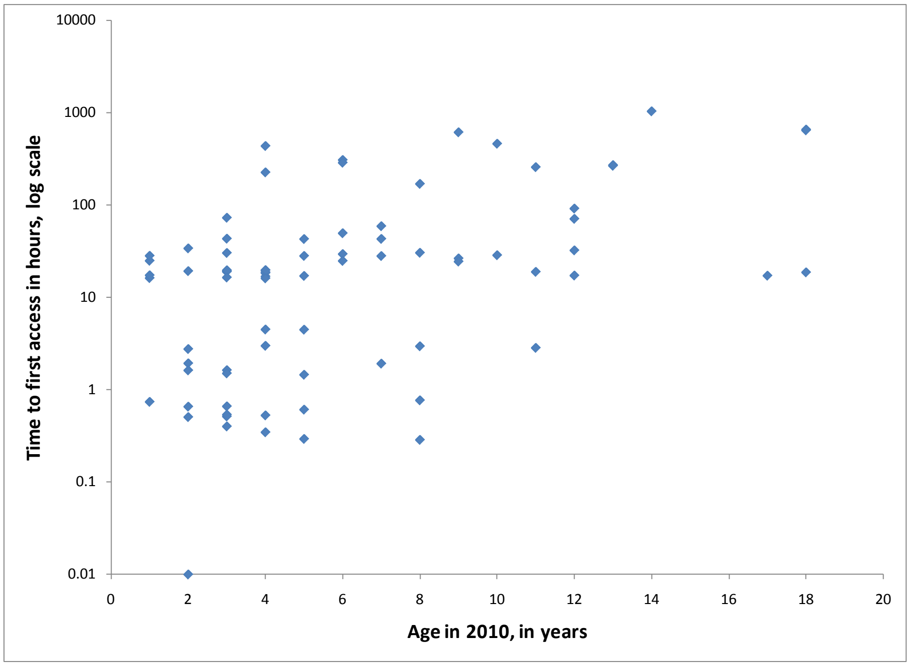


Figure 9: Scatter plot of age and time to first access the kiosk. Time on the Y-axis is plotted on a log scale to demonstrate the dramatic differences in times.

Older subjects were also slower to complete their first trial. Time to the first completed trial – the time to touch the screen from the time of first access, was analyzed for all animals that were able to test at the kiosk before August 24, 2010. There was a significant overall effect of age group on time to first completed trial, Kruskal-Wallis $H(3)=11.75$, $p=.008$. Post-hoc tests revealed that animals 7 years and older took significantly more time to complete the first trial than did 1-2 year-olds (Figure 10). A significant positive Spearman correlation was found for age and time to first completed trial, $r_s(99)=.37$, $p<.001$ (Figure 11).

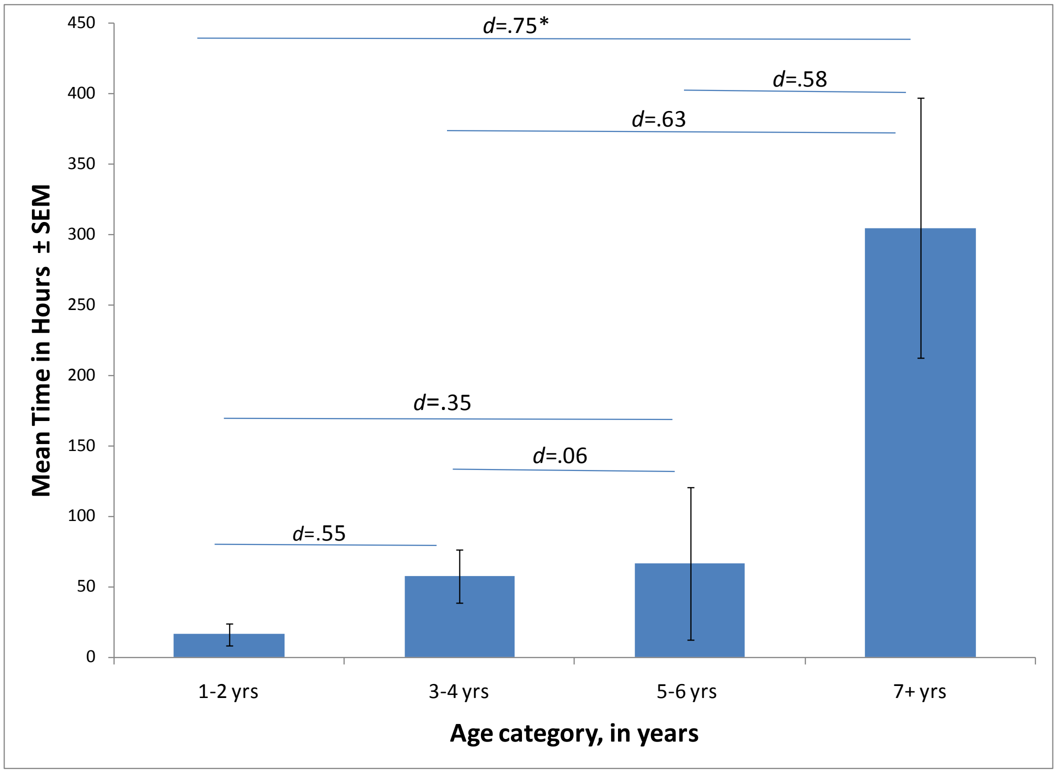


Figure 10: Average time to complete the first trial from the time of first access, in hours, by age group. Effect sizes are reported for all comparisons, * indicates p<.05 in post-hoc tests.

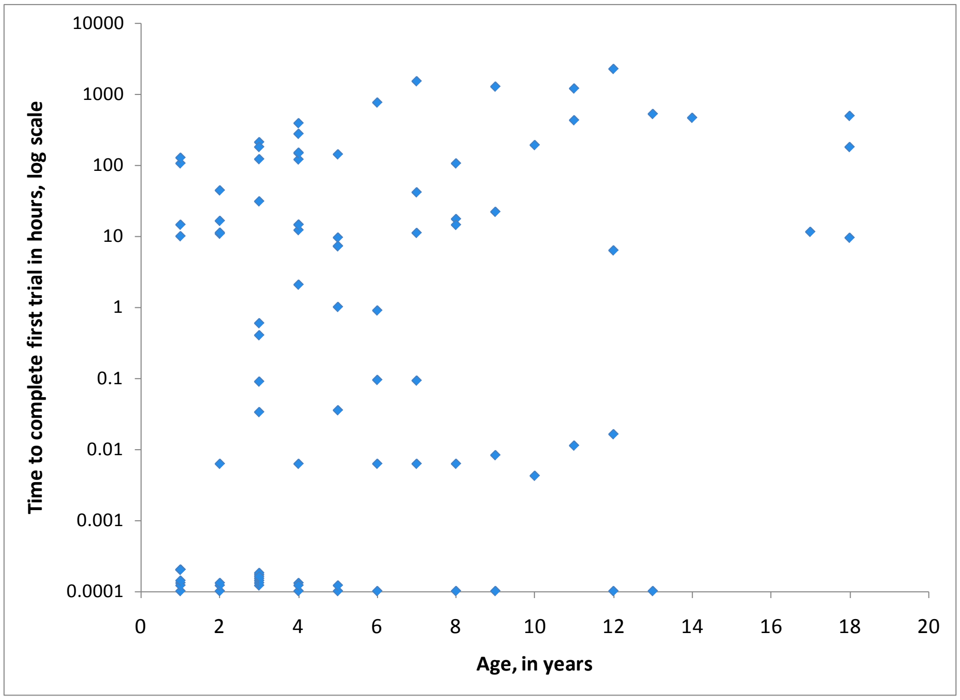
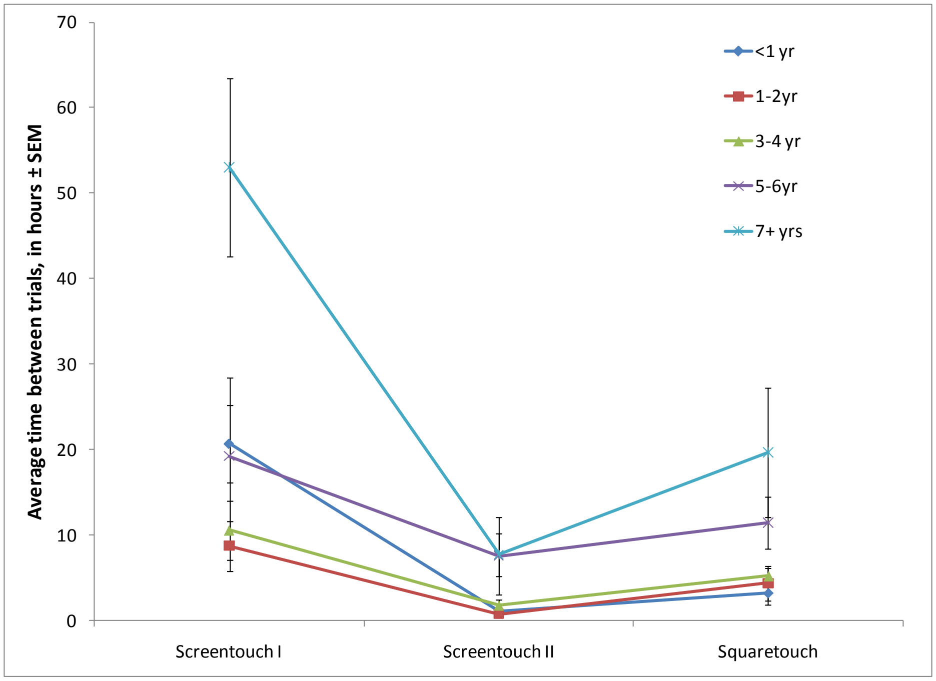


Figure 11: Age and time to first completed trial. Time on the Y-axis is plotted on a log scale to reflect the broad time distribution across subjects. Note: All times <.001 are actually "0" but values have been adjusted for plotting on the log scale and to show where multiple animals of the same age completed the first trial at the time of the first kiosk access. For analyses, the actual value (0) was used.

Repeated access of the kiosk without completing a trial did not contribute to the age difference in time to complete the first trial. Groups did not differ significantly in the number of aborted trials before the first completed trial, Kruskal-Wallis $H(3) = 5.94$, $p=.11$. The mean number of aborted trials across all groups was 4.18 ± 0.72 *SEM*.

Age and participation rate

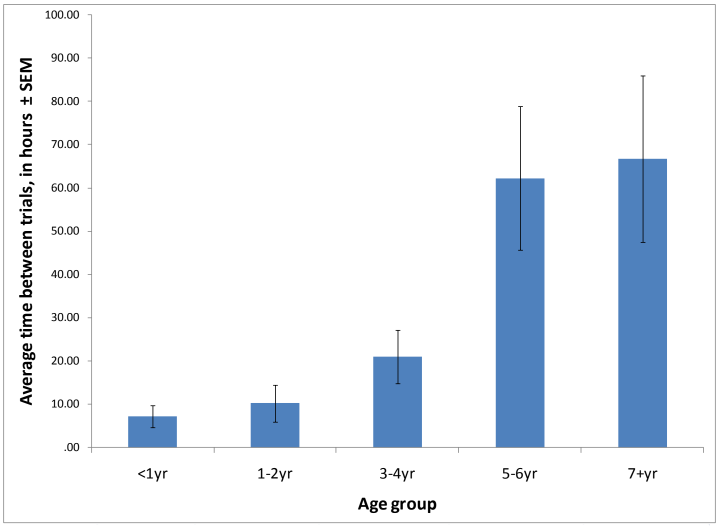
Age effects persisted throughout Touch Training. For each Touch Training task (Screentouch I, Screentouch II, and Squaretouch), the average elapsed time between trials (natural-log transformed data) was analyzed by age group. Only animals that completed the task of interest were included in these analyses. A significant effect of age group was found for Screentouch I, *F*(4,101) = 9.62, *p*<.001, Screentouch II, *F*(4,98) = 5.03, *p*=.001 and for Squaretouch, *F*(4,77) = 5.36, *p*=.001. Figure 12 shows means for each stage of testing, as well as the significant post-hoc comparisons and effect sizes.



		Screentouch I		Screentouch II		Squaretouch	
Group 1	Group 2	*d*	*p*<.05	*d*	*p*<.05	*d*	*p*<.05
<1yr	1-2yr	1	*	0.16		0.19	
<1yr	3-4yr	0.86	*	0.39		0.66	
<1yr	5-6yr	0.4		0.76	*	1.51	*
<1yr	7+yr	0.64		1.18	*	0.83	*
1-2yr	3-4yr	0.18		0.25		0.8	
1-2yr	5-6yr	0.55		0.65		1.57	*
1-2yr	7+yr	1.54	*	1.08	*	0.95	*
3-4yr	5-6yr	0.4		0.43		0.91	
3-4yr	7+yr	1.45	*	0.81	*	0.35	
5-6yr	7+yr	0.95	*	0.29		0.25	

Figure 12: Age category and average time between trials by Touch Training task. Below the graph, effect sizes are reported, with significance (*p*<.05) indicated by *.

Age effects were particularly dramatic for the Match Task. None of the 16 animals over 5 years of age who started the Match Task completed it. Thus, age comparisons of average time between trials on the Match Task (natural log-transformed) were made using all individuals that started it. A significant effect of age group was found, *F*(4,73)=11.50, *p*<.001. Post-hoc comparisons showed that the only age groups that did not differ significantly from each other were animals less than 1 year of age compared to 1-2-year-olds, and 5-6-year-olds compared to animals 7 years and older. Age differences in average time between trials also existed among Match Task noncompleters, *F*(4,34)=3.52, *p*=.02 (natural log transformed). Post-hoc analyses revealed significant differences between 1-2 year-olds and all other groups except animals less than one year of age. Figure 13 shows the mean data by age for all individuals that started the Match Task, as well as effect sizes and significant post-hoc comparisons for analyses with all animals and with noncompleting animals alone.



		All Match Task starters		Match Task noncompleters	
Group 1	Group 2	*d*	*p*<.05	*d*	*p*<.05
<1yr	1-2yr	0.03		0.42	
<1yr	3-4yr	0.6	*	1.17	
<1yr	5-6yr	2.29	*	1.26	
<1yr	7+yr	2.5	*	1.56	
1-2yr	3-4yr	0.6	*	1.05	*
1-2yr	5-6yr	2.16	*	1.15	*
1-2yr	7+yr	2.34	*	1.28	*
3-4yr	5-6yr	1.41	*	0.18	
3-4yr	7+yr	1.55	*	0.35	
5-6yr	7+yr	0.11		0.14	

Figure 13: Age category and average time between trials in the Match Task for all subjects that started the task. Below the graph, effect sizes are reported, with significance (*p*<.05) indicated by *, for all task starters and for noncompleters alone.

At each stage of training, the distribution of completing and noncompleting animals differed by age group. At each training stage, chi-square analyses confirmed that the distribution of completers and noncompleters differed significantly between animals aged 0-4 years and animals 5 years and older. Figure 14 shows the cumulative proportion of animals remaining in each of these groups at the conclusion of each task, and the chi-square values for the comparison of completing and noncompleting animals by age group.   It is important to note that at each stage, noncompleting animals had more time available to complete a task than completing animals took to finish the task. That is, noncompleters cannot be explained by animals being permanently removed from the group with little time to complete a task. This difference was significant at every stage except for Screentouch II, which only two animals failed to complete (Mann-Whitney U tests, *p*<.05 for all).

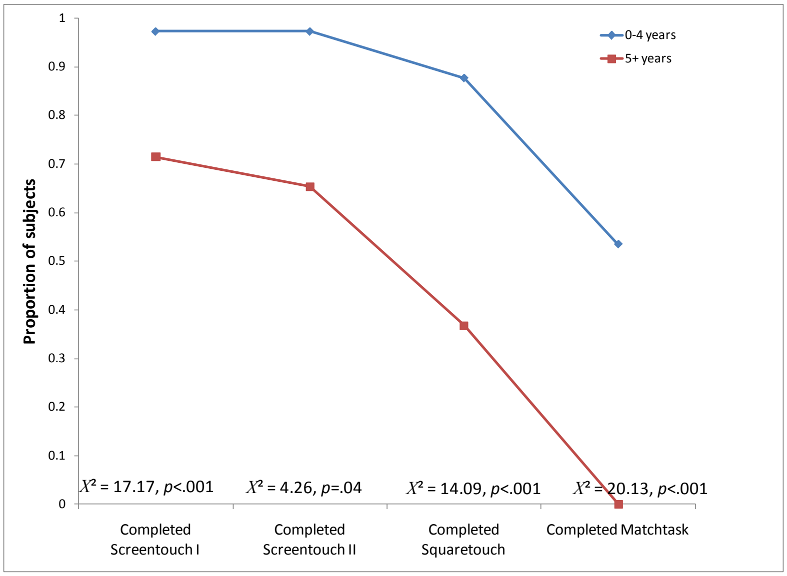


Figure 14: The cumulative proportion of subjects completing each of the first 4 stages of training, with separate lines for 0-4-year-olds and subjects 5 years or older. The difference between the two age groups in the number of completing animals compared to

noncompleting animals was significant for each task, as indicated by the chi-square results reported on the graph.

The negative relationship between age and participation rate grew over the course of the study. Rate of trial completion was calculated by dividing the total number of completed trials by the number of days available for each animal for a time period of interest. An examination of trial completion rates at the start of the study revealed a significant negative relationship between age and trial completion rate, from the first day of the study. The correlation coefficient increased from -.27 on the first day to -.68 for the trial completion rate over the first three months of the study. Table 5 shows the correlation coefficient and *p*-value for each time period analyzed.

	r_s	*p*	n
day 1	-0.27	0.02	86
days 1-2	-0.47	<.001	89
week 1	-0.47	<.001	89
month 1	-0.64	<.001	91
months 1-2	-0.68	<.001	92
months 1-3	-0.68	<.001	92

Table 5: Spearman correlations for age and trial completion rate (adjusted for each subject's time in the group) for different portions of the data collection period. As time progressed, age explained a greater proportion of the variance in trial completion rate.

Rate of trial completion for the entire duration of the study was also examined. A Spearman correlation revealed a significant negative relationship between age and rate of trial completion, $r_s(122) = -.77$, $p<.001$ (Figure 15). A similar negative relationship was found for age and proportion of days with at least one trial completed, r_s $(122) = -.70$, *p*<.001, and age and proportion of days with at least 20 trials completed, r_s (122) = -.59, *p*<.001.

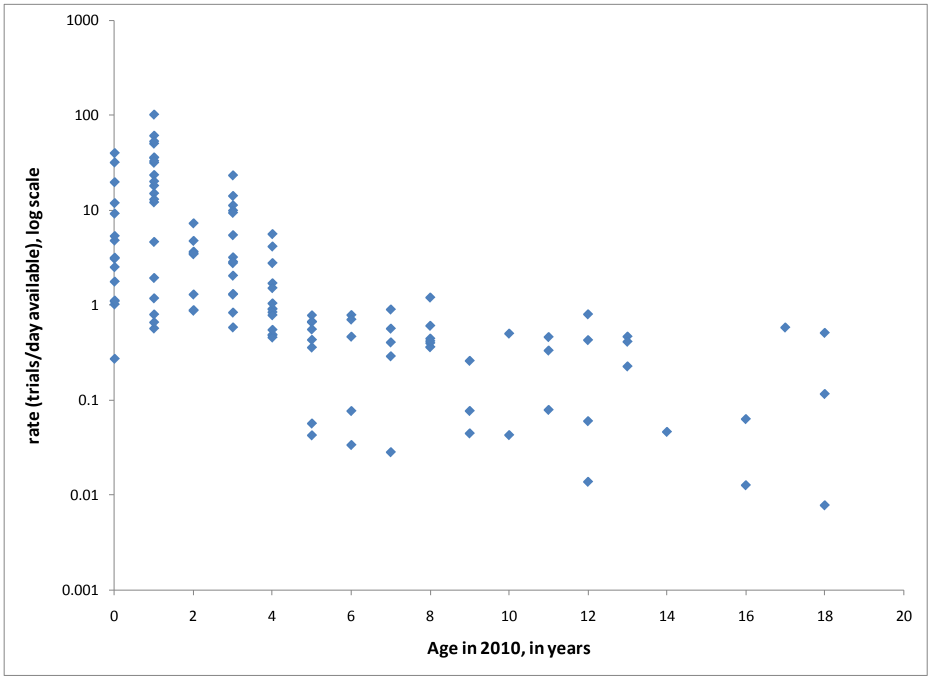


Figure 15: Age and trial completion rate, with trial completion rate plotted on a log scale to reflect the variability in rates. Notably, only one subject over the age of 5 had a completion rate higher than one trial per day.

Even though no subjects over 5 years passed the Match Task and thus never moved on to more difficult tasks, the rate of trial completion per task completed was still slower for older subjects compared to younger subjects. Since animals that completed the Match Task went on to a series of additional tasks, the number of tasks completed was determined for each animal. No individual passed more than 8 tasks total. The total number of days available for an individual was divided by the number of tasks passed to determine an average of days spent per task for each animal. Analyses of days per task (natural log-transformed) by age group revealed a significant effect, *F*(4, 116) = 34.72, *p*<.001 (Figure 16). Post hoc analyses revealed that ages 2 and younger differed significantly from ages 3 and older, 3-4 year-olds differed significantly from all other groups. Effect sizes between age groups were very large. Five-six-year-olds and animals 7 years and older did not differ significantly.

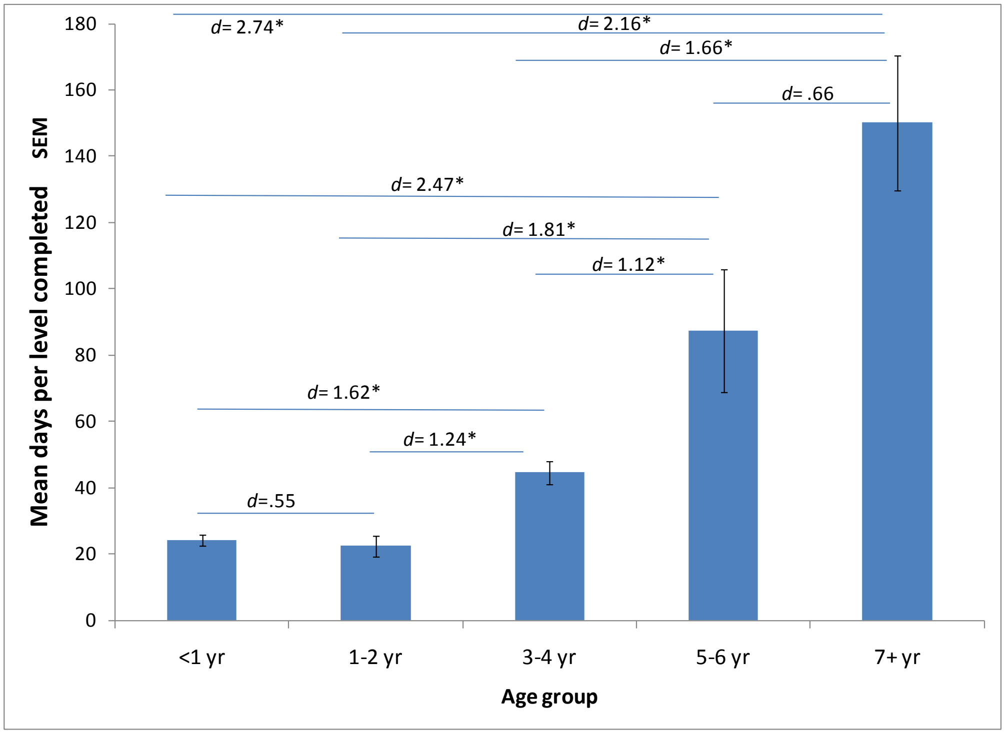
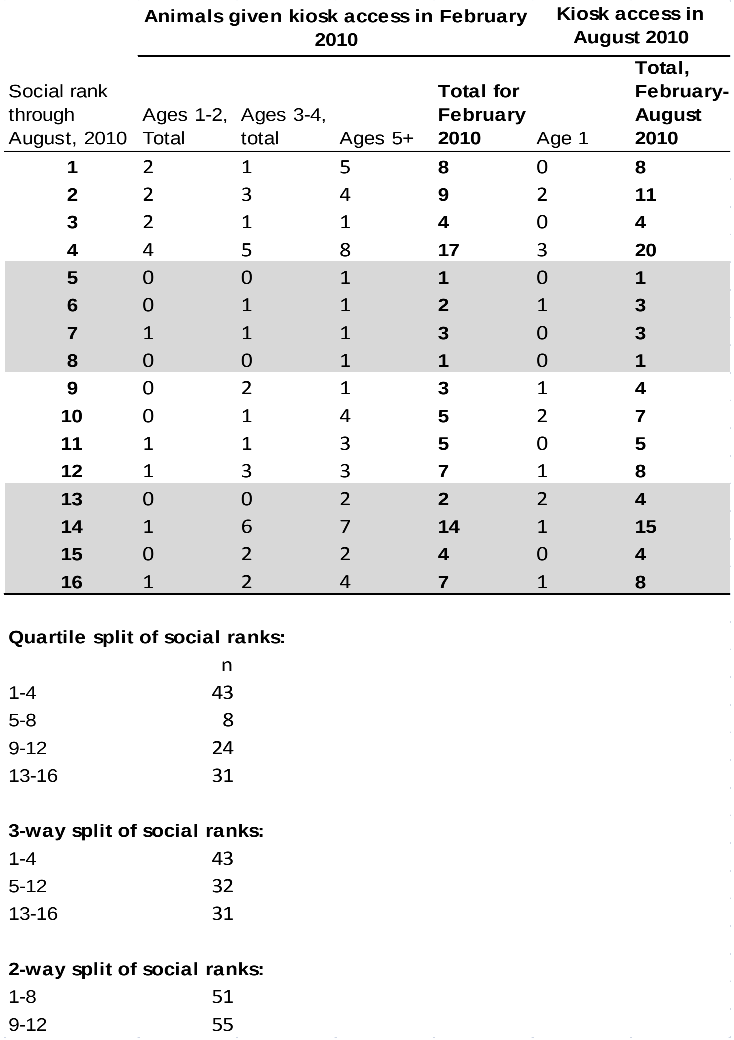


Figure 16: Age group and the average number of days per task completed. Effect sizes are shown for all comparisons, * indicates *p*<.05 in post-hoc tests.

Social rank

Table 6 shows the distribution of animals in the group by social rank. The ranks shown are for February-August of 2010 only. Since two shifts in rank occurred during the data collection period, analyses of social rank effects were restricted to animals in the social group and participating in kiosk testing before those shifts. Social rank and age were not significantly correlated, whether all subjects were included (r_s(120) = -.13, *p*=.17), or when only subjects that were given kiosk access by August, 2010 were included (r_s (97) = .16, *p*=.12). For this reason, rank and age were analyzed separately for effects. However, since 1-2-year-old monkeys were heavily concentrated in the top four social ranks, analyses were completed for all ages and for ages 3 and older only. Analyses were also completed with three different social rank categorizations to ensure consistency among relatively arbitrary splits between matrilines. Thus, analyses were completed with the rank groups split into four groups, three groups, and two groups. These are also shown in Table 6.



	Animals given kiosk access in February 2010				**Kiosk access in August 2010**	
Social rank through August, 2010	Ages 1-2, Total	Ages 3-4, total	Ages 5+	**Total for February 2010**	Age 1	**Total, February-August 2010**
1	2	1	5	**8**	0	**8**
2	2	3	4	**9**	2	**11**
3	2	1	1	**4**	0	**4**
4	4	5	8	**17**	3	**20**
5	0	0	1	**1**	0	**1**
6	0	1	1	**2**	1	**3**
7	1	1	1	**3**	0	**3**
8	0	0	1	**1**	0	**1**
9	0	2	1	**3**	1	**4**
10	0	1	4	**5**	2	**7**
11	1	1	3	**5**	0	**5**
12	1	3	3	**7**	1	**8**
13	0	0	2	**2**	2	**4**
14	1	6	7	**14**	1	**15**
15	0	2	2	**4**	0	**4**
16	1	2	4	**7**	1	**8**

Quartile split of social ranks:

	n
1-4	43
5-8	8
9-12	24
13-16	31

3-way split of social ranks:

1-4	43
5-12	32
13-16	31

2-way split of social ranks:

1-8	51
9-12	55

Table 6: Subject distribution by social rank for subjects with kiosk access between February and August 2010. Also shown are the three divisions of the social ranks used in analyses.

Social rank and time to first kiosk access and first completed trial

There was a significant effect of social rank on time to first kiosk access, for all three categorizations of social rank (Quartile split: Kruskal-Wallis $H(3) = 22.67$, $p<.001$, significant post-hoc comparisons shown in Figure 17; Three-way split: Kruskal-Wallis $H(2) = 20.52$, $p<.001$, ranks 1-4 showed significantly faster times than ranks 5-12 (d=.41) and 13-16 (d=.90), and 5-12 did not differ significantly from 13-16 (d=.58); Two-way split: Mann-Whitney $U = 361.0$, $p<.001$, ranks 1-8 showed significantly faster times than ranks 9-16 (d=.69)). Analyses completed for ages three and older also showed significant effects with the same significant post-hoc comparisons. The correlation between social rank and time to first access was also significant for all ages, $r_s(86)= .49$, $p<.001$ (Figure 18), and for ages three and older only, $r_s(73) = .44$, $p<.001$.

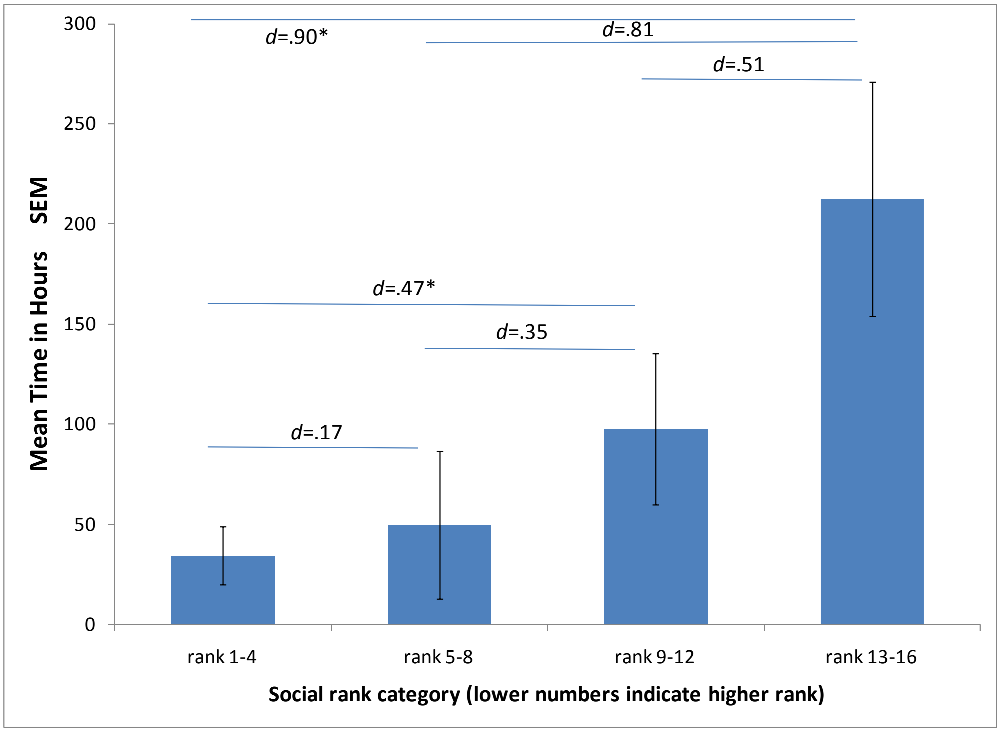


Figure 17: Social rank quartiles and time to initial kiosk access. Effect sizes are reported for all comparisons, * indicates *p*<.05 in post-hoc tests.

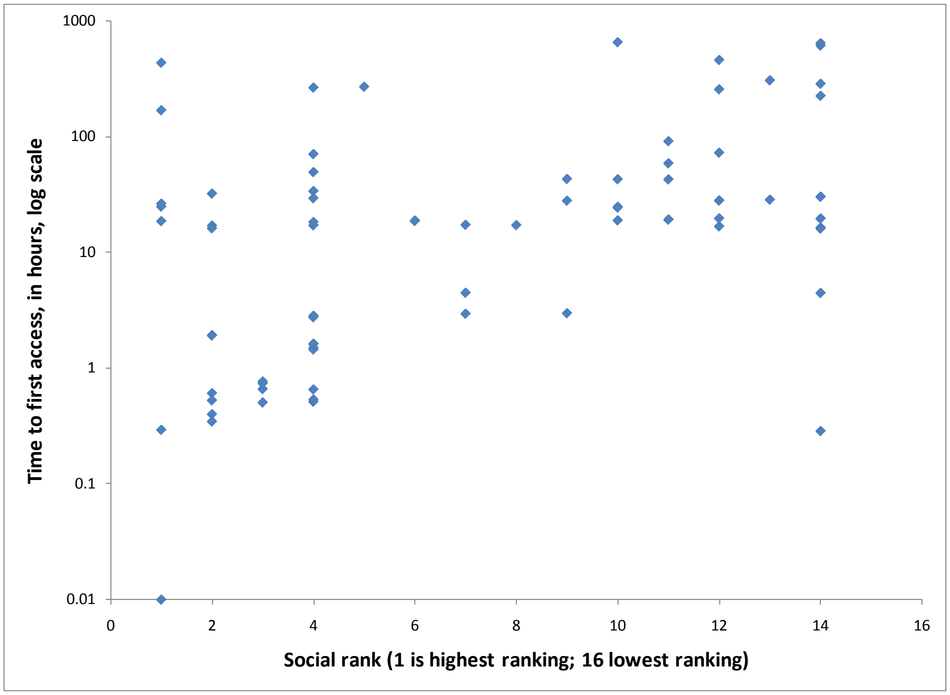


Figure 18: Social rank and time to initial kiosk access. Time on the Y-axis is plotted on a log scale.

There was a significant effect of social rank on time to first completed trial, for all three categorizations of social rank (Quartile split: Kruskal-Wallis *H*(3) = 14.53, *p*=.002, ranks 1-4 differed significantly from ranks 9-12 (Figure 19); Three-way split: Kruskal-Wallis *H*(2) = 13.28, *p*=.001, ranks 1-4 showed significantly faster times than ranks 5-12; Two-way split: Mann-Whitney *U*= 812.0, *p*=.01, ranks 1-8 showed significantly faster times than ranks 9-16). Analyses for ages three and older revealed the same significant effects, with the exception of the two-way split, which no longer yielded a significant result: Mann-Whitney *U* = 542.0, *p*=.08. Low-ranking subjects accessed the kiosk more without actually completing the first trial. Analysis of aborted trials before the first completed trial revealed a significant overall effect (Quartile split: Kruskal-Wallis *H*(3)=11.81, *p*=.01; Three-way split: Kruskal-Wallis *H*(2) = 9.98, p=.01; Two-way split:

Mann-Whitney U = 895.5, *p*=.02), and post-hoc comparisons revealed the same pattern as for time to first completed trial. The correlation between social rank and time to first completed trial for all ages was not significant, $r_s(99) = .18$, *p*=.08 (Figure 20), or for ages three and older only, $r_s(78) = .11$, *p*=.34.

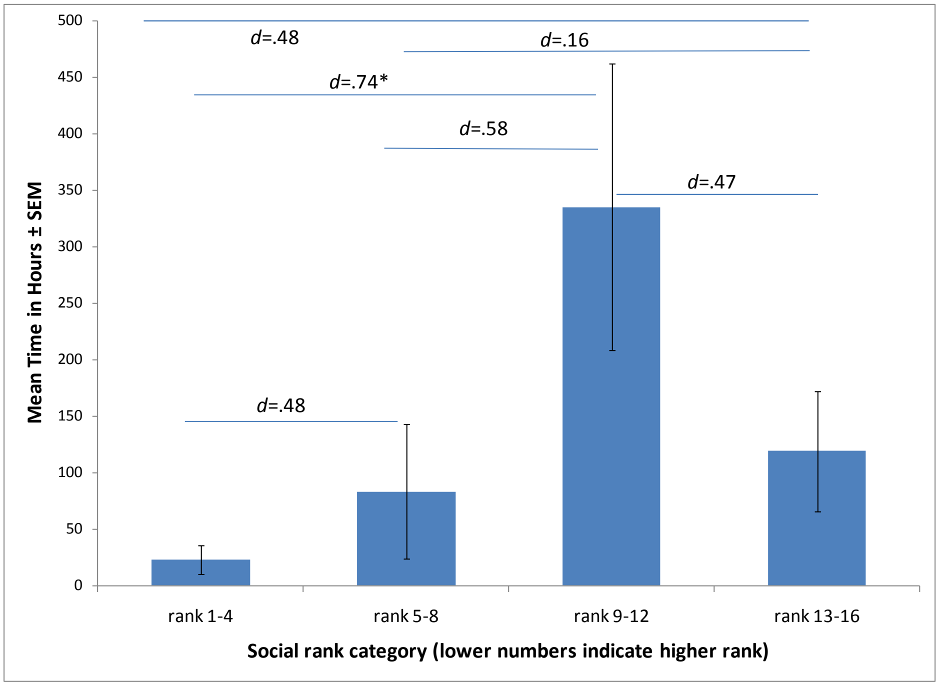


Figure 19: Social rank quartiles and time to the first completed trial. Effect sizes are reported for all comparisons, * indicates *p*<.05 in post-hoc tests.

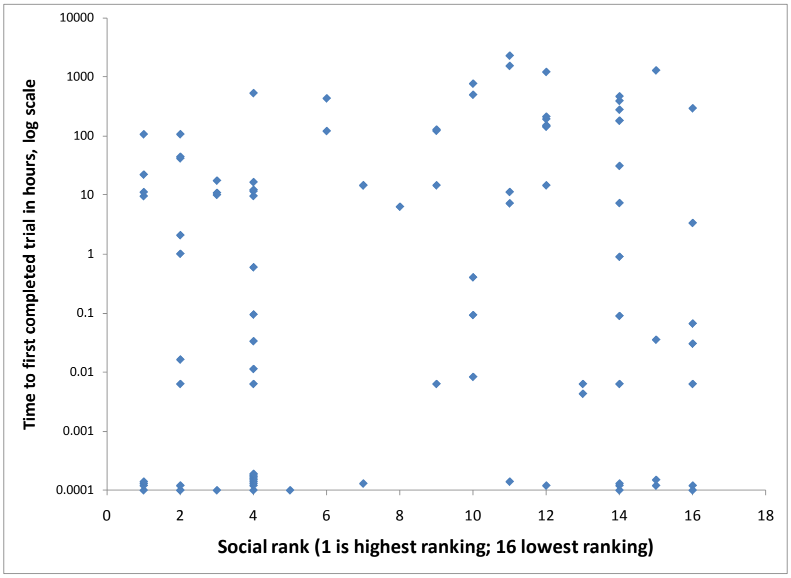


Figure 20: Social rank and time to first completed trial. Time on the Y-axis is plotted on a log scale to reflect the broad time distribution across subjects. Note: All times <.001 are actually "0" but values have been adjusted for plotting on the log scale and to show where multiple animals of the same rank completed the first trial at the time of the first kiosk access. For analyses, the actual value (0) was used.

Social rank and participation over time and tasks

Correlation analyses of trial completion rates at the start of kiosk testing revealed a significant relationship with rank, and this relationship persisted through the first month of testing. After two months of testing, however, this relationship was no longer significant. Table 7 shows all correlation coefficients from these analyses.

	r_s	p	n
day 1	-0.32	0.003	84
days 1-2	-0.25	0.02	87
week 1	-0.36	0.001	87
month 1	-0.28	0.008	89
months 1-2	-0.18	0.1	90
months 1-3	-0.14	0.18	90

Table 7: Spearman correlations for social rank and trial completion rate (adjusted for each subject's time in the group) for different portions of the data collection period. As time progressed, social rank explained a smaller proportion of the variance in trial completion rate.

Participation rates did not differ by rank for any Touch Training tasks. For each Touch Training task, the average elapsed time between trials by rank group was analyzed using natural log-transformed data. Only animals with no data for the task of interest after 8/24/2010 were included in these analyses. There were no significant differences by rank group for Screentouch I (Quartile split: *F*(3,74) = 2.36, *p*=.08; Two-way split: *F*(1,76) = 2.77, *p*=.10.), for Screentouch II (Quartile split: *F*(3,72) = 1.24, *p*=.30; Two-way split: *F*(1,74)= 1.56, *p*=22, or for Squaretouch (Quartile split: *F*(3, 49) = 1.30, *p*=.28; Two-way split: *F*(1, 51) = 1.88, *p*=.18). There were also no significant differences by rank group for the Match Task (Quartile split and Three-way split: *F*(2,36)=.32, *p*=.73 (no animals ranked 5-8 had started the Match Task); Two-way split: *F*(1,37) = .51, *p*=.48.

Chi-square analyses comparing the numbers of completing and noncompleting animals for each task revealed no significant rank effects, with social rank groups split into quartiles or into two groups, and with all ages or ages three and older only (*p*>.05 for all analyses).

Sex

Only 4 males over the age of 2 were a part of this study. Two males were 3 years of age, and the other two were 16 years of age. Thus, comparisons of males and females were completed only for animals 2 years of age and younger.

Sex and time to first kiosk access and first completed trial

Time to first access the kiosk was restricted to the 1-2-year-olds available to test on 2/17/10. There was not a significant difference in the distribution of males and females by rank in this group of 13 animals, X^2=2.86, 2.d.f. p=.24. Time to first access (natural log transformed) did not show a significant effect of sex, t(10.98) = -1.07, p=.31, d=.58 (Females: n=5, M=7.21 hours ± 3.9 *SEM*; Males: n=8, M=13.95 hours ± 4.95 *SEM*).

Time to complete the first trial included all 44 individuals 2 years of age and younger. The distribution of males and females by rank did not differ significantly in either the monkeys less than 1 year of age (X^2=.00, p=1.00) or in the monkeys 1-2 years of age (X^2=2.55, p=.48). Time to first completed trial did not show a significant effect of sex, Mann-Whitney U = 206.00, p=0.39, d=0.22. (Females: n=23, M = 32.60 hours ± 17.09 *SEM*; Males: n=21, M = 55.02 hours ± 25.31 *SEM*).

Sex and overall rate

Overall participation rates, adjusted for total days available, did not differ between males and females, t(42) = .01, p=0.996, d=.13 (Females: n=23, M = 13.41 ± 3.29 *SEM*; Males: n=21, M = 17.97 ± 26.03 *SEM*). There were also no significant differences between males and females for the number of trials completed, the number of tasks passed, days available, days with trials completed, or days in the social group without access to the kiosk (all Mann-Whitney *U* tests, $p > 0.05$).

Discussion

While primate learning and cognition studies in the laboratory often use food deprivation and some have even argued that consistent performance is not possible without food deprivation (Taffe, 2004), this study has shown that socially housed rhesus monkeys will voluntarily participate in computerized testing, even when they have continuous access to food, water, social group members, substantial physical space, and nearly unregulated choice over the activities in which they engage within their social group. Moreover, this study has shown that not only animals will participate, but that participation continues over time, at least in a subset of animals, and that animals can successfully progress through successively more difficult tasks, moving at their own pace and as they meet criterion on tasks.

This study revealed significant age effects from the start of kiosk testing, and effects emerged with a range of measures. Consistent with predictions, age effects became stronger over the data collection period, as tasks got harder and the kiosk became less novel. These were not small effects. The overall rates (Figure 15) provide the most striking example of differences between age groups: no subject less than one year of age showed an overall rate slower than 1 trial per day, and very few subjects between 1 and 3 years of age showed a rate slower than one trial per day, with most of these subjects showing much higher rates of participation. However, 8 of 14 four-year-old subjects showed rates averaging less than one trial per day, and all but one subject (with a rate of 1.21 trials/day) over the age of 5 participated at a rate of less than one trial per day.

The age differences observed in the latency to access the kiosk most closely reflect differences in age and attraction to novelty reported for primates in the wild and in captivity, with young animals more inclined to engage with novel objects and reduced attention and manipulation of novel and familiar objects by adult primates (Fairbanks, 1993; Glickman & Sroges, 1966; Joubert & Vauclair, 1986; Menzel, 1966; Stephenson, 1973; Tsumori, 1966). If interacting with the kiosk can be considered a form of play, it is consistent with reduced levels of play in adult primates (Fagen, 1993).

While we predicted that adult animals would work more slowly, we were surprised that no adult animals successfully completed the Match Task. From laboratory studies, we know that animals of all ages are capable of learning such a simple task – and of learning far more complicated tasks as well. In this case, it did not seem to be a matter of ability to learn as much as a matter of a lack of motivation to participate.

There are many potential variables that may explain reduced motivation in adult animals in this study. First, the novelty of the kiosk may wear off faster for older animals. Changes in tasks may not be viewed with great interest, and the older animals may be more motivated by the novelty of the food reward than by the novelty of the task. As soon as the tasks reached a point where substantial attention to the screen was required to obtain a reward, substantial numbers of adult animals started to drop out. It is possible that some adults simply never attended to the tasks enough to understand the full contingency, as suggested by their slower participation overall, even in the Touch Training tasks. It is also possible that the pellet reward stopped being motivating once greater effort was required to obtain it. The size of the pellet rewards was very small (94mg), and did not change in relation to the subject’s body mass index (BMI). Thus, the reward that adult animals obtained for their efforts was proportionally smaller than the reward obtained by young animals for the same amount of effort. This could be directly tested by altering the number of rewards per successful trial according to subject BMI. On the other hand, it may be that the magnitude of reward was not critical and that adults were less attracted to the opportunity to solve a novel task. This notion is interesting given that adults have more experience with different environmental contingencies than do young animals and thus one might think that the tasks would simpler for them and thus more attractive. This does not appear to be the case.

Social facilitation may also have played a role in the reduced participation of adult animals. Adult females spend much of their time with other adults, engaged in activities such as grooming, infant care, feeding, and sleeping. Since it was uncommon for adult animals to work actively at the kiosk, this may have led to an exaggerated low level of participation among adults because adults would have had to leave their peers to interact with the kiosk. Interacting with the kiosk would essentially be a solitary activity for adults. The same did not appear to be true for young animals, as informal observations suggested that it was relatively common for younger animals to work actively at the kiosk in the presence of other young animals or with the mother nearby. Thus, it is possible that young animals' high levels of participation as a group resulted from social facilitation effects.

Seasonal changes in the roles of adult animals may also have contributed to the age effects observed in this study. The start of kiosk testing corresponded with the end of the mating season and with the very beginning of the birthing season, which would peak two-three months later. Since the majority of adult females give birth in a given year, it is possible that individual females showed reduced participation rates as their pregnancy progressed, and that reduced participation continued once they gave birth to their infants. Certainly, the reduced participation rates in 4 and 5-year-olds are consistent with this. The 4-year-old females who participated at higher rates may have been those individuals who did not give birth to infants in 2010.

While many of the potential reasons for reduced participation in adult animals relate to the environment in which these animals were tested, aspects of these findings may apply to age effects in cognitive testing that are sometimes reported for singly tested animals (Herndon, Moss, Rosene, & Killiany, 1997; Lacreuse, Espinosa, & Herndon, 2006; Moore, Killiany, Herndon, Rosene, & Moss, 2006). Even in food-restricted animals, it is possible that older animals have reduced motivation to participate or to perform compared to younger animals. This possibility is suggested by informal reports that older animals in the laboratory attempt fewer trials compared to younger animals (James Herndon, personal communication). Young animals generally have higher metabolisms and require food at more frequent intervals compared to adult animals. Thus, in laboratory cognitive testing, it is still possible that older animals are less food-motivated than are younger animals. If laboratory animals perform more poorly on cognitive tests when they are not food restricted (Taffe, 2004), then animals that are food restricted but with slower metabolisms may perform more poorly compared to animals that are food restricted with faster metabolisms.

Social rank effects appeared only at the very beginning of data collection, in the time to first access the kiosk, and, less strongly, in the time to the first completed trial. The effect for time to first access the kiosk was potentially affected by the small amount of peanut butter that was placed on the screen at the time that the program was started. However, the amounts of peanut butter were so small that they were likely consumed by the first animal to access the kiosk, who completed two trials 2 minutes after the kiosk became available. No animals accessed the kiosk again for 16 minutes after that, suggesting that any “peanut butter effect” is unlikely. Moreover, the long times to first access the kiosk by many low-ranking animals (far more than 24 hours, as shown by Figure 18) also suggest that this effect is actually driven by the novelty of the kiosk itself.

The weaker effects of rank on the time to complete the first trial, with the primary significant contrast existing between the top four families and families 9-12, might be explained by social observation effects. The lowest ranking four families, ranked 13-16, did not take significantly more time to complete the first trial than did the top four families. They did, however, take significantly more time to make their initial access compared to the top four families, a contrast with a large effect size. Thus, the lowest-ranking animals may have had time to observe other animals at the kiosk before approaching, making their first access, and completing their first trial in a relatively short span of time because they already understood the contingency.

While social rank effects were also significantly correlated with participation rates at the start of the study, this relationship dissipated relatively quickly. After two months of testing were completed, there was no significant relationship between social rank and trial completion rate. Similarly, no rank effects were observed for overall rates of task completion of any task, and no effects were observed for the distribution of task completers compared to task noncompleters.

These findings were consistent with predictions. At the start of data collection, the kiosk was a novel item from which it was possible to obtain a novel, desirable food. Access was limited not by the duration of availability, but by the fact that only one animal at a time could access it. As in studies which have examined social rank and its relationship to access to desirable foods or other items, high ranking animals obtained access first (Belzung & Anderson, 1986; Chancellor & Isbell, 2008; Deutsch & Lee, 1991; DeWaal, 1986). Informal observations, as well as the range of latencies even for high ranking animals, suggest that high ranking animals did not first obtain access because they rushed ahead of lower-ranking individuals to gain it, but rather that low-ranking individuals were somewhat reluctant to initially access the kiosk, as shown in the scatterplot with very long latencies to access for lower-ranking animals.

As expected, rank effects did not persist over the course of testing and we did not observe any rank effects related to performance. In contrast to other studies of social rank, the kiosk was continuously available over an extended time period. The access effects that were observed are likely a result of the fact that the animals had to learn over time that the kiosk was almost always available, and that there were many times when no animals were accessing it, and so gaining access to it was possible for all individuals. In addition, unlike the group discrimination studies completed by Drea & Wallen (1998b, 1999), subjects were not participating and obtaining food at the expense of the opportunity for other subjects to obtain food. Again, however, this was something that the animals needed to learn, as almost all of their prior experience with desirable food (all foods other than their primate chow) had been that its availability was quickly depleted.

The lack of sex differences observed in this study was not predicted. Interestingly, while initial access did not show a significant difference between males and females, means were in the predicted directions, with a medium effect size. One major issue for the examination of sex differences in this study is that most of the animals under the age of 2 started kiosk testing at different time points during data collection. Thus, few individuals were able to be included in initial access analyses, reducing the power of analyses, and the start dates over several months may have allowed for observational learning, obscuring any potential differences in time to first completed trial. The lack of sex differences in overall participation rate seems more robust, and this finding is interesting given the high rates of participation in this age group over the course of the study. It suggests that despite the many sex differences that are observed in juvenile monkeys (Brown & Dixson, 2000; Hassett et al., 2010; Herman, Measday, & Wallen, 2003; Lovejoy & Wallen, 1988; Wallen, 1996), motivation to participate in computerized tasks does not differ by sex, and this persists as tasks get more difficult. Groups of young animals were often observed at the kiosk, and often play behaviors were also observed, suggesting that interactions with the kiosk became a part of the play repertoire of the young animals in this group. Potential social facilitation effects of task acquisition would be particularly interesting to study in a systematic manner in both males and females ages two and younger. Sex differences might be observed in older juvenile animals, between ages 2 and 4 years, as females enter puberty earlier and the roles of males and females continue to diverge. Many of the fastest subjects to access the kiosk were females between these ages. Unfortunately, there were not enough males of these ages to compare sex differences in participation for older juveniles.

The prominent age effects for participation in voluntary cognitive testing as reported here raise questions for studies of changes in cognition with age in any testing context. In our study, if subjects were not motivated to work, they faced few consequences for a lack of participation, as their complete dietary needs were provisioned throughout the study and they could easily move away from the kiosk, engaging in other activities as they chose. In a more restricted environment, less motivated animals, even if motivated by the desire or need for food, may perform more poorly, finding that they can obtain needed food even by performing at chance levels. The potential consequences of differences in motivation to participate between focal groups of subjects should be considered for the findings of any study reporting differences in performance between groups.

In summary, this study confirms that computerized cognitive testing is possible in large social groups of rhesus monkeys and over long-term data collection periods. Subjects participated voluntarily and were auto-shaped to interact with the kiosk and to complete tasks. Among social demographic characteristics, age has the most striking effect on participation. Future studies should work to determine whether it is possible to improve the motivation of older subjects, and to determine how the reduced participation of older subjects may affect performance in more restricted testing settings.

References

Andrews, M. W. (1994). An automated identification system for use with computer-controlled tasks. *Behavior Research Methods Instruments & Computers, 26*(1), 32-34.

Andrews, M. W., & Rosenblum, L. A. (1994). Automated recording of individual performance and hand preference during joystick task acquisition in group-living bonnet macaques (*Macaca radiata*). *Journal of Comparative Psychology, 108*(4), 358-362.

Andrews, M. W., & Rosenblum, L. A. (2002). Response patterns of bonnet macaques following up to 75 weeks of continuous access to social-video and food rewards. *American Journal of Primatology, 57*(4), 213-218.

Bartlett, D. P., & Meier, G. W. (1971). Dominance status and certain operants in a communal colony of Rhesus macaques. *Primates, 12*(3-4), 209-219.

Belzung, C., & Anderson, J. R. (1986). Social rank and responses to feeding competition in rhesus monkeys. *Behavioural Processes, 12*(4), 307-316.

Benton, A. L., Varney, N. R., & Hamsher, K. D. (1978). Visuospatial Judgment - Clinical Test. *Archives of Neurology, 35*(6), 364-367.

Berman, C. M. (1982). The Ontogeny of Social Relationships with Group Companions among Free-Ranging Infant Rhesus-Monkeys .1. Social Networks and Differentiation. *Animal Behaviour, 30*(Feb), 149-162.

Bernstein, I. S., & Sharpe, L. G. (1966). Social roles in a rhesus monkey group. *Behaviour, 26*(1/2), 91-104.

Boelkins, R. C., & Wilson, A. P. (1972). Intergroup social dynamics of the Cayo Santiago rhesus (*Macaca mulatta*) with special references to changes in group membership by males. *Primates, 13*(2), 125-140.

Brown, G. R., & Dixson, A. F. (2000). The development of behavioural sex differences in infant rhesus macaques (Macaca mulatta). *Primates, 41*(1), 63-77.

Chance, M. R. A. (1956). Social structure of a colony of Macaca mulatta. *British Journal of Animal Behaviour, 4,* 1-13.

Chance, M. R. A. (1967). Attention structure as the basis of primate rank orders. *Man, 2*(4), 503-518.

Chancellor, R. L., & Isbell, L. A. (2008). Punishment and competition over food in captive rhesus macaques, Macaca mulatta. *Animal Behaviour, 75*, 1939-1947.

Collaer, M. L., & Nelson, J. D. (2002). Large Visuospatial sex difference in line judgment: Possible role of attentional factors. *Brain and Cognition, 49*(1), 1-12.

Collaer, M. L., Reimers, S., & Manning, J. T. (2007). Visuospatial Performance on an Internet Line Judgment Task and Potential Hormonal Markers: Sex, Sexual Orientation, and 2D:4D. *Arch Sex Behav*.

Colvin, J. D. (1986). Proximate causes of male emigration at puberty in rhesus monkeys. In R. G. Rawlins & M. J. Kessler (Eds.), *The Cayo Santiago Macaques*. Albany, NY: State University of New York Press.

Deutsch, J. C., & Lee, P. C. (1991). Dominance and feeding competition in captive rhesus monkeys. *International Journal of Primatology, 12*(6), 615-628.

DeWaal, F. B. M. (1986). Class structure in a rhesus monkey group: the interplay between dominance and tolerance. *Animal Behaviour, 34*, 1033-1040.

Drea, C. M. (1998a). Social context affects how rhesus monkeys explore their environment. *American Journal of Primatology, 44*(3), 205-214.

Drea, C. M. (1998b). Status, age, and sex effects on performance of discrimination tasks in group-tested rhesus monkeys (Macaca mulatta). *Journal of Comparative Psychology, 112*(2), 170-182.

Drea, C. M., & Wallen, K. (1995). Gradual Acquisition of Visual-Discrimination Tasks in a Social Group of Rhesus-Monkeys (Macaca-Mulatta). *Animal Learning & Behavior, 23*(1), 1-8.

Drea, C. M., & Wallen, K. (1999). Low-status monkeys "play dumb" when learning in mixed social groups. *Proceedings of the National Academy of Sciences of the United States of America, 96*(22), 12965-12969.

Drickamer, L. C., & Vessey, S. H. (1973). Group changing in free-ranging male rhesus monkeys. *Primates, 14*(4), 359-368.

Ehardt, C. L., & Bernstein, I. S. (1987). Patterns of affiliation among immature rhesus monkeys (*Macaca mulatta*). *American Journal of Primatology, 13*(3), 255-269.

Fagen, R. (1993). Primate juveniles and primate play. In M. E. Pereira & L. A. Fairbanks (Eds.), *Juvenile Primates: Life History, Development, and Behavior*. New York: Oxford University Press.

Fagot, J., & Bonte, E. (2010). Automated testing of cognitive performance in monkeys: Use of a battery of computerized test systems by a troop of semi-free-ranging baboons (Papio papio). *Behavior Research Methods, 42*(2), 507-516.

Fagot, J., & Paleressompoulle, D. (2009). Automatic testing of cognitive performance in baboons maintained in social groups. *Behavior Research Methods*, *41*(2), 396-404.

Fairbanks, L. A. (1993). Risk-taking by juvenile vervet monkeys. *Behaviour, 124*, 57-72.

Fitchett, A. E., Collins, S. A., Barnard, C. J., & Cassaday, H. J. (2005). Subordinate male mice show long-lasting differences in spatial learning that persist when housed alone. *Neurobiology of Learning and Memory*, *84*(3), 247-251.

Glickman, S. E., & Sroges, R. W. (1966). Curiosity in zoo animals. *Behaviour, 26*(1/2), 151-188.

Hamilton, C. R. (1983). Lateralization for orientation in split-brain monkeys. *Behav Brain Res, 10*(2-3), 399-403.

Hassett, J. M., Martin-Malivel, J., Lange, H., Fischer, A., & Wallen, K. (2007). *Age and rank influences on access to an automated system for cognitive testing in socially housed rhesus monkeys*. Paper presented at the Comparative Cognition Society Conference.

Hassett, J. M., Rupp, H. A., & Wallen, K. (2010). Social segregation in male, but not female yearling rhesus macaques (*Macaca mulatta*). *American Journal of Primatology, 72*, 87-92.

Herman, R. A., Measday, M. A., & Wallen, K. (2003). Sex differences in interest in infants in juvenile rhesus monkeys: relationship to prenatal androgen. *Hormones and Behavior, 43*(5), 573-583.

Herndon, J. G., Moss, M. B., Rosene, D. L., & Killiany, R. J. (1997). Patterns of cognitive decline in aged rhesus monkeys. *Behavioural Brain Research, 87*(1), 25-34.

Jay, P. (1965). Field studies. In A. M. Schrier, H. F. Harlow & F. Stollnitz (Eds.), *Behavior of nonhuman primates* (Vol. 2, pp. 525-591). New York: Academic Press.

Joubert, A., & Vauclair, J. (1986). Reaction to novel objects in a troop of guinea baboons: approach and manipulation. *Behaviour, 96*(1/2), 92-104.

Lacreuse, A., Espinosa, P. M., & Herndon, J. G. (2006). Relationships among cognitive function, fine motor speed and age in the rhesus monkey. *Age, 28*(3), 255-264.

Lepoivre, H., & Pallaud, B. (1986). Learning set formation in a group of Guinea baboons (*Papio papio*): Importance of the behavioral variable measured. *American Journal of Primatology, 10*(1), 25-36.

Lindburg, D. G. (1971). The rhesus monkeys in North India: an ecological and behavioral study. In L. A. Rosenblum (Ed.), *Primate Behavior* (Vol. 2, pp. 1-106). New York: Academic Press.

Lovejoy, J., & Wallen, K. (1988). Sexually dimorphic behavior in group-housed rhesus-monkeys (*Macaca mulatta*) at 1 year of age. *Psychobiology, 16*(4), 348-356.

Menzel, E. W. J. (1966). Responsiveness to objects in free-ranging Japanese monkeys. *Behaviour, 26*(1/2), 130-150.

Mondragon-Ceballos, R., Chiappa, P., Mayagoitia, L., & Lee, P. (2010). Sex differences in learning the allocation of social grooming in infant stumptailed macaques. *Behaviour, 147*(9), 1073-1099.

Moore, T. L., Killiany, R. J., Herndon, J. G., Rosene, D. L., & Moss, M. B. (2006). Executive system dysfunction occurs as early as middle-age in the rhesus monkey. *Neurobiology of Aging*, *27*, 1484-1493.

Novak, M. A., Musante, A., Munroe, H., Oneill, P. L., Price, C., & Suomi, S. J. (1993). Old, social housed rhesus monkeys manipulate objects. *Zoo Biology, 12*, 285-298.

Pelaez, F., Gil-Burmann, C., & Sanchez, S. (2000). Feeding tactics in juvenile rhesus monkeys (Macaca mulatta). *American Journal of Primatology, 51*(2), 147-152.

Rowell, T. E. (1974). The concept of social dominance. *Behavioral Biology, 11*, 131-154.

Sade, D. S. (1967). Determinants of dominance in a group of free-ranging rhesus monkeys. In S. A. Altmann (Ed.), *Social communication among primates* (pp. 99-113). Chicago: University of Chicago Press.

Southwick, C. H., Beg, M. A., & Siddiqi, M. R. (1965). Rhesus monkeys in North India. In I. DeVore (Ed.), *Primate behavior: Field studies of monkeys and apes* (pp. 111-159). New York: Holt, Rinehart, and Winston, Inc.

Stephenson, G. R. (1973). Biology of communication and population structure. In C. R. Carpenter (Ed.), *Behavioral Regulators of Behavior in Primates*. Cranbury, New Jersey: Associated University Presses, Inc.

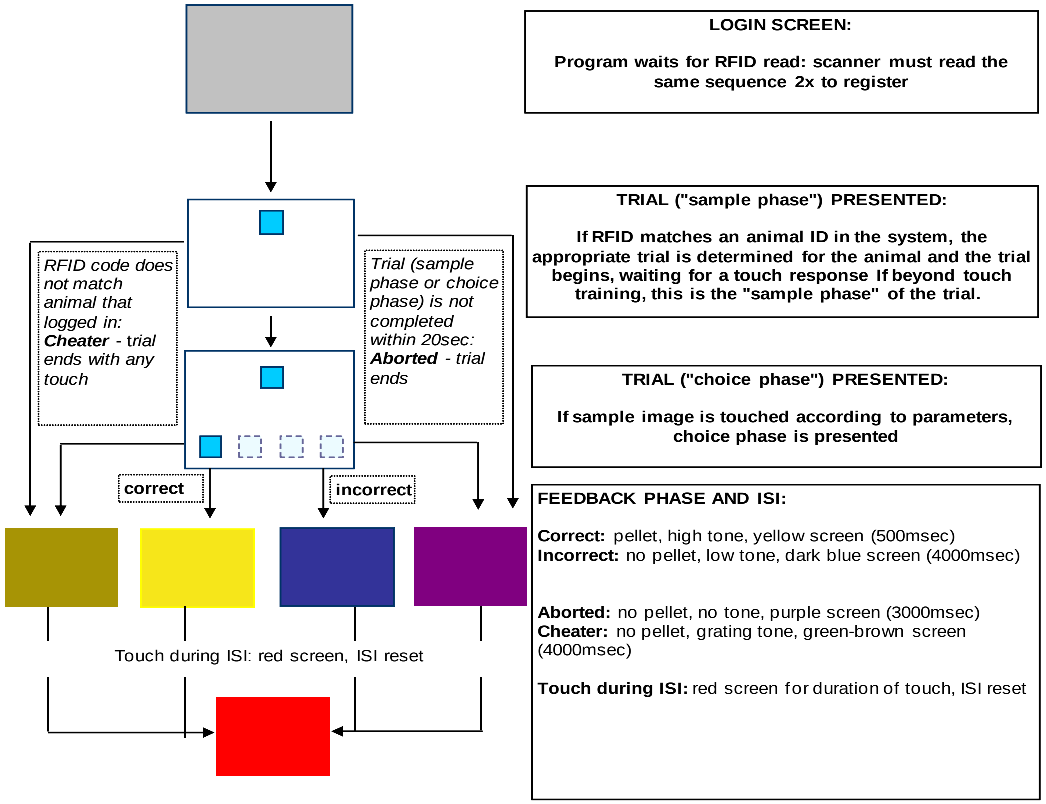
Taffe, M. A. (2004). Effects of parametric feeding manipulations on behavioral performance in macaques. *Physiology & Behavior, 81*(1), 59-70.

Tsumori, A. (1966). Delayed response of wild Japanese monkeys by the sand-digging method (II). *Primates, 7*(3), 363-380.

Wallen, K. (1996). Nature needs nurture: The interaction of hormonal and social influences on the development of behavioral sex differences in rhesus monkeys. *Hormones and Behavior, 30*(4), 364-378.

Washburn, D. A., Hopkins, W. D., & Rumbaugh, D. M. (1991). Perceived control in rhesus monkeys (Macaca mulatta) - enhanced video-task performance. *Journal of Experimental Psychology-Animal Behavior Processes, 17*(2), 123-129.

Appendix



LOGIN SCREEN:

Program waits for RFID read: scanner must read the same sequence 2x to register

TRIAL ("sample phase") PRESENTED:

If RFID matches an animal ID in the system, the appropriate trial is determined for the animal and the trial begins, waiting for a touch response If beyond touch training, this is the "sample phase" of the trial.

TRIAL ("choice phase") PRESENTED:

If sample image is touched according to parameters, choice phase is presented

FEEDBACK PHASE AND ISI:

Correct: pellet, high tone, yellow screen (500msec)
Incorrect: no pellet, low tone, dark blue screen (4000msec)

Aborted: no pellet, no tone, purple screen (3000msec)
Cheater: no pellet, grating tone, green-brown screen (4000msec)

Touch during ISI: red screen for duration of touch, ISI reset

Figure 1: The sequence of events in a trial of any task in which incorrect responses were possible.

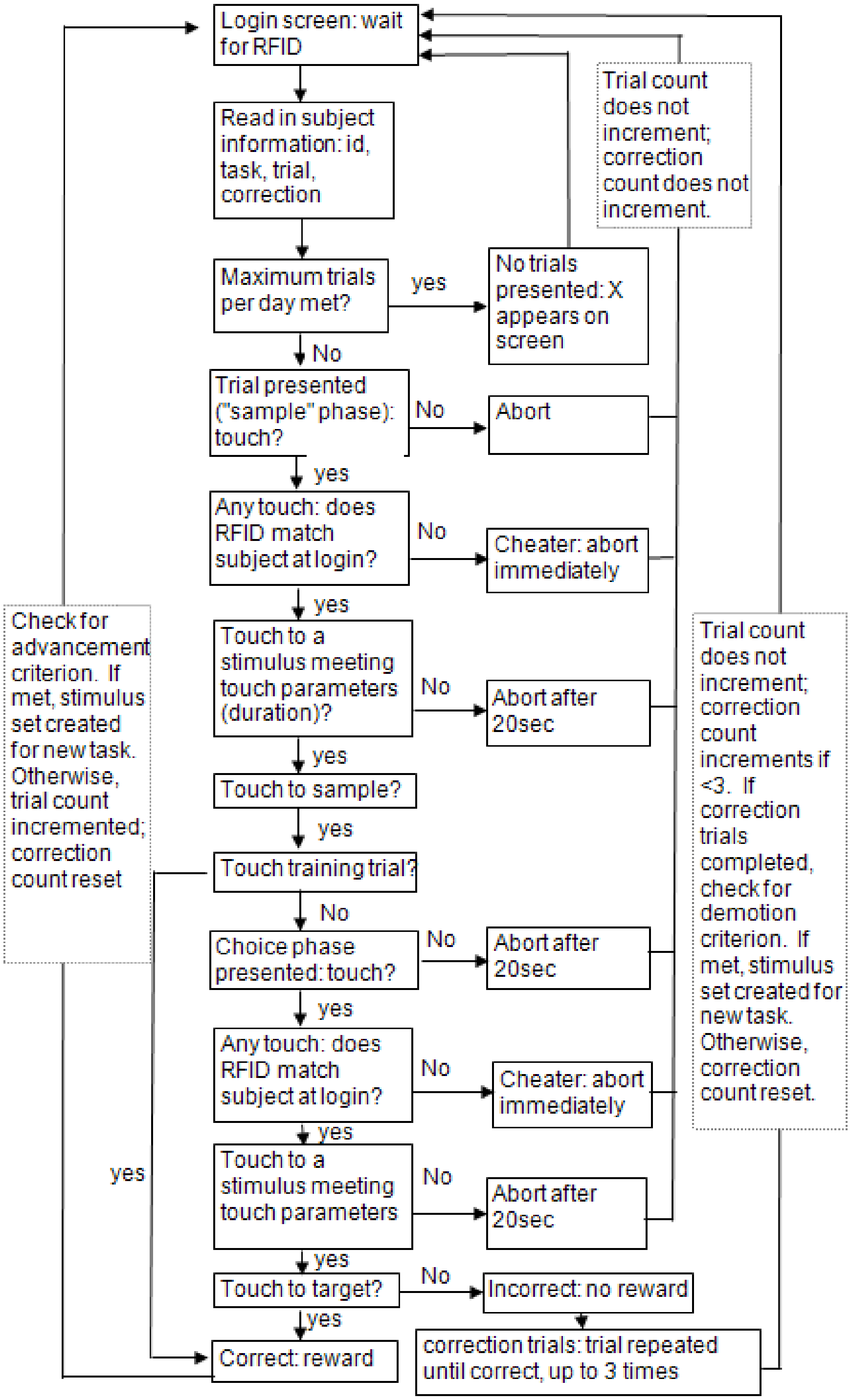


Figure 2: The basic construction of the Presentation program written to run all kiosk trials for all subjects, tracking subject progress and advancing or demoting subjects as they met criterion.

Self-regulated learning in rhesus monkeys: timing and performance

Janice M. Hassett

Emory University and Yerkes National Primate Research Center

Kim Wallen

Emory University and Yerkes National Primate Research Center

Abstract

The schedules imposed on human participants and animal subjects in studies of learning tell us more about the needs and assumptions of the experimenter than they do about the preferred and optimal schedules of the learner. In this study, we put the learners in control of their own schedules. Specifically, we created a computerized testing system which allowed socially housed rhesus monkeys to engage in learning tasks whenever they chose. Based on the relationship between self-efficacy and performance in humans and on preferences for control in both humans and animals, we predicted that when subjects perceived greater control over a contingency – when they performed better – they would participate at a higher rate. When they performed more poorly, they were expected to participate at a lower rate. In addition, we drew from a literature on the effect of incubation on problem-solving to predict that subjects that required fewer trials to acquire a task also would show a slower pace in early task acquisition, with longer breaks between trials. These predictions were supported. Early task acquisition was characterized by slower participation and poorer performance, and late task acquisition by faster participation and improved performance. Subjects returned to the task sooner after correct trials than after incorrect trials. Finally, three types of subjects emerged from analyses: subjects that readily learned the contingencies of a task in very few trials, subjects that took long breaks in early acquisition and required relatively few trials to learn the contingencies of a task, and subjects that took less time between trials in early acquisition but took many trials to fully learn the contingencies of a task. More research is needed to investigate possible differences in learning style and a benefit of an

incubation period in learning, but these findings suggest that allowing subjects to engage in learning at their own rate may reveal important differences in approaches to learning.

Self-regulated learning in rhesus monkeys: timing and performance

Not every individual learns best when they lock themselves in an empty room at the same time every day and proceed to learn the task at hand, whether they are learning a new language, trying to master geometry, or learning to play piano. Any parent knows that if they try to impose such a schedule on a child, the results are often disastrous. In animal learning research, reinforcement schedules and precise control over environmental conditions have long taken precedence over the potentially variable schedules of the subjects (Skinner, 1963). In an address to the Midwestern Psychological Association in 1948, Harry Harlow noted that theoretical psychologists working with animals had ". . . one great advantage over those psychological citizens who study men and women. The theoreticians can subject their sub-human animals, be they rats, dogs, or monkeys, to more rigorous control than can ordinarily be exerted in human beings" (Harlow, 1949, p. 51). Even in humans, learning is often studied on a schedule that conforms to the needs of the experimenter, rather than to the needs or motivations of the learners. Despite these restricted schedules generally used in research, the fact remains that most "real-world" learning occurs in a self-regulated fashion (Artino & Stephens, 2009; Nistor & Neubauer, 2010; Noe, Tews, & Dachner, 2010; Shockley & Allen, 2010), with the learner engaging spontaneously in learning when they are motivated to do so, and disengaging from it when they are no longer motivated – even when the schedules of others are imposed upon them (Lepper, Corpus, & Iyengar, 2005). Such self-regulated learning is rarely studied, but the variation in schedules and performance that result could make a considerable contribution to our understanding of learning.

The importance of a sense of autonomy and choice has been demonstrated in both humans and in animals. In many species including humans (Inglis, Forkman, & Lazarus, 1997; Neuringer, 1969; Singh, 1970), individuals have been shown to prefer to perform a simple operant to obtain food (in children: marbles (Singh, 1970)) over having food freely available, sometimes even when the freely available food can be obtained at a much faster rate. This phenomenon, known as contrafreeloading (Inglis et al., 1997), is thought to result from a preference to exert control over the environment when such control is possible, which is a preference that can be adaptive for learning (Inglis et al., 1997). In both humans and animals, choices are preferred over non-choices when the reward outcomes are equal (Bown, Read, & Summers, 2003; Catania & Sagvolden, 1980; Leotti, Iyengar, & Ochsner, 2010; Suzuki, 1997, 1999). Moreover, the availability of choice can also affect performance: in a traditional testing environment, adult male rhesus monkeys performed best in testing sessions in which they were provided with a choice of computerized testing tasks. They performed more poorly when the experimenter chose the task (Washburn, Hopkins, & Rumbaugh, 1991).

Despite the importance of autonomy and choice, most studies of primate learning rely on restricted autonomy and a lack of choice – animals are tested in small cages with no or minimal social stimulation, and motivation is often manipulated by some form of restriction of access to food or water – their diet is reduced to a percentage below maintenance, or they are fed after testing (Meyer, 1951; Taffe, 2004). Thus, the animals are highly motivated to work to obtain food. Even when food restrictions are not implemented, subjects are likely to be motivated to work for food because there are few viable alternatives in activities of choice.

As already described in detail in the accompanying manuscript (this issue), we created a cognitive testing system that we implemented within a social group of over 100 socially housed rhesus monkeys, and allowed the group members nearly continuous access to the system. Whether they participated and when they participated was determined, at least to a large extent, by their own motivations – in essence, we designed a testing system which allowed us to examine self-regulated learning in rhesus monkeys.

In the vast majority of studies of learning, there is little discussion of variation in time between trials completed by subjects. Rather, the focus is simply on learning curves, with trials, blocks of trials, or sessions plotted on the x-axis and proportion correct plotted on the y-axis. Despite the implied temporal changes in performance and the measures of latencies to complete trials once they are started, latencies between trials are rarely discussed, except, in some cases, in relation to cumulative records of participation, which are generally used to determine optimal rates of responding (Skinner, 1963). In more traditional studies of learning, with a caged animal working for a limited portion of a day in a small space, variability in the time between trials is almost certainly reduced and may not even be a meaningful measure of learning. However, it seems likely that there remains some variability in this measure even under the most controlled conditions and the best reinforcement schedules.

One analytical approach sometimes used to interpret learning curves in traditional learning studies is known as “backwards plotting”, which allows for a learning curve to be broken into two stages and for individuals to be more readily compared (Hayes, 1953). A normal learning curve is plotted with the first trial of a task as trial 1, but in a backwards curve the first trial indicates how many trials a subject was from entering trials which counted towards its attainment of criterion. Thus, if, as in the current study, 80 trials must be correct out of any consecutive 100, then the first trial that counted towards the attainment of criterion is the 80th correct trial from the final trial which resulted in the achievement of criterion. The 80th correct trial from the end becomes trial "zero," and all trials before it can be defined as "pre-criterial", with negative trial numbers, and trial zero and all trials after it can be defined as "criterial". Using this method allows for a better comparison of individuals, and it is expected that most of the variation between subjects lies in the pre-criterial stage, since by definition the criterial stage was where subjects demonstrated that they had learned the task. While most studies that use backwards plotting plot trials or blocks of trials on the X-axis, the same method can also be used to plot cumulative time spent on a task, so that the total time in the pre-criterial stage and the total time in the criterial stage can be obtained.

In this study, use of the backwards plotting method in exploratory examination of learning curves revealed substantial variability in both time and trials in the pre-criterial stage of the simplest of the tasks in which trials could be answered correctly or incorrectly, the Match Task. The learning curves also suggested that around the time that most subjects entered criterial trials, substantial changes took place in their patterns of participation. As expected, animals started to improve their performance, but many of them also appeared to complete trials much more quickly. Thus, it seemed that elapsed time between trials, a measure of the rate of participation, was a potentially meaningful measure, if it in fact related to performance.

Historically, participation has served as a measure of motivation, especially in other kinds of animal research. Particularly when the context provides the subject with choices, participation can be an excellent measure. For example, the rate at which a female monkey exhibits proceptive mating behavior reflects her motivation to mate, especially as compared to her behavior at other times, or compared to the behavior of other female monkeys (Wallen, 2001). In the current study, participation rate at the kiosk served as a measure of the motivation to interact with the system to obtain food rewards. But could the motivation to interact be demonstrably linked to performance? In humans, performance has been related to self-efficacy: in short, the more an individual perceives that they have the ability to do something, the greater their interest will be in engaging in the activity to complete the task successfully (Bandura & Schunk, 1981; Niemivirta & Tapola, 2007). In the monkeys, the trial-by-trial feedback that serves the role of both "instruction" and feedback also can be thought of as a measure of efficacy: when the animal does well, we expect that efficacy and motivation increase. When it does poorly, we expect that it decreases. Thus, in this self-regulated learning context, we expected that when subjects were doing well, they would participate more, and that when they were doing poorly, they would participate less. The notion of efficacy involves an internal perception of performance and thus is different from a strictly behaviorist interpretation in which the decreased reward from poor performance could actually increase participation to potentially increase reward. Whether rhesus monkeys have any internal perception of their performance is not known, but expressed in less cognitive terms and to relate to the contrafreeloading literature (Inglis et al., 1997), they may have a sense of their relative control over contingencies related to getting a reward. When they perform well, there may be a strong sense of control, and when they perform poorly, this sense of control may be reduced.

While some consistency between subjects in the relationship between performance and participation was expected, variability in participation might explain some of the observed variability in task acquisition. In creativity and problem-solving research, “incubation time” is studied in relation to problem-solving fixation. Theories of incubation time suggest that when individuals or collaborative groups are fixated on a poor or incorrect solution to a problem, a period of incubation, or time away from conscious thought about the problem, can lead to appropriate solutions more quickly than can working continuously on the problem (Beeftink, van Eerde, & Rutte, 2008; Smith & Blankenship, 1991).

In the current study, if subjects who were able to reach criterial trials in a smaller number of trials allowed more time to elapse between trials, they may have been able to more easily break any sort of fixation or perseverance error that occurred early in learning the task. Thus, we predicted that animals that required fewer trials before entering criterial trials would show more time between pre-criterial trials, as compared to animals that completed more trials before entering criterial trials.

To our knowledge, this is the first study to examine whether differences in task acquisition in animal subjects can be attributed to differences in participation rates. We believe that studies of self-regulated learning are important in research with both humans and animals. Often, the assumption is that fast and persistent work on a problem will lead to the best learning, and many environments in research and education support only this form of learning. When the learner is allowed to choose when to engage in learning, different patterns may emerge. Such patterns may suggest differences in learning styles or strategies. Certainly, these ideas are the foundation for alternative approaches to childhood education (Rathunde & Csikszentmihalyi, 2005), but they are ideas which have been little studied even in children and have not been tested in any systematic fashion in nonhuman animals.

Methods

The methods for this study were identical to the methods of the accompanying article, and the same subjects were used for the same data collection period.

One aspect of data collection was not described in the accompanying article but is relevant to the results reported here. In April of 2011, the 16 animals that had met criterion on the Match Task and remained in the social group were placed on the Squaretouch task for 50 trials, from wherever they had been in their training beyond the Match Task. At the time of this manipulation, the kiosk had been off for 11 days. Once subjects completed the 50 trials of Squaretouch, they returned to whatever task they had been working on.

A few variables calculated for analyses in this article should be described at the outset. All time variables used adjusted times, with nighttime and times that an individual subject was unable to test due to temporary removal not included. Average elapsed times after incorrect trials were calculated using elapsed times after incorrect trials for both first-presentation and for correction trials. Average elapsed times after correct trials were calculated using only correct trials for first-presentation trials, since pellet rewards were not disbursed for correct correction trials.

Results

Match Task Completion

Seventy-eight monkeys started the Match Task, and 39 met criterion (80 correct trials out of any consecutive 100) on it. Overall, significantly more time elapsed from the start of the Match Task to the final completed trial for Match Task noncompleters compared to Match Task completers, $t(76)=3.63$, $p=.001$, natural log transformed data (Noncompleters *M:* 1464.64 hours ± 160.45 *SEM*; completers: *M*: 497.03 hours ± 78.23 *SEM*). Noncompleting animals also completed significantly fewer trials than Match Task completers, $t(43.22) = -8.75$, $p<.001$ (Noncompleter $M = 28.44 \pm 4.06$ *SEM*; Completer $M = 168.10 \pm 15.44$ *SEM*).

In addition to not being disadvantaged in time available to complete the task, noncompleting animals did not appear to be disadvantaged by their specific Match Task assignment, though the changes in task assignment over the course of the study made this more difficult to determine. As described in the methods of the accompanying manuscript, the Square Match version of the Match Task always presented blue squares of four different sizes, while Clipart Match presented black and white clipart images, with 1000 different images in the stimulus set. In both tasks, the images that appeared on a given trial were identical to each other. Proportionally, more subjects assigned to the Square Match task were noncompleters, compared to subjects assigned to the Clipart Match task ($X^2=6.33$, $p=.01$). However, this effect is most likely due to the fact that the Clipart Match task, because it was introduced later, was assigned almost exclusively to animals one year of age or younger. The mean age of those assigned to the Square Match task, on the other hand, was 3.71 years. As shown in the accompanying manuscript, 16 animals over the age of 5 started the Match Task, but none of these subjects completed it.

Match Task Position Biases

While the different Match Tasks varied in image positions on the screen, the proportion of animals showing significant position biases did not vary between tasks. Chi-square analyses for individual subjects compared numbers of correct and incorrect first-presentation trials for each of the four target positions, and revealed significant response biases in some animals. Among Match Task completers, 19 of the 39 animals showed a significant response bias. For the two forms of Match Tasks with targets appearing in one of four positions on the bottom of the screen, the most neglected position was almost always the far right (8 subjects) or the far left position (2 subjects), and sometimes one animal neglected both of these positions (5 subjects). One subject neglected both positions on the right side of the screen, and one subject neglected the middle right position (third position from the left side of the screen). For the one form of the Match Task with targets appearing in the four corners of the screen, significant biases were found for only 2 of the 9 completers. Despite the relatively low bias in this form of the Match Task, chi-square analyses revealed no significant differences in response bias between Match Task types. Subjects with significant response biases did not require significantly more correction trials per incorrect trial, in either the pre-criterial ($t(33) = 1.10$, $p=.28$) or in the criterial ($t(37)=-.94$, $p=.35$) stage of acquisition.

Reponse biases do not appear to have affected the likelihood of Match Task completion. Among all noncompleters, 34 animals completed enough trials to evaluate position biases. Only two of these 34 animals showed a significant response bias, a significantly smaller proportion compared to task completers (X^2=13.41, *p*<.001).

Performance and Participation

Subjects that completed the Match Task participated less frequently in the pre-criterial stage of task acquisition, when performance was low. They participated at a faster rate in the criterial stage, when performance was high. As expected given the definition of the two stages, subjects performed significantly worse in the pre-criterial stage than in the criterial stage, when correction trials were included (*t*(28)=-9.91, *p*<.001, *d*=2.87; pre-criterial *M*=0.47 ± 0.03 *SEM*; criterial *M*=0.78 ± 0.01 *SEM*), and when only first-presentation trials were included (Wilcoxon *Z*=-4.70, *p*<.001, *d*=2.59; pre-criterial *M*=0.48 ± .03 *SEM*; criterial *M*=0.81 ± .002 *SEM).* Subjects averaged longer times between trials in the pre-criterial stage, *t*(34) = 3.96, *p*<.001, *d*=.91 (pre-criterial average elapsed time: *M*=5.55 ± 1.24 *SEM,* criterial average elapsed time: *M*=.80 ± .13 *SEM).*

A comparison of average elapsed times after correct trials and after incorrect trials in both pre-criterial and criterial stages allowed a closer examination of the variation in time between trials, and confirmed that subjects spent more time away from the task after incorrect trials. With the pre-criterial and criteral stages combined, elapsed time after incorrect trials was significantly greater than elapsed time after correct trials, Wilcoxon *Z* = -4.47, *p*<.001, *d*=.91. Separate analyses confirmed that in both stages, the elapsed time after incorrect trials was significantly greater than the elapsed time after correct trials (pre-criterial: Wilcoxon *Z* = -2.89, *p*=.004; criterial: Wilcoxon *Z* = -2.89, *p*=.004). In addition, elapsed time after correct trials and after incorrect trials was significantly reduced in the criterial stage compared to the pre-criterial stage (correct trials: Wilcoxon *Z*=-2.67, *p*=.01; incorrect trials: Wilcoxon Z=-3.80, *p*<.001). Figure 1 displays these comparisons, within and between pre-criterial and criterial stages.

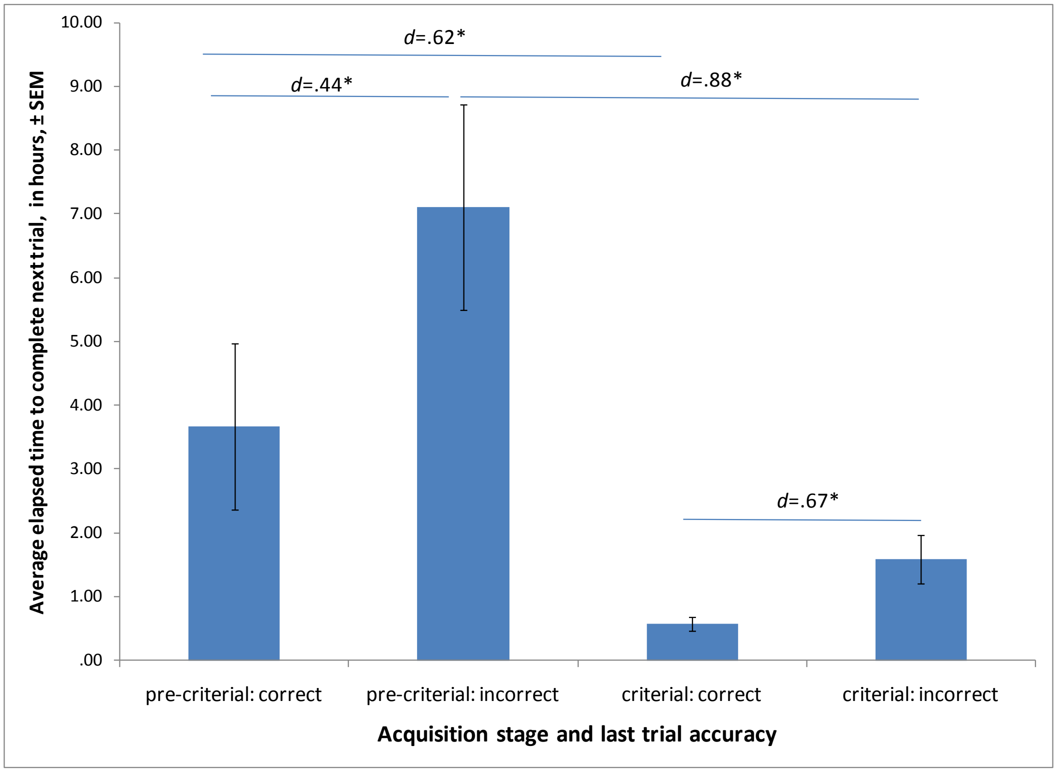


Figure 1: Elapsed times to the next completed trial for Match Task completers, by acquisition stage and previous trial accuracy. Effect sizes are shown for all comparisons of interest, * indicates *p*<.05.

Match Task noncompleters did not spend more time away from the task when trials were incorrect, and breaks between trials overall were much longer. Elapsed times after incorrect and correct trials did not differ significantly, *Z*=-.90, *p*=.37, *d*=.44. As is evident from comparison of Figures 1 and 2, the average elapsed times between trials (natural log transformed) were significantly longer for noncompleters than for completers, *t*(58.91)=11.49, *p*<.001, *d*=2.59. Average elapsed times remained significantly different with longer times for noncompleting animals when only the first 10 trials for each subject were included, $t(76) = 6.56$, $p<.001$, $d=1.48$, natural log transformed data. Noncompleting animals, however, did not differ from completing animals in the proportion of the first 10 trials answered correctly, with correction trials included ($t(76)=-.40$, $p=.69$) or with first-presentation trials only ($t(76) = -1.02$, $p = .31$).

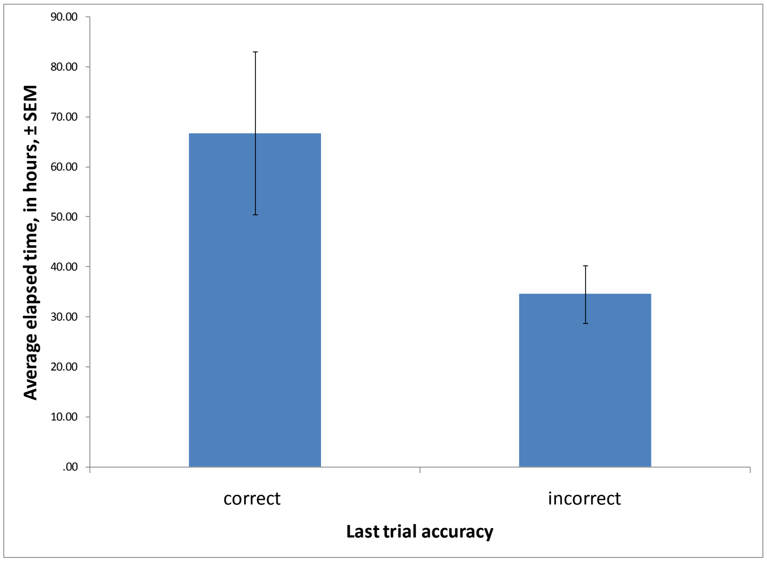


Figure 2: Elapsed times to the next completed trial, by previous trial accuracy, for Match Task noncompleters, all trials.

Participation and Variation in Task Acquisition

Within Match Task completers, performance varied tremendously, even on this relatively simple task. The variation in the number of trials required to enter criterial trials is shown in the histogram in Figure 3.

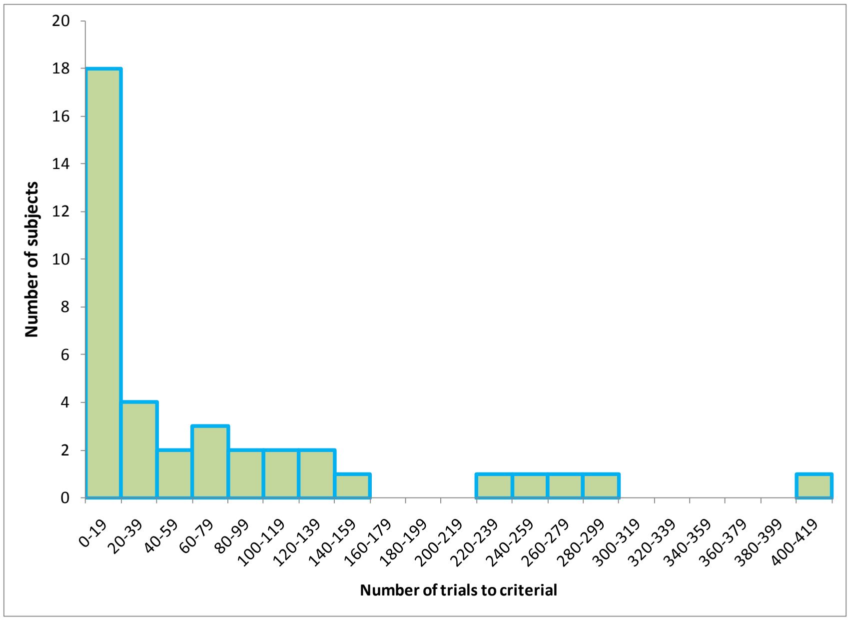


Figure 3: Histogram showing the distribution of subjects by the number of pre-criterial trials required in the Match Task.

To examine this variability, Match Task completers were split into four groups, based on the number of trials that they required to enter criterial trials. Subjects that required very few trials to enter criterial trials were considered a special group, and thus any individuals with 5 or fewer first-presentation pre-criterial trials comprised one group (n=10, actual range: 0-3 trials). The remaining subjects were divided into three groups: 6-24 pre-criterial trials (n=10, actual range: 7-23), 25-99 pre-criterial trials (n=9, actual range: 33-85), and 100 or more pre-criterial trials (n=10, actual range: 103-402). These divisions were selected based on natural break-points. While additional break-points were observed (including at 50 and 200), four groups allowed for at least 9 subjects in each group. Groupings were based on the number of first-presentation pre-criterial trials required to enter criterial trials, but the relationship between the number of first-presentation trials and the number of total trials required to enter criterial trials was very strong, $r_s(35) = .99$, $p<.001$.

As shown in Figure 4, the four pre-criterial trials groups showed substantial within-group variability in pre-criterial time, resulting in no significant differences between groups, $F(3,31)=2.39$, $p=0.09$. A notable exception to this, as seen in the calculated effect sizes shown in Figure 4, was the 0-5 trials group, with very little time between pre-criterial trials for those who had any (four of these subjects had 0 pre-criterial trials). However, a correlation confirmed that requiring fewer pre-criterial trials was not significantly equated with requiring less pre-criterial time, $r(35) = .24$, $p=.17$, Figure 5. Thus, subjects with few pre-criterial trials required comparable pre-criterial time to those subjects requiring more pre-criterial trials. This finding suggested that rate of trial completion should differ between groups.

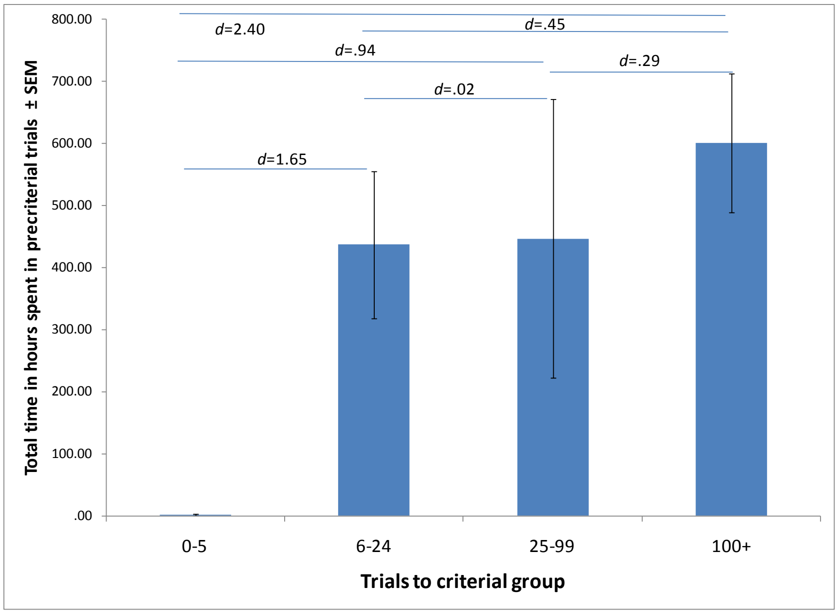


Figure 4: Total cumulative time to criterial trials, by trials to criterial group. Despite the large effect sizes between the 0-5 trials group and all other groups, the omnibus test was not significant.

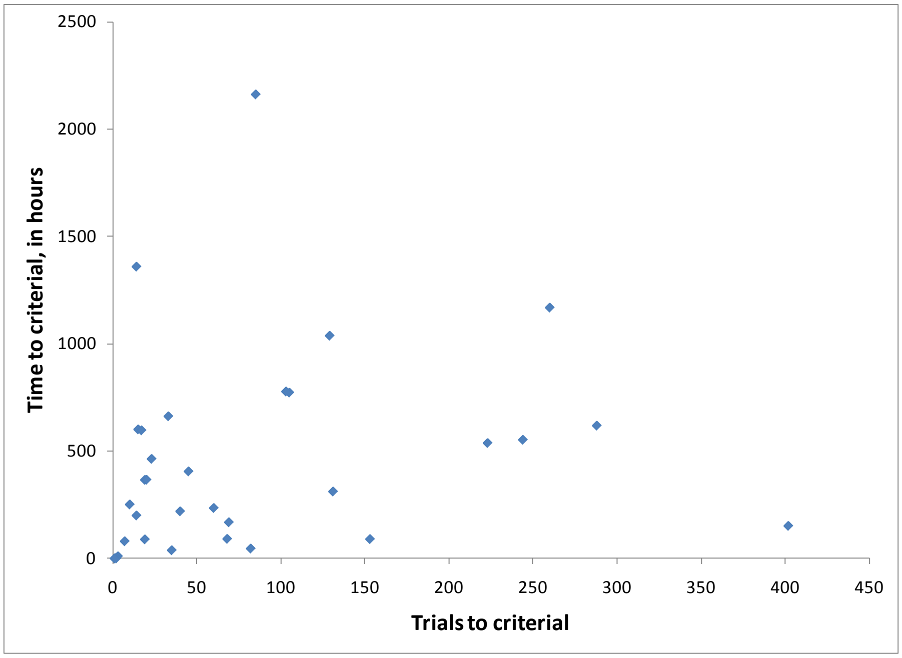


Figure 5: Scatter plot for trials to criterial and time to criterial. There was not a significant relationship between the number of trials and the amount of time required to enter criterial trials.

The variation in the number of trials required to enter criterial trials was not easily explained by position biases, task assignment, or social demographics. The four trials to criterial groups did not significantly differ in the proportion of animals showing significant position response biases, X^2=1.90, d.f.=3, *p*=.59. In addition, the groups did not differ significantly in whether the completed Match Task was of the Clipart Match or the Square Match type, X^2=5.84, d.f.=3, *p*=.12. Given the social demographic effects on participation in the first article, we also examined these variables for the trials to criterial groups. The groups did not differ significantly in age, Kruskal-Wallis *H*(3)=6.58, *p*=.09, or in the distribution of males and females, X^2=3.83, d.f.=3, *p*=.28. Because of the multiple changes in social rank that occurred over the course of the study, rank effects were not formally analyzed, but an examination of the ranks of the completing animals suggested that there was not an effect.

The lack of differences in time to criterial on the Match Task between trials to criterial groups suggested that there were differences between groups in the rate of participation, and analyses of average elapsed times between trials confirmed this. In a repeated-measure analysis with stage (pre-criterial and criterial) as the repeated measure, the average elapsed time between trials showed a significant stage by group interaction, *F*(3,31) = 4.80, *p*=0.01, and the 6-24 pre-criterial trials group differed significantly from all other groups. Figure 6 shows that subjects in the 6-24 trials group showed a much steeper decrease in the average elapsed time between trials from the pre-criterial to the criterial stage.

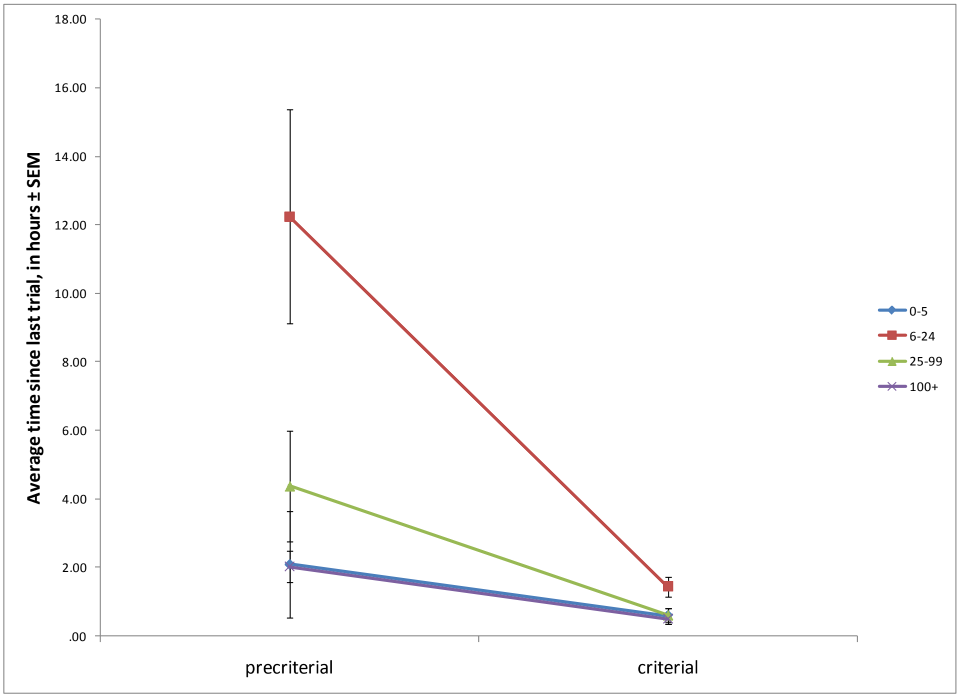


Figure 6: Average time between trials by trials to criterial group, in the pre-criterial and the criterial stages of the Match Task.

The 6-24 trials group differed from other groups in time between trials only in the pre-criterial stage. Analysis of time between trials confirmed that there were differences between groups in the pre-criterial stage, *F*(3,31)=5.86, *p*=.003, with the 6-24 trials group showing longer times between trials compared to all other groups. There were no significant between-group differences for elapsed time between trials in the criterial stage, *F*(3,35)=1.57, *p*=.22.

Elapsed time after incorrect trials appeared to contribute more to overall elapsed time between trial differences between groups than did elapsed time after correct trials. Average elapsed time after incorrect trials showed a significant group by stage interaction, *F*(3,31)=3.90, *p*=.02, and the 6-24 trials group differed significantly from all other groups (Figure 7). In contrast, average elapsed time after correct trials (natural log transformed) did not show a significant group by stage interaction, *F*(2,26)=.50, *p*=.62 (the 0-5 trials group is not represented because none of these animals had correct first-presentation trials in the pre-criterial stage), but there was a significant main effect for change in elapsed time between the pre-criterial and criterial stages, *F*(1,26) = 8.95, *p*=.01, suggesting that times after correct trials decreased for all subjects (Figure 8).

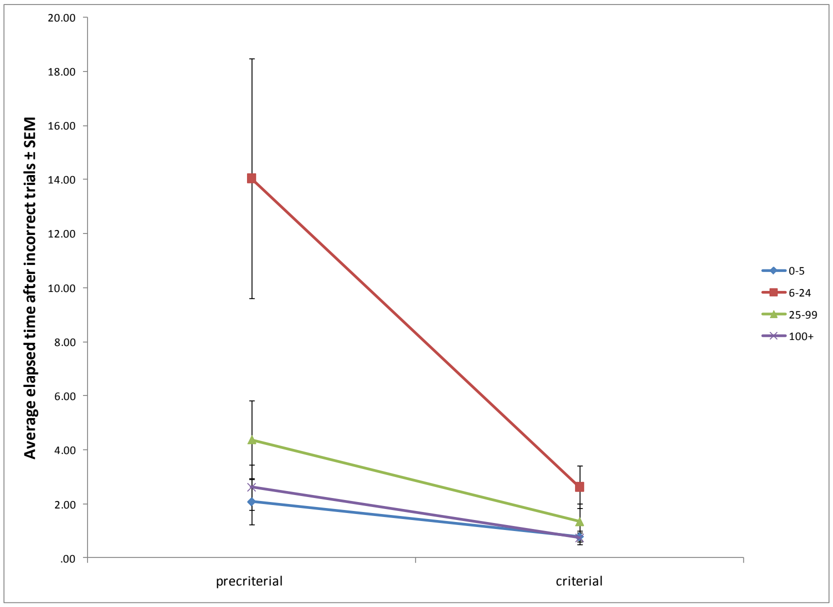


Figure 7: Average elapsed times after incorrect trials by trials to criterial group, in the pre-criterial and the criterial stages of the Match Task.

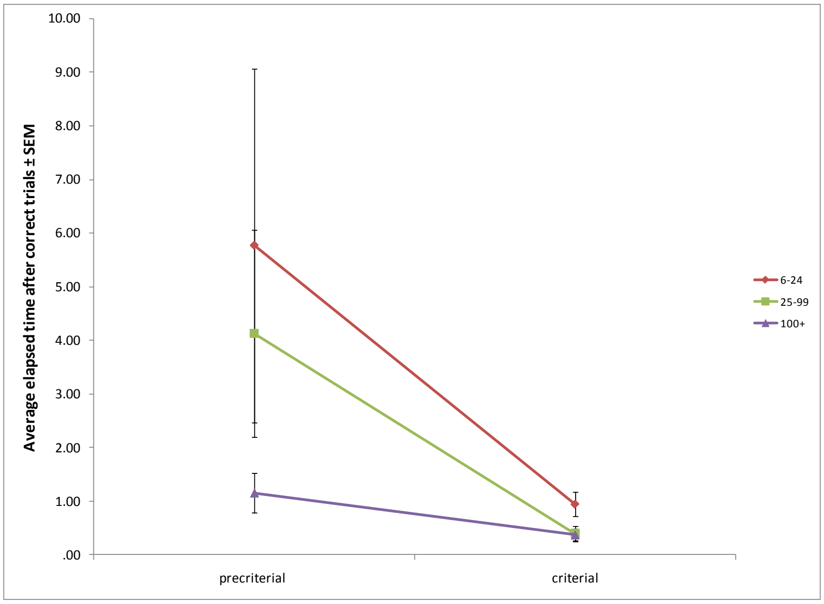


Figure 8: Average elapsed times after incorrect trials by trials to criterial group, in the pre-criterial and the criterial stages of the Match Task. The 0-5 trials to criterial group is not included here because they had no correct pre-criterial trials.

The pattern of results for elapsed times after incorrect and correct trials suggested that the groups differed in the magnitude of the difference for elapsed time after correct trials compared to incorrect trials, and this was confirmed. A repeated measures analysis comparing pre-criterial elapsed time after correct trials and pre-criterial elapsed time after incorrect trials (natural log transformed data for both variables due to skew for average after correct) showed a significant accuracy by group interaction, $F(2,26)=5.08$, $p=.01$, and post-hoc analyses revealed that the 6-24 trials group differed significantly from the 100+ trials group. Calculations of effect sizes for differences in elapsed times for correct and incorrect trials, however, suggested other important differences between the groups, with the 6-24 trials group showing the largest effect, the 25-99 trials group showing only a small effect, and the 100+ trials group showing a large effect, despite lower average times (Figure 9).

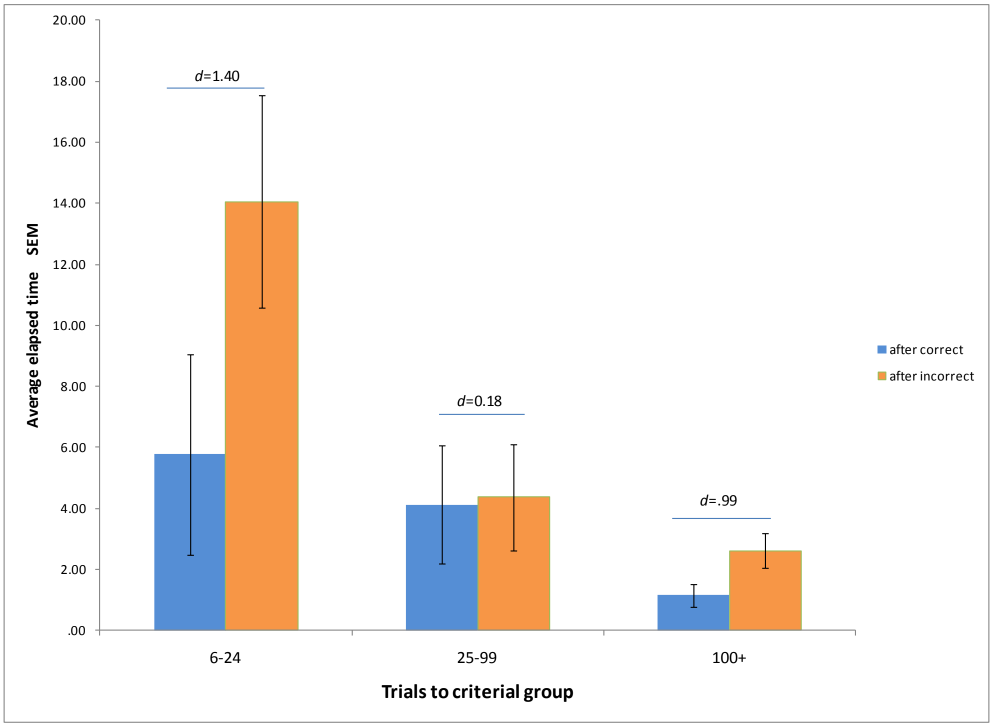


Figure 9: Average elapsed time after correct and after incorrect trials in the pre-criterial stage of the Match Task, by trials to criterial group.

The 6-24 trials group, in addition to taking more time between trials in the pre-criterial stage, showed more dramatic changes in performance between the pre-criterial and criterial stages, and they were joined by the 0-5 trials group in this effect. A repeated measures analysis of proportion correct (correction trials included) between the pre-criterial and criterial stages revealed a significant interaction, *F*(3,31) = 17.56, *p*<.001. Both the 0-5 trials group and the 6-24 trials group differed significantly from each other and from the 25-99 and 100+ groups, showing a steep increase (Figure 10). Repeated-measures analysis was not possible for the first-trial presentation proportion correct data due to unresolved skew even after natural log transformations.

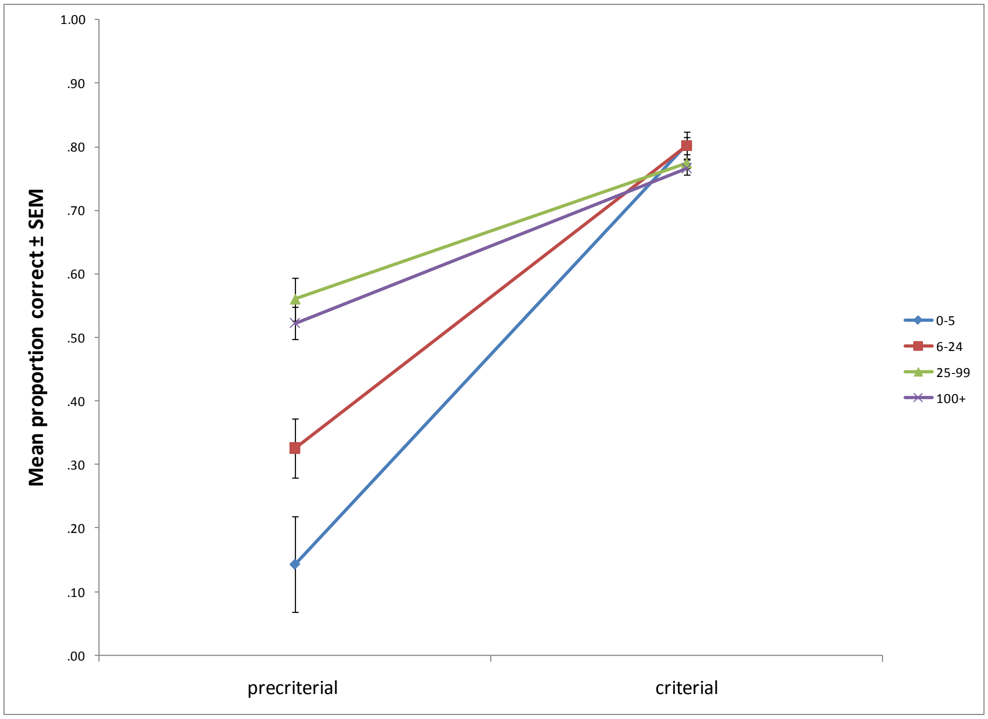


Figure 10: Mean proportion correct by trials to criterial group in the pre-criterial and criterial stages of the Match Task.

A one-way ANOVA (*F*(3,31)=16.80, *p*<.001) confirmed that the 0-5 and 6-24 trial groups performed more poorly on pre-criterial trials than did all other groups These two groups also did better on criterial trials compared to animals requiring 100 or more trials, *F*(3,31) = 2.91, *p*=.048.

Because of the great variation in the number of pre-criterial trials required between these groups, it was important to also conduct analyses on more comparable samples of trials. Did these groups differ significantly on the first 10 trials, or on the final 10 pre-criterial trials? What about the first 10 criterial trials, or the final 10 criterial trials? For these analyses, each block was composed of 10 first-presentation trials, but averages of elapsed times were based on both first-presentation trials and correction trials. Calculations of proportion correct were calculated with and without correction trials. The 0-5 trials to criterial group was not included in analyses of the last 10 pre-criterial trials, due to the extensive overlap between the first 10 trials, last 10 pre-criterial and first 10 pre-criterial.

The primary point of difference between groups for time between trials was at the pre-criterial stage immediately prior to entering criterial trials. The average elapsed time between trials (natural log transformed) did not differ significantly between groups in the first 10 trials, $F(3,35)=2.87$, $p=0.05$. Average elapsed time differed significantly in the last 10 pre-criterial trials, $F(2,26)= 37.95$, $p<.001$, and the 6-24 trials group differed significantly from all other groups. In the first 10 criterial trials, average elapsed time again did not differ significantly between groups, $F(3,35)=2.34$, $p=.09$. In the final 10 criterial trials, the average elapsed time also did not differ significantly between groups, Kruskal-Wallis $H(3)=2.05$, $p=.56$. Figure 11 shows means for each group at each stage.

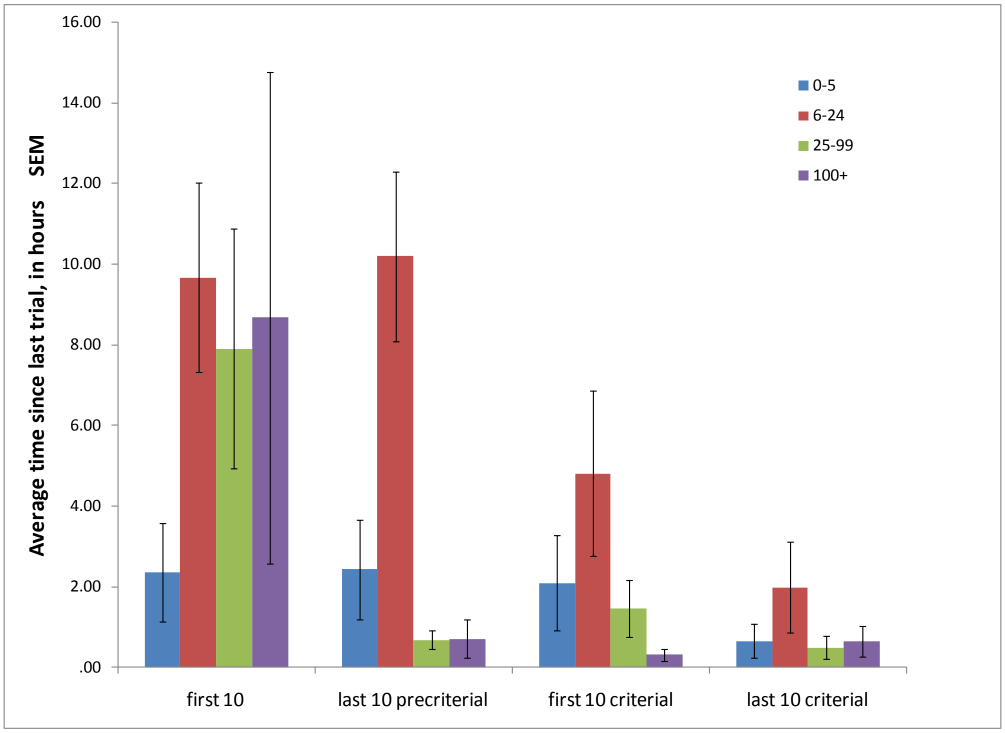


Figure 11: Average time between trials, 10 trial blocks and trials to criterial groups in the Match Task. While last 10 pre-criterial means are shown for the 0-5 trials group, this group was not included in analyses of the last 10 pre-criterial trials.

Elapsed times after incorrect trials showed more persistent differences between groups. In the first 10 trials, the groups differed significantly in elapsed time after incorrect trials, *F*(3,35)= 4.48, *p* =.01. The 6-24 trials group averaged significantly longer times after incorrect trials compared to the 0-5 group and the 25-99 group, but not compared to the 100+ group. In the last 10 pre-criterial trials, the omnibus test was significant, *F*(2,26) = 35.67, *p*<.001, and the 6-24 trials group averaged significantly longer times after incorrect trials compared to all other groups. In the first 10 criterial trials, there remained significant differences between groups, Kruskal-Wallis *H*(3)=8.25, *p*=.04, with the 6-24 trials group averaging longer times after incorrect trials compared to the 100+ group only. In the final 10 criterial trials, there were no significant differences between groups for average elapsed time after incorrect trials, Kruskal-Wallis *H*(3)=.02, *p*=.99. Figure 12 shows the means for elapsed time after incorrect trials in each 10-trial block. The pattern of these results indicates that the 6-24 trials group was consistently slower to complete the next trial after an incorrect trial compared to other groups. Only at the end of criterial trials did they not differ in elapsed time after incorrect trials.

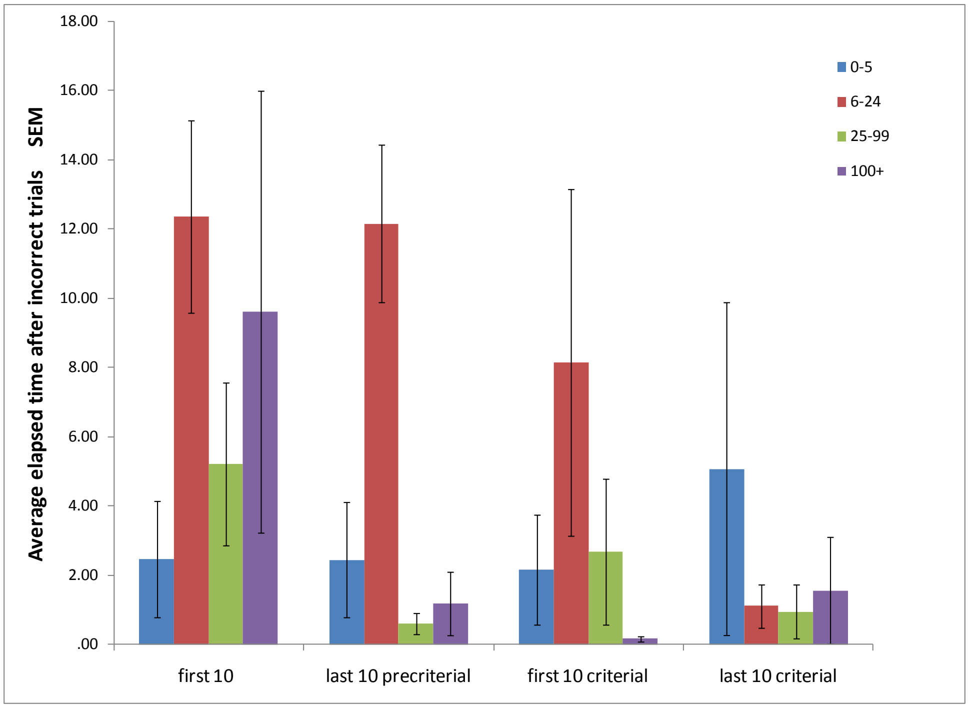


Figure 12: Average elapsed time after incorrect trials, 10 trial blocks and trials to criterial groups. While last 10 pre-criterial means are shown for the 0-5 trials group, this group was not included in analyses of the last 10 pre-criterial trials.

In contrast to elapsed times after incorrect trials, elapsed times after correct trials did not distinguish between groups in any stage. Unresolved skew for average after correct trials in all blocks required the use of Kruskal-Wallis tests to compare groups. There were no significant differences between groups for any of the four stages (First 10:

H(3)=2.99, p=.39; Last 10 pre-criterial: H(2)=3.71, p=.16; First 10 criterial: H(3)=5.10, p=.17; Last 10 criterial: H=2.52, p=.47).

As in the findings for time between trials, the primary point of difference between groups for proportion correct was in pre-criterial trials immediately prior to entering criterial trials. The 0-5 trials group performed more poorly in the first 10 trials compared to all other groups, though most of the first 10 trials were criterial trials for these subjects. The proportion of correctly completed trials did not differ significantly in the first 10 trials when correction trials were included in the proportion correct calculation, $F(3,35)=1.91$, $p=.15$, but differed significantly between groups when correction trials were not included, $F(3,35)=3.46$, $p=.03$. Only the 0-5 trials group differed significantly from the 6-24 and 100+ groups, with a significantly higher proportion of the first 10 trials answered correctly. The proportion of correctly completed trials differed significantly between groups in the last 10 pre-criterial trials, whether correction trials were included ($F(2,26)=35.67$, $p<.001$) or not included ($F(2,26) = 6.81$, $p=.004$), and in both cases the 6-24 trials group performed more poorly than the 25-99 and 100+ pre-criterial trials groups. In the first 10 criterial trials, the proportion of correctly completed trials did not differ significantly between groups, for either calculations with correction trials ($F(3,35)=1.71$, $p=.18$), or for calculations without correction trials ($F(3,35)=.64$, $p=.59$). For the final 10 criterial trials, again no differences were found, with correction trials included ($F(3,35)=.54$, p=.66), or without ($F(3,35)=.84$, $p=.48$). Figure 13a shows proportion correct means, without correction trials, for each trials to criterial group and each block, and Figure 13b shows proportion correct means with correction trials included. Table 1 summarizes the omnibus tests comparing groups on the elapsed time and proportion correct variables.

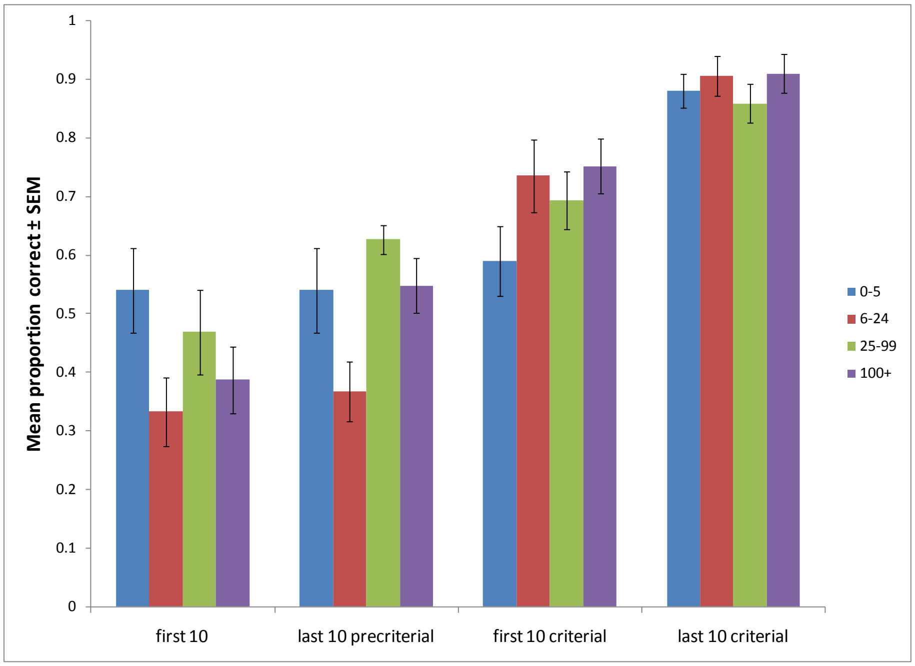


Figure 13a: Average proportion correct, correction trials not included, 10 trial blocks and trials to criterial groups for the Match Task. While last 10 pre-criterial means are shown for the 0-5 trials group, this group was not included in analyses of the last 10 pre-criterial trials.

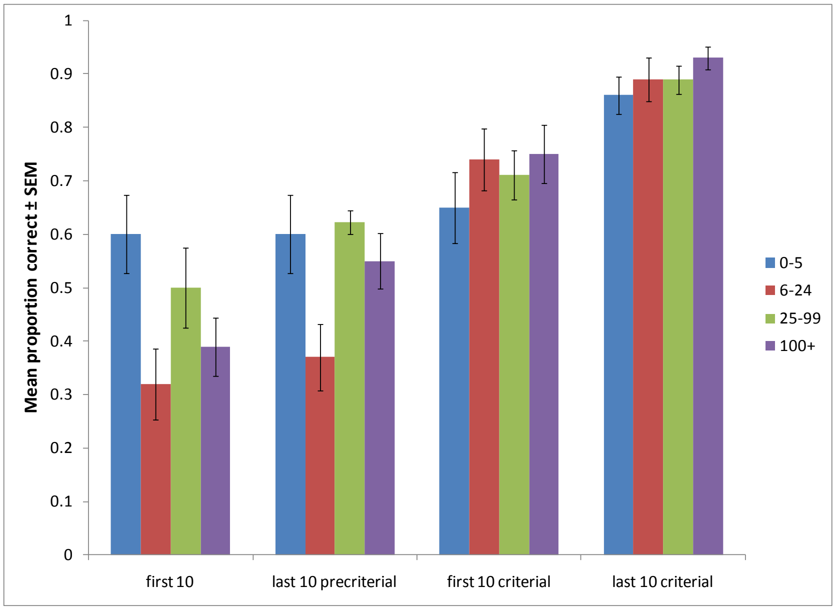


Figure 13b: Average proportion correct, correction trials included, 10 trial blocks and trials to criterial groups for the Match Task. While last 10 pre-criterial means are shown for the 0-5 trials group, this group was not included in analyses of the last 10 pre-criterial trials.

		First 10 trials	Last 10 pre-criterial trials (0-5 not included here)	First 10 criterial trials	Last 10 criterial trials
average elapsed time between trials (all types)	Omnibus result	Not significant	Significant	Not significant	Not significant
	post-hoc results		6-24 group shows longer elapsed times between trials compared to all other groups		
average elapsed time after incorrect trials	Omnibus result	Significant	Significant	Significant	Not significant
	post-hoc results	6-24 group shows longer elapsed times after incorrect trials compared to 0-5 or 25-99 group	6-24 group shows longer elapsed times after incorrect trials compared to all other groups	6-24 group shows longer elapsed times after incorrect trials compared to 100+ group	
average elapsed time after correct trials	Omnibus result	Not significant	Not significant	Not significant	Not significant
	post-hoc results				
proportion correct, all completed trials	Omnibus result	Not significant	Significant	Not significant	Not significant
	post-hoc results		6-24 group answers significantly less correct than 25-99 or 100+ groups		
proportion correct, first-presentation trials only	Omnibus result	Significant	Significant	Not significant	Not significant
	post-hoc results	0-5 group answers significantly more correct than 6-24 or 100+ groups	6-24 group answers significantly less correct than 25-99 or 100+ groups		

Table 1: Summary of comparisons between trials to criterial groups for elapsed time and proportion correct variables by 10 trial blocks at four stages of acquisition in the Match Task.

To better illustrate the learning curves of these groups in the Match Task, Figure 14 shows proportion correct data for the first eight blocks of 10 trials, and Figure 15 shows average time between trials data for the first eight blocks.

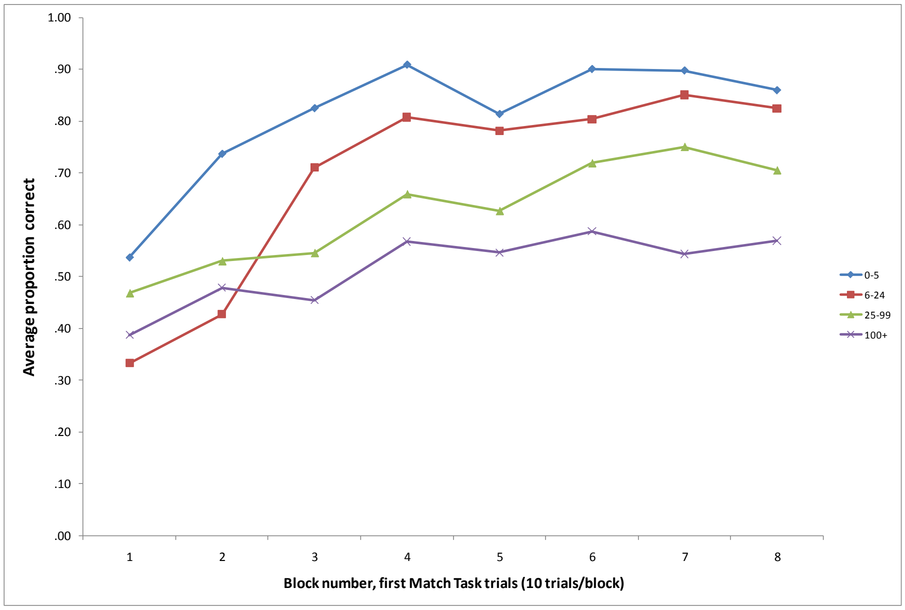


Figure 14: Average proportion correct, first-presentation trials only, by 10-trial block and trials to criterial group. The first 80 trials of the Match Task are shown.

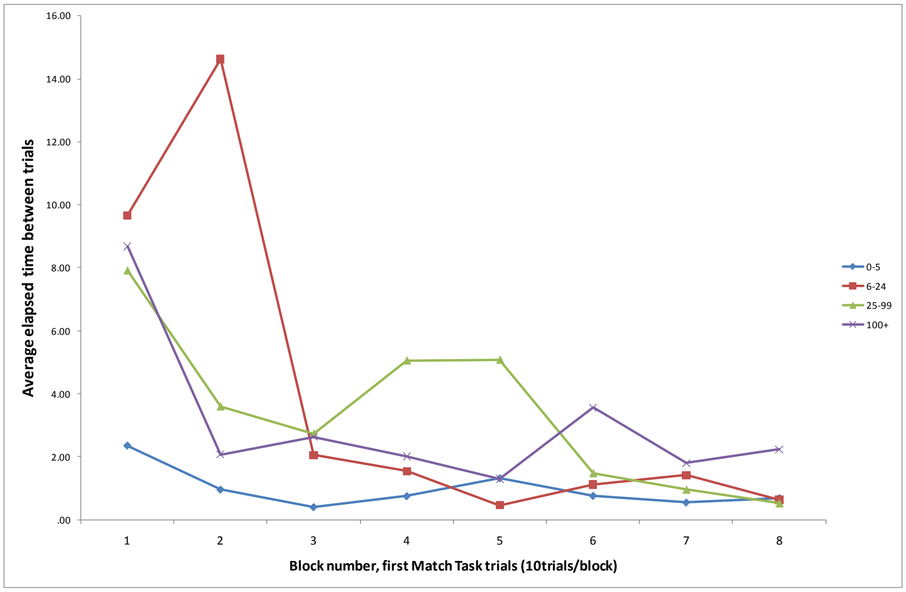


Figure 15: Average time between trials, by 10-trial block and trials to criterial group. The first 80 trials of the Match Task are shown.

Trials to criterial groups and patterns of early trial accuracy

While the 6-24 trials group did not differ from the 25-99 and 100+ groups in the proportion of correctly completed trials in the first 10 trials of the Match Task, they did differ in the maximum number of consecutive incorrect trials in the first 10 trials, *F*(3,35)=3.80, *p*=.02. Post-hoc tests confirmed that the 6-24 trials group completed significantly more consecutive incorrect trials in the first 10 trials compared to all other groups (Figure 16). This difference was not related to accuracy on the first trial of the task. The first trial for 18 of the 39 Match Task completers was correct, but these 18 individuals were evenly distributed among the trials to criterial groups, X^2=2.79, d.f.=3, *p*=.43.

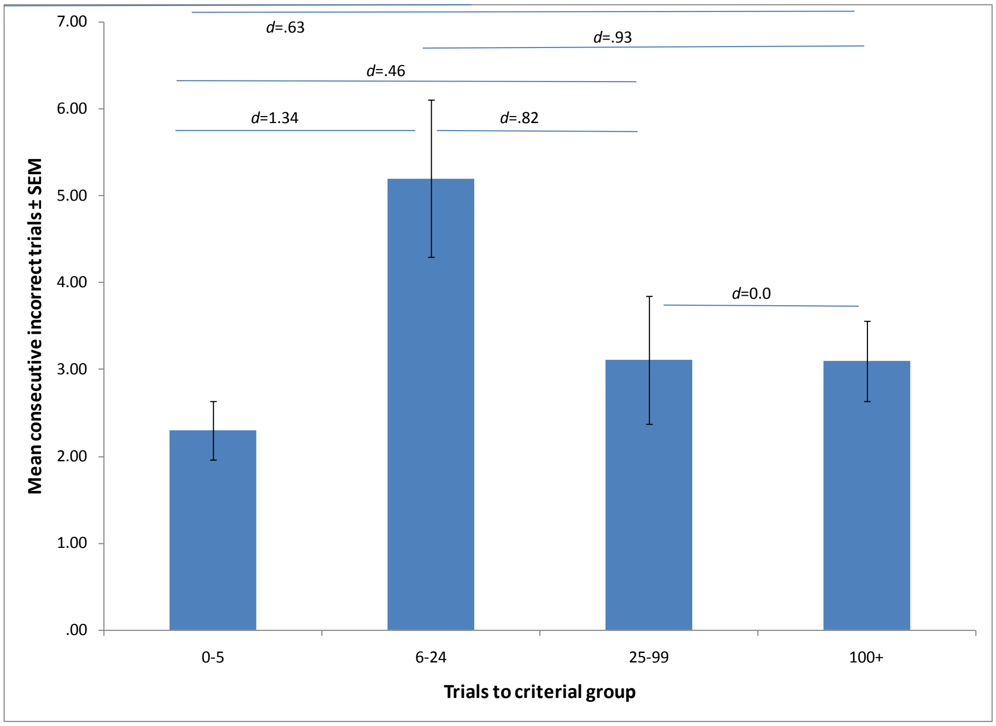


Figure 16: Average consecutive incorrect trials in the first 10 trials of the Match Task, by trials to criterial group.

Social observation

Some animals had time in group before being provided with experimenter access to the kiosk, and thus these animals had greater potential “observation time”. The trials to criterial groups did not differ in the days available to observe, Kruskal-Wallis *H*(3) = 7.36, *p*=.06. Since this effect was close to significance, effect sizes were calculated and revealed large effects, with particularly few potential observation days in the 6-24 trials group. Means and effect sizes are shown in Figure 17.

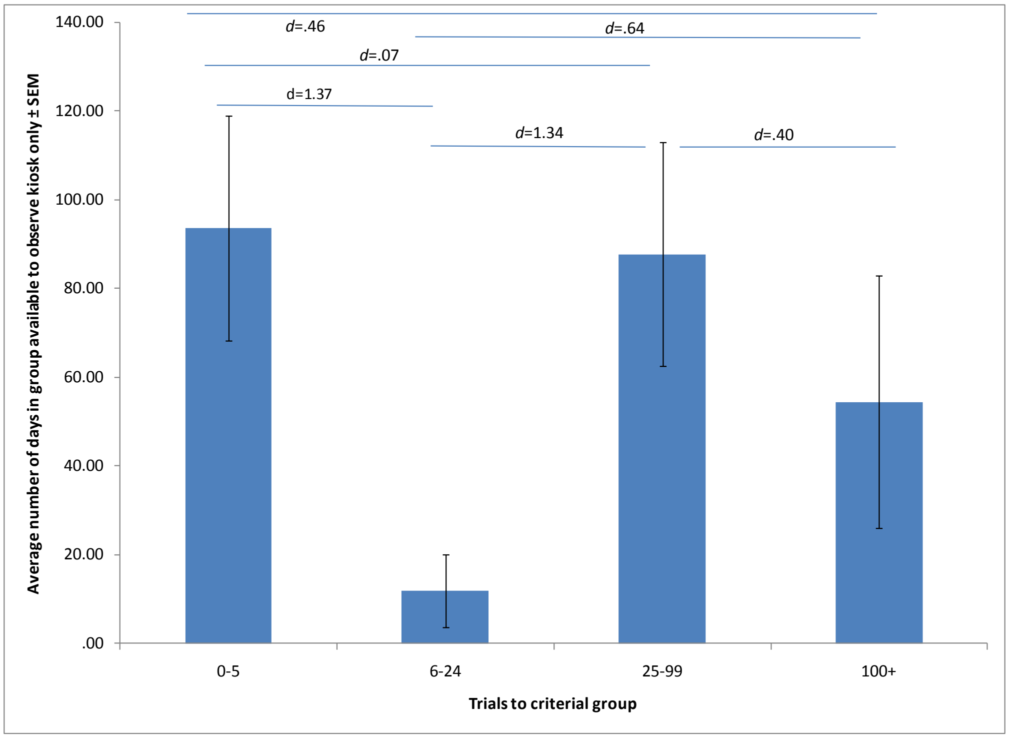


Figure 17: Average number of days in the group able to observe but not complete trials at the kiosk, by trials to criterial group.

Trials to criterial groups: previous and subsequent participation

In the manipulation which returned Match Task completers to 50 Squaretouch trials, time between trials did not differ significantly between trials to criterial groups, *F*(2,13)=3.61, *p*=.06 (No subjects from the 25-99 trials group remained in the social group, thus the ANOVA was completed with the three remaining groups). However, based on this small *p*-value, effect sizes were calculated. As Figure 18 shows, there were large effects, even in this limited sample, between the 0-5 trials group and the 6-24 and 100+ trials groups, indicating some stability across tasks in differences between groups, though for all subjects these trials were completed very quickly. Participation rates of these same animals on their initial exposure to the Squaretouch task were also analyzed, but there were no significant differences between trials to criterial groups, F(2,13) = .27, p=.77 (natural log transformed), and effect sizes were small (Figure 18).

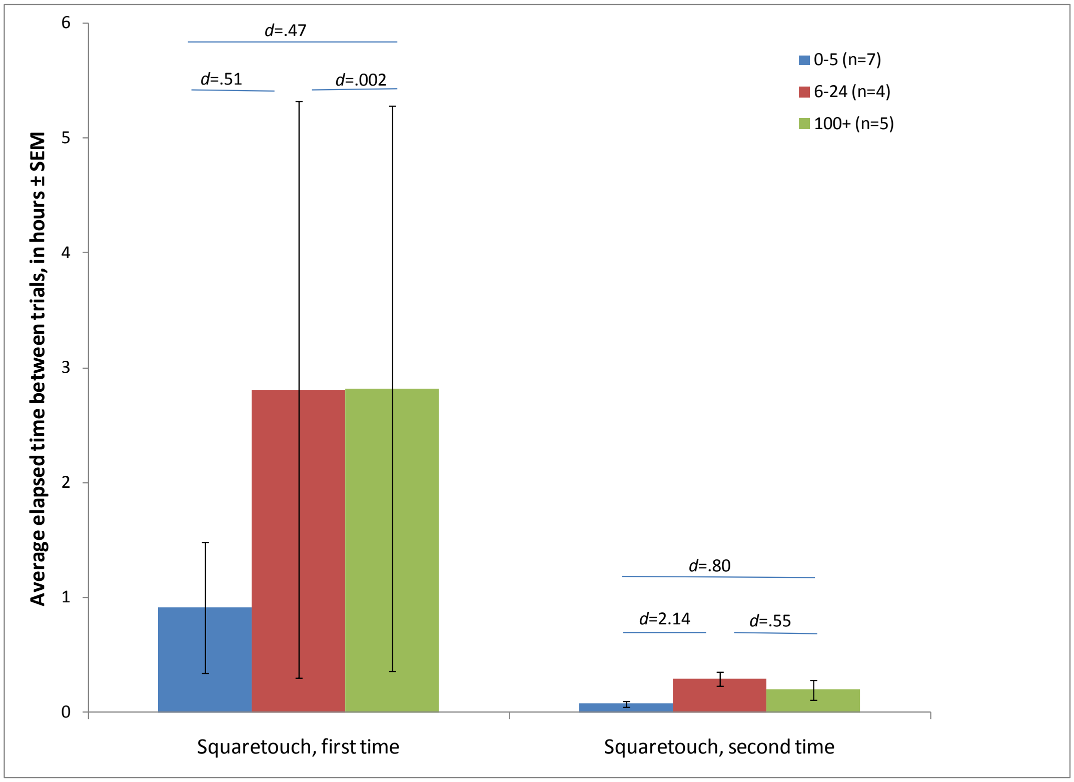


Figure 18: Average time between trials by trials to criterial group for the Squaretouch task, the first time the subjects received the task as part of Touch Training, and the second time the subjects received it, after completion of the Match Task.

After meeting criterion on the Match Task, subjects in the 6-24 trials group showed a slower participation rate in their next task, Match to Sample with one distractor. There was a significant difference between Match Task trials to criterial groups in the average elapsed time between trials in the first attempt at this task (*F*(3,35)=4.90, *p*=.01, and the 6-24 group differed significantly from the 0-5 and 25-99 groups (Figure 19). There were no differences in the proportion of correct trials, whether correction trials were included (*F*(3,35)=.45, *p*=.72) or not (*F*(3,35)=1.52, *p*=.23), and all subjects failed the first attempt at the task. Analyses of the number of trials to enter criterial trials was not possible by group because only one subject from the 6-24 trials group and one subject from the 100+ trials group met criterion on this task. Five subjects from the 0-5 trials group and 3 subjects from the 100+ trials group also met criterion on the task, but these differences between trials to criterial groups in numbers of subjects meeting and failing to meet criterion did not meet significance (X^2=6.84, *p*=.08). The Match Task completers did not differ by group in the total number of levels passed, Kruskal-Wallis *H*(3)=4.18, *p*=.24, or in the total number of trials completed, Kruskal-Wallis *H*(3)=3.65, *p*=.30.

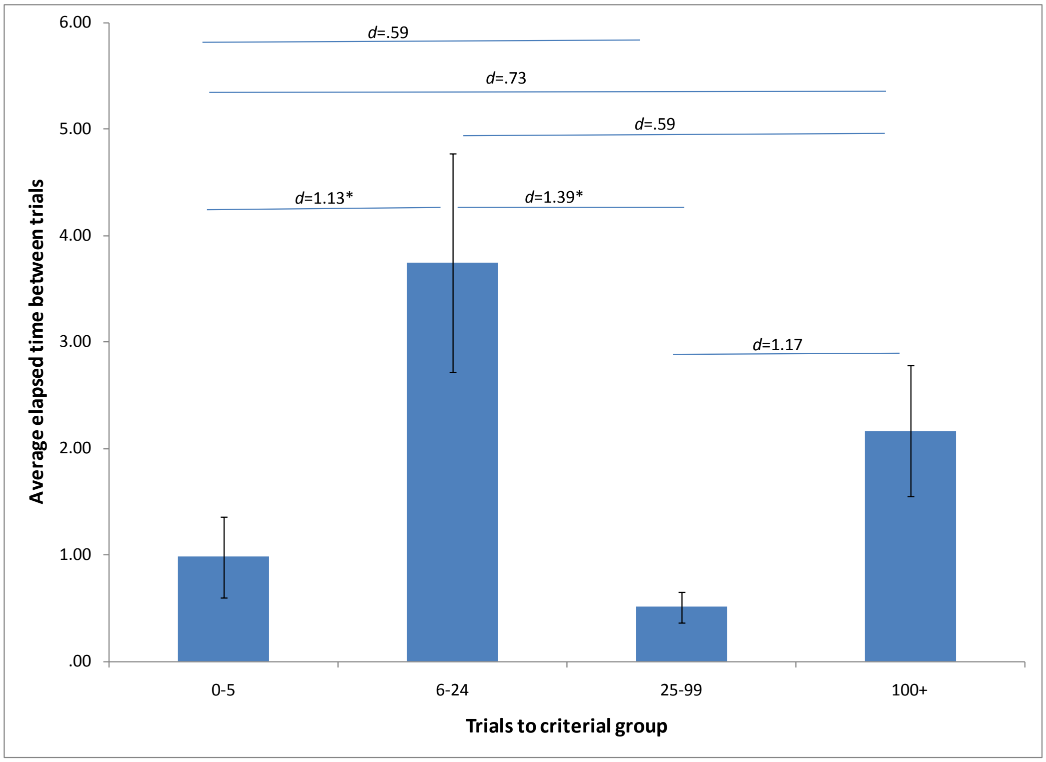


Figure 19: Average time between trials for the first attempt at Match to Sample with one distractor, by Match Task trials to criterial group. * indicates *p*<.05 in post-hoc tests.

Discussion

The results of this study supported our hypothesis that performance and participation would be positively related. Subjects spent approximately six times longer between trials in the pre-criterial stage than in the criterial stage, and, as expected, their performance was significantly worse in the pre-criterial stage.

In relation to accuracy of the last completed trial, a relationship between performance and participation was also supported. When the most recently completed trial was incorrect, subjects took significantly more time to complete the next trial relative to when their last completed trial was correct. Thus, when they answered a trial correctly, subjects were more likely to keep working or to return to work sooner. When they answered a trial incorrectly, they were more likely to stop working and to stay away for longer.

Interestingly, animals that never completed the Match Task did not show this same relationship between elapsed time after incorrect versus correct trials. Overall, they allowed significantly more time to pass between trials than did the completing animals, though they did not perform more poorly on the trials that they did complete when compared to the early trials of completing animals. These findings suggest that the noncompleting animals were not motivated to work in the same way that the completing animals were. The findings of the accompanying article suggest that much of the difference in motivation may lie in the age difference between completing and noncompleting animals, but some noncompleting individuals were as young as completing subjects. Thus, motivation differences likely exist even in young subjects.

The relationship between performance and participation is often related to self-efficacy in studies of human learning (Bandura & Schunk, 1981; Niemivirta & Tapola, 2007). Because of its focus on goal orientation, self-efficacy is difficult to apply to our monkey subjects, who likely don’t have a sense of the “goal” of a task in the same way that humans often do. Instead, this relationship might be more readily described in terms of an ability to exert control over the environment in a predictable way. When subjects are first learning a task, their control over whether they obtain a pellet likely seems unrelated to their actions. However, as they learn the task, obtaining a pellet becomes more strongly associated with their actions, making them more inclined to participate consistently.

In the second part of this study, we examined variability in acquisition of the Match Task. With our subjects split into four groups based on the number of trials they required before entering criterial trials, we found that subjects that entered criterial trials after relatively few trials performed more poorly in pre-criterial trials compared to subjects that took many trials to enter criterial trials. The subjects in the 0-5 pre-criterial trials group did not take more time between pre-criterial trials, and it seems likely that from their initial incorrect responses, they quickly learned the “rule” of the task from those early trials, increasing their correct responses with little or no backsliding. Thus these animals used the information obtained from their performance to move quickly into criterial trials. Subjects in the 6-24 trials group differed from the 0-5 pre-criterial trials group and other groups in many ways. They took more time between pre-criterial trials, but only when the previous trial was answered incorrectly. Analysis of their early trials revealed that this group responded incorrectly on more consecutive trials than other groups, though they did not differ in the overall proportion correct in these trials. Thus, it seems possible that this difference, perhaps best described as an aversion to incorrect trials, which may have resulted from their persistent incorrect responses early on, helped these animals enter criterial trials in a smaller number of trials. With their low pre-criterial performance and high numbers of consecutive incorrect trials, the subjects in this group were somewhat fixated on touching the sample image rather than the new target image in the Match Task trials. After time away from the task – an incubation period - these animals returned to show dramatically improved performance. In contrast, subjects in the 25-99 and 100+ groups appear to have adopted a different approach. Relatively soon after starting the Match Task, subjects in these groups started completing trials relatively quickly, resulting in less time between trials overall in the pre-criterial stage. Their breaks after correct and incorrect trials did not differ dramatically. They never showed dramatic improvements in performance between blocks, but instead hovered near chance, eventually improving enough to enter criterial trials.

These findings relate to the incubation literature. Incubation has been shown to be effective in problem-solving only when fixation on an incorrect solution occurs. Thus, if the solution is seen immediately, as in the 0-5 trials group described here, no incubation is needed (Smith & Blankenship, 1991). If the solution is not seen immediately, then incubation can lead to discovery of the solution more effectively than persisting with attempts at finding a solution (Smith & Blankenship, 1991). This appears to have been the case for subjects in the 6-24 trials group. Whether subjects in the 25-99 or 100+ trials groups would have benefitted similarly from longer breaks between trials is unknown. Manipulations could impose a break on animals that complete trial after trial at a low level of performance, but studies of incubation effects have also shown that incubation is more effective when individuals take breaks when they choose, rather than being interrupted (Beeftink et al., 2008).

Interpretation of these findings requires some consideration of this task from the monkey’s perspective. The Match Task was the first task in which subjects could make an incorrect response. Previously, all that was required was a specific touch to a single image. In the Match Task, only a touch to the first image, followed by a touch to the new second image, would result in a pellet reward. Touches to the original image or the failure to emit a second touch would result in no reward, a different sound, and a longer inter-trial interval.

The criterion set by the experimenter of any 80 correct trials out of 100 is cryptic to the subject and would hold no meaning if they did know it. Their primary motivation had nothing to do with criterion, and, presumably, everything to do with obtaining pellet rewards. To these animals, the results of an incorrect trial may have at first seemed random – sometimes they got a pellet, and sometimes they did not. Thus, they had to learn that the events of an incorrect trial were related to their actions. Furthermore, the task was simple and subjects had a fifty percent chance of achieving a correct response without actually understanding the task, and thus this chance rate of return may have been sufficient for many subjects, particularly if they hadn't learned that it is possible to get many more rewards if they solved the task. Many of the animals in the 25-99 and 100+ groups likely performed at levels significantly higher than chance well before they entered criterial trials. Because they were not food deprived and could leave at any time to obtain food from other sources or to engage in other activities, their motivation to obtain as many food rewards as possible likely differed from the motivation of a monkey in a more traditional testing environment. This is consistent with the findings of Taffe (2004), in which laboratory monkeys allowed to feed ad libitum performed significantly more poorly compared to when they were restricted to 85% of maintenance levels

The performance of these different groups might be summarized in the following way. For those taking 0-5 trials to enter criterial trials, they got a few trials wrong, and immediately discovered what they had to do to avoid incorrect responses. For those taking 6-24 trials, they got trials wrong, they didn't particularly like some aspect of incorrect trials (not obtaining food, the associated sound, or the delay to the next trial), and they took longer breaks. When they returned to the task, they were able to overcome their previous fixation on the sample image, leading to a substantial and immediate improvement in their performance. Animals that required more pre-critierial trials also got trials wrong, but did not make the connection between their behavior and incorrect trials. However, they found that if they did a lot of trials, they could still get many pellets, satisfying their primary motivation. They eventually reached criterion, more or less by chance, or they accidently discovered the solution. These differing approaches suggest that monkeys may bring different styles of learning to even simple tasks – though the task is not so simple when considered from the monkey's perspective and its lack of previous experience with such contingencies. Whether these different styles reflect a trait of the monkeys, or result from random processes reflecting the initial trials is the subject of further investigation.

These findings must be interpreted with some caution, as they come from only one group of animals for performance on a single task, and no manipulations were completed to test these findings in greater depth. However, analysis of the next stage of training revealed that the 6-24 trials group again showed longer times between trials compared to the 0-5 trials and 25-99 trials groups, suggesting the possibility that subjects applirf their prior strategy to a new task. The groups did not appear to differ in task motivation during touch training, when incorrect trials were not possible, as in the square touch task completed immediately before the Match Task. Analysis of the rate of trial completion in this stage revealed no differences between the groups. When the square touch task was repeated for the subset of animals remaining on the social group, no significant differences emerged, but large effect sizes for faster completion times in the 0-5 trials group and slower times in the 6-24 trials group suggested that subjects in the 0-5 group may have been more motivated by the pellet rewards than subjects in the 6-24 trials group.

Given the complex social context in which these animals were tested, additional variables were examined in an attempt to understand differences between subjects. In this study we reported a nonsignificant effect between groups for available time to observe other animals before being allowed access to kiosk testing. The lack of effect is not surprising, given the limits of our approximation of opportunity to observe others. However, the effect sizes between groups were large, suggesting that an examination of actual observation or proximity to the kiosk while others complete trials might reveal significant effects in future studies. Possibly, subjects in the 0-5 trials group took advantage of observation opportunities more than subjects in the 25-99 and 100+ trials groups, leading the their fast mastery of the Match Task.

The behavioral responses of study subjects to trial outcomes would also be interesting to document. Anecdotally, a variety of behaviors were observed while animals completed trials at the kiosk, including self-scratching, brief visits to mothers on the kiosk perch, turning briefly away from the kiosk, and chasing and threatening others. Potentially, these behaviors occurred more often when a subject was performing poorly, which would suggest that subjects have an affective response to their performance.

If motivation is linked with performance, how can we maintain participation of subjects in a self-regulated learning context? The findings here suggest that very incremental training may be important. However, such incremental training raises questions of what the animals are actually learning – are they learning a concept and making conceptual “leaps”, or are they simply shaped to perform at high levels with little understanding of what they are doing? Attempts to maintain participation of the majority of subjects may also wash out important individual or group differences in motivation or in the capacity to learn. One approach to this dilemma is to use a simple touch to allow and animal to ”work” for its daily food ration and intersperse more complex tasks for highly palatable rewards throughout the day. We are currently investigating this approach of cognitive testing becoming an integral part of daily feeding. It holds promise of addressing the problem of differential motivation between voluntary subjects.

Motivation might also be influenced in self-regulated learning contexts through the use of stimuli which are interesting to the subjects. The stimuli in this study were not particularly interesting – blue or black and white images. However, if testing stimuli or stimuli associated with rewards are themselves interesting to the subjects – even or perhaps especially if they appear only occasionally – motivation to participate may be more easily maintained. Interest in different kinds of visual and auditory stimuli could be tested using a preference paradigm on a computerized testing system prior to selecting stimuli. For better comparisons to traditional learning studies, the kiosk system could be used within a social group to examine learning of visual discrimination tasks and of learning set formation within these tasks. Use of the progressive ratio schedule task, in which the number of operant responses required to obtain a food reward increases with each trial (Taffe, 2004), would allow for a baseline measure of motivation in all subjects.

What do these findings mean for our understanding of learning? If we imagine these same subjects tested individually in a more traditional cognitive testing environment, how might they behave? The subjects that would likely show the greatest difference in participation are those in the 6-24 trials group, but it is hard to predict the direction of change in their responding. When faced with incorrect trials and no other activities to engage in, they might increase their rate of responding, showing persistent perseverance errors and requiring more trials to acquire the task. Alternatively, if the incorrect trials are truly aversive, they might stop responding altogether. The direction of change may depend on the specific parameters of the testing situation – the nature of food deprivation, the kinds of rewards they receive, the duration of the testing session, the availability of alternative activities, and whether a session is ended if they stop responding.

To our knowledge, this is the first suggestion of an incubation effect in animal learning. Regardless of whether the incubation effect is real, the data suggest that rate of participation in testing is a meaningful measure. Moreover, when subjects have broad control over their participation, multiple effective strategies can emerge. More research is needed, but the findings imply that it may not always be desirable for studies of learning to attempt to maximize response rates in subjects, such as through manipulations of reinforcement schedules, food deprivation, or restriction of available activities. In addition, even in more controlled environments, variation in participation rates within and between subjects could help us understand differences in approaches to learning. Attention to self-regulated rate as an important variable in learning could contribute to our understanding of alternative learning approaches in child and adult education which emphasize self-directed learning and internal motivations (Rathunde & Csikszentmihalyi, 2005). For as long as the learner is restricted in its choices, the application of learning research to self-directed learning will be restricted in its implications.

References

Artino, A. R., & Stephens, J. M. (2009). Academic motivation and self-regulation: A comparative analysis of undergraduate and graduate students learning online. *Internet and Higher Education, 12*(3-4), 146-151.

Bandura, A., & Schunk, D. H. (1981). Cultivating competence, self-efficacy, and intrinsic interest through proximal self-motivation. *Journal of Personality and Social Psychology, 41*(3), 586-598.

Beeftink, F., van Eerde, W., & Rutte, C. G. (2008). The Effect of Interruptions and Breaks on Insight and Impasses: Do You Need a Break Right Now? *Creativity Research Journal, 20*(4), 358-364.

Bown, N., Read, D., & Summers, B. (2003). The lure of choice. *Journal of Behavioral Decision Making, 16*, 297-308.

Catania, A. C., & Sagvolden, T. (1980). Preference for choice over forced choice in pigeons. *Journal of the Experimental Analysis of Behavior, 34*, 77-86.

Harlow, H. F. (1949). The formation of learning sets. *Psychological Review, 56*(1), 51-65.

Hayes, K. J. (1953). The backward curve: a method for the study of learning. *Psychological Review, 60*(4), 269-275.

Inglis, I. R., Forkman, B., & Lazarus, J. (1997). Free food or earned food? A review and fuzzy model of contrafreeloading. *Animal Behaviour, 53*, 1171-1191.

Leotti, L. A., Iyengar, S. S., & Ochsner, K. N. (2010). Born to choose: the origins and value of the need for control. *Trends in Cognitive Sciences, 14*(10), 457-463.

Lepper, M. R., Corpus, J. H., & Iyengar, S. S. (2005). Intrinsic and extrinsic motivational orientations in the classroom: Age differences and academic correlates. *Journal of Educational Psychology, 97*(2), 184-196.

Meyer, D. R. (1951). Food deprivation and discrimination reversal learning by rhesus monkeys. *Journal of Experimental Psychology 41*(1), 10-16.

Neuringer, A. J. (1969). Animals respond for food in the presence of free food. *Science, 166*(3903), 399-401.

Niemivirta, M., & Tapola, A. (2007). Self-efficacy, interest, and task performance: Within-task changes, mutual relationships, and predictive effects. *Zeitschrift Fur Padagogische Psychologie, 21*(3-4), 241-250.

Nistor, N., & Neubauer, K. (2010). From participation to dropout: Quantitative participation patterns in online university courses. *Computers & Education, 55*(2), 663-672.

Noe, R. A., Tews, M. J., & Dachner, A. M. (2010). Learner engagement: A new perspective for enhancing our understanding of learner motivation and workplace learning. *The Academy of Management Annals, 4*, 279-315.

Rathunde, K., & Csikszentmihalyi, M. (2005). Middle school students' motivation and quality of experience: a comparison of Montessori and Traditional School Environments. *American Journal of Education, 111*(3), 341-371.

Shockley, K. M., & Allen, T. D. (2010). Investigating the missing link in flexible work arrangement utilization: an individual difference perspective. *Journal of Vocational Behavior, 76*, 131-142.

Singh, D. (1970). Preference for bar pressing to obtain reward over freeloading in rats and children. *Journal of Comparative and Physiological Psychology, 73*(2), 320-327.

Skinner, B. F. (1963). Operant behavior. *American Psychologist, 18*(8), 503-515.

Smith, S. M., & Blankenship, S. E. (1991). Incubation and the persistence of fixation in problem-solving. *American Journal of Psychology, 104*(1), 61-87.

Suzuki, S. (1997). Effects of number of alternatives on choice in humans. *Behavioural Processes, 39*, 205-214.

Suzuki, S. (1999). Selection of forced- and free-choice by monkeys (Macaca fascicularis). *Perceptual and Motor Skills, 88*(1), 242-250.

Taffe, M. A. (2004). Effects of parametric feeding manipulations on behavioral performance in macaques. *Physiology & Behavior, 81*(1), 59-70.

Wallen, K. (2001). Sex and context: hormones and primate sexual motivation. *Hormones and Behavior, 40*, 339-357.

Washburn, D. A., Hopkins, W. D., & Rumbaugh, D. M. (1991). Perceived control in rhesus monkeys (Macaca mulatta) - enhanced video-task performance. *Journal of Experimental Psychology-Animal Behavior Processes, 17*(2), 123-129.

General Discussion

In this dissertation, we demonstrated the feasibility of conducting automated computerized testing of nonhuman primate subjects housed in large, age-graded and naturalistic social groups, without removal of the subjects from the social group, and in a manner that allowed subjects to participate on an entirely voluntary basis, with all of the same activities and space available to them as had been available before the start of cognitive testing. This study differs from previous studies in several important ways. First, we were able to collect data from over 100 members of a single social group with a single testing system, demonstrating that multiple systems are not required for large-scale data collection. Second, all subjects were auto-shaped to interact with the kiosk and learned the contingencies of the touch screen without any human intervention. It is likely that such auto-shaping was enhanced by the social environment, and individuals learned the contingencies of kiosk interaction from observing others. Last, subjects in this study were able to progress through tasks at their own pace. In the largest computerized testing studies completed previously (Fagot & Bonte, 2010; Fagot & Paleressompoulle, 2009), all subjects were tested on the same tasks at any given point, and thus some subjects were highly overexposed to some levels compared to others, making comparisons of performance between subjects difficult. Importantly, overt aggression was not observed related to access the kiosk or to the procurement of pellet rewards for correct responses, though the design of the kiosk was such that pellets were sometimes stolen by other individuals. Thus, while future similar studies will no doubt improve and expand upon the training methodologies and apparatus used here, the importance of the feasibility of such testing should not be understated, as it opens up opportunities for many kinds of research to be completed with large numbers of subjects.

In this study, we found that subject participation varied considerably, both within and between subjects. The manuscripts included in this dissertation demonstrated that a large portion of the variability in participation between subjects was driven by age. Younger subjects participated at much higher rates than older subjects, and this became more pronounced over the course of the study, with older subjects participating at slower rates as tasks became harder. Initial participation was partially explained by effects of social rank with more participation from higher ranking subjects at the start of testing. However, the effect of social rank diminished over time, and no rank effects were observed after three months of testing. Sex of the subjects did not affect participation of juvenile subjects, either for initial participation or overall rates of participation. .

While the age effects we report may reflect that our reward pellets provided less incentive for the older and larger animals, it also raises the possibility that adults are simply less inclined to engage with novel objects and devices. Our findings suggest that this may happen in very early adulthood. If considered in relation to the human literature, a common problem in education is that students show a substantial decline in intrinsic motivation to learn between the early elementary (3rd grade) and middle school (8th grade) years (Lepper, Corpus, & Iyengar, 2005; Rathunde & Csikszentmihalyi, 2005). Potentially, biological and behavioral changes related to pubertal onset contribute to such changes in motivation, but this is a little studied topic. In addition, while much research focuses on changes between early childhood and adolescence, very little research examines changes in learning motivation from adolescence to early and middle adulthood. However, there is a variety of evidence that suggests that individuals exposed to learning environments in which they are allowed greater autonomy in their learning transition better in later stages of education (Rathunde & Csikszentmihalyi, 2005; Shankland, Genolini, Franca, Guelfi, & Ionescu, 2010). Indeed, this effect is shown even with control over simple contingencies in infancy: infants provided with experience over controllable stimulation in an experimental setting showed better learning of new contingencies (Finkelstein & Ramey, 1977). Our specific results do suggest that younger animals were faster to learn to interact with the kiosk, with faster times to initial access, to complete the first trial, and to complete touch training tasks. Thus, even when a pellet could be obtained easily, younger subjects were more inclined to complete trials. Possibly, they understood the contingencies of interaction better than did adults.

If experience with controllable stimulation contributes to better learning of contingencies, then it is possible that the age effects reported in this study are related to developmental exposure to such stimulation. The rhesus monkey subjects in our study, while housed in a large physical space and allowed to a large extent to engage in activities of their choosing, do not have a lot of experience with contingent stimulation – with their actions resulting in a change in the environment. Thus, for older animals, learning the contingencies of the kiosk may be more foreign than it is for younger animals, due to many years without such experiences. A longitudinal study of kiosk participation and performance may reveal whether subjects exposed to kiosk tasks from a young age would show continued participation even as they aged. If experience with controllable stimulation affects learning, then the experiential histories of subjects in any testing setting may be important for the understanding of differences in performance.

In contrast to the age effects, rank effects diminished over the course of the study. This seems to have resulted from low-ranking animals participating more frequently as the study progressed, possibly as they learned that the pellets were not depleted in availability. If a similar study were conducted with a cognitive testing system in a social group but with the system available to subjects for only a few hours a day, it is possible that rank effects would be more persistent. Also, larger or more desirable food rewards might lead to more exaggerated effects of social rank, the size and desirability has been shown to effect access by rank in other contexts (Belzung & Anderson, 1986; Chancellor & Isbell, 2008). An additional reason for the decline in rank effects may have been that tasks got harder relatively quickly. If simple touch trials continued for many trials, rank effects may continue for a longer duration.

In this study, variability in participation was also related to performance. Overall, subjects participated less when their performance was poor, and they participated more when their performance improved. It must be emphasized, however, that these rates were relative – for some individuals, a high rate of participation was completing 10 trials in a day, whereas for others, a high rate of participation was completing 200 trials in a day. Moreover, while relative participation rates within subjects were higher when performance was better, a slow rate of participation did not necessarily lead to poorer performance. Indeed, we demonstrated that for one group of animals, slower participation rates appear to have led to fewer trials required to learn the rule of a task.

The findings of both manuscripts raise many questions for our understanding of motivation. Studies of animal learning, coming from a behaviorist history, have historically not made distinctions between varieties of intrinsic and extrinsic motivation, putting them at odds with studies of human learning, which primarily approach learning from a cognitive perspective. The findings of this study raise the importance of considering animal learning from a motivational perspective. What motivated the volunteer monkey to participate? Was it simply a drive to obtain banana-flavored pellets, or was it also attraction to the task itself? Did other aspects of reward events, such as the yellow screen and the sound (“Woohoo!”) become secondary reinforcers? Was participation motivated by watching other members of the social group successfully complete trials and obtain rewards? This study was not designed to differentiate between different kinds of motivation, but the fact that monkeys chose to participate and continued to participate over a long period of testing suggests that a variety of motivating factors may have contributed to their participation. The testing setting emphasized the likelihood that motivation to participate was not driven by a simple drive to obtain food, which might be an assumption when learning occurs in a setting where food is restricted. The difference between “I work because I need food to satiate my hunger” and “I work because I really like these pellets, even though my cheek pouches are stuffed with monkey chow and oranges” is rather substantial. The difference between “I work because I really like these pellets” and “I work because I like learning new things” is even bigger.

A decline in intrinsic motivation to learn in humans has been demonstrated between early childhood and adolescence (Lepper et al., 2005). Possibly, similar differences in motivation were present in our subjects, with young subjects driven by a curiosity about a novel object, and older subjects driven by a motivation to obtain a desirable food.

Additional questions about motivation are raised by the finding that sometimes slower participants may be better learners. Were slower participants more or less motivated than their faster counterparts? Were they motivated more by aspects of the actual task than by pellet rewards, or were they actually motivated more by pellet rewards? Were faster participants motivated by the opportunity to manipulate an object and by the contingencies of their interactions, or were they simply motivated to obtain more food rewards? If provided with a choice to work on tasks in which a pellet reward is guaranteed or tasks in which a pellet reward is dependent on learning a new contingency, will some subjects always choose the easy route and others the “learning” route? Effort theories suggest that subjects will choose the task in which they obtain the most food for the least effort (Hull, 1943), but contrafreeloading studies have confirmed that this theory of motivation is flawed, and that subjects often choose to work for food even when food can be obtained more readily with no effort (Neuringer, 1969; Singh, 1970). There are, however, limits to the difference in effort subjects are willing to make before they will choose the freely available food (Inglis, Forkman, & Lazarus, 1997), and thus it is unknown how subjects would behave in the context of our testing system. The fact that contrafreeloading is observed in both children and animals does suggest that learning motivation in humans and nonhumans may have more in common than has previously been acknowledged, and that efforts to understand the kinds of motivation that contribute to self-regulated learning in animals are worthwhile.

Motivations can also be influenced by social factors. In this study, low-ranking animals were slower to participate, suggesting that they either inhibited their motivation to participate, or that their motivation to participate was initially reduced by their motivation to avoid the possibility of conflict with higher-ranking individuals. The social modulation of motivation in learning is an under-studied topic in both humans and nonhuman animals. While this study was completed in a social group of monkeys and the kiosk design allowed for multiple animals to sit in the vicinity of the kiosk at a time, we did not complete any formal observations of social interactions at the kiosk. The presence or absence of social others may have had a strong effect on participation and performance. In addition, it is possible that the positive reinforcement was reinforcing and motivating not only for the subject receiving the pellet reward, but for other members of the social group. Correct and incorrect trials were accompanied by sounds loud enough to be heard by any subjects in the outdoor living area. It is likely that all subjects learned to associate the positive reinforcement sound with the receipt of a pellet reward. In an experimental setting, a preference for other subjects to receive a reward over no subjects receiving a reward has been demonstrated in rhesus monkeys, suggesting vicarious reinforcement – the preference of positive outcomes to others (Chang, Winecoff, & Platt, 2011). Subjects preferred to receive a reward themselves over another subject receiving a reward, suggesting that positive outcomes to others are not equivalent to positive outcomes to the self. If the receipt of rewards by other subjects is rewarding to all members of the social group, then motivation may be enhanced when a subject or multiple subjects are performing well on a task. An examination of participation or performance in relation to the recent performance of others could reveal whether subjects are affected by the reward outcomes of others.

The specific training scheme used in this study may have affected our findings. For example, the small and relatively plain food rewards may have resulted in more exaggerated differences in participation between subjects than might have been observed. If food rewards are larger for all subjects, are the same age effects observed, or do adult animals increase their participation? Do larger food rewards result in increased and more persistent rank effects? It would also be interesting to determine whether the disbursement of rewards proportional to body mass index would result in reduced differences in participation by age, or if differences would continue due to actual differences in interest in kiosk interaction. Similarly, if food rewards are more desirable or more variable, does this improve the long-term participation of all subjects? Other groups have used a combination of pellet and chocolate rewards, with chocolate rewards disbursed less frequently and on a random schedule (Paxton et al., 2010). In addition, the use of a correction procedure, with repeated trials and longer inter-trial intervals after incorrect trials may have caused frustration for some subjects, leading them to decrease participation. The same procedures that work well when the animal is in a restricted setting may not function as optimally in this large, naturalistic setting, since subjects can extract themselves from testing if it at any point becomes frustrating or aversive. Future studies might systematically vary parameters to determine optimal parameters for retaining participation in subjects, regardless of age and learning style. A more elaborate automated system might change tasks when subjects have shown especially long intervals between trials in an attempt to increase participation. While testing subjects in this voluntary context allowed subjects to choose when to participate, providing additional choices might improve retention of subjects – for example, if subjects are allowed to choose between two types of tasks, this might function both to improve participation and to avoid problems of persistence with incorrect responses, allowing subjects to continue to work and obtain pellets while also allowing for the opportunity for incubation on a task that has not been solved.

The findings reported here imply that subjects may develop different styles of learning, with some subjects able to learn quickly from incorrect trials, others taking long breaks between trials but able to show marked improvement with a relatively small number of trials, and others completing trials at a relatively fast rate, but with only gradual improvement. Possibly, these learning styles are not traits of the individuals, but simply styles that apply well in the particular circumstances of learning – all learners sometimes experience a problem to which the solution is not readily found, and other times discover an immediate solution. These findings suggest that some subjects may benefit from a self-regulated break as they learn tasks, and it is possible that other subjects would benefit from an imposed break, though this hypothesis needs to be tested. More broadly, these findings suggest that an examination of participation rates may contribute to understanding of performance variability and learning styles in any testing context.

Does an examination of self-regulated learning in monkeys in a rich social and physical context contribute to our understanding of learning in humans? At a minimum, it suggests that investigations of human learning might also benefit from studying learning in more mixed contexts and with greater flexibility allowed for the rate of task completion. Often, human participants are provided with time limits or encouraged to work as quickly as possible without jeopardizing performance. In some ways, self-regulated learning is more difficult to study in humans because humans are accustomed to time limits and deadlines, and may expect them even when they are not imposed, especially in experimental settings. For this reason, self-regulated learning may be more easily studied in very young children. An example, which would be analogous to the study reported here, would be to allow children in a preschool or daycare access to a videogame "kiosk" which they can interact with as they choose, and to examine patterns of participation in relation to learning and performance. An important aspect in the study of self-regulated learning is the lack of instruction, and such a kiosk system could be developed for use with any human age group.

With more studies of self-regulated learning in social contexts, we will come closer to an understanding of how we learn throughout development, engaging with and disengaging from different elements within our environment, sometimes making demonstrable leaps in progress, and other times merely inching along. As we learn more about the self-regulated learner, we may find more reasons and ways to move towards less structured and regulated environments for learning and for working.

References

Belzung, C., & Anderson, J. R. (1986). Social rank and responses to feeding competition in rhesus monkeys. *Behavioural Processes, 12*(4), 307-316.

Chancellor, R. L., & Isbell, L. A. (2008). Punishment and competition over food in captive rhesus macaques, Macaca mulatta. *Animal Behaviour, 75*, 1939-1947.

Chang, S. W. C., Winecoff, A. A., & Platt, M. L. (2011). Vicarious reinforcement in rhesus macaques (*Macaca mulatta*). *Frontiers in Neuroscience, 5*, 1-9.

Fagot, J., & Bonte, E. (2010). Automated testing of cognitive performance in monkeys: Use of a battery of computerized test systems by a troop of semi-free-ranging baboons (Papio papio). *Behavior Research Methods, 42*(2), 507-516.

Fagot, J., & Paleressompoulle, D. (2009). Automatic testing of cognitive performance in baboons maintained in social groups. *Behavior Research Methods, 41*(2), 396-404.

Finkelstein, N. W., & Ramey, C. T. (1977). Learning to control the environment in infancy. *Child Development, 48*(3), 806-819.

Hull, C. L. (1943). *Principles of Behavior*. New York: Appleton-Century.

Inglis, I. R., Forkman, B., & Lazarus, J. (1997). Free food or earned food? A review and fuzzy model of contrafreeloading. *Animal Behaviour, 53*, 1171-1191.

Lepper, M. R., Corpus, J. H., & Iyengar, S. S. (2005). Intrinsic and extrinsic motivational orientations in the classroom: Age differences and academic correlates. *Journal of Educational Psychology, 97*(2), 184-196.

Neuringer, A. J. (1969). Animals respond for food in the presence of free food. *Science, 166*(3903), 399-401.

Paxton, R., Basile, B. M., Idachi, I., Suzuki, W. A., Hampton, R. R., & Wilson, M. E. (2010). Rhesus monkeys (Macaca mulatta) rapidly learn to select dominant individuals in videos of artificial social interactions between unfamiliar conspecifics. *Journal of Comparative Psychology, 124*(4), 395-401.

Rathunde, K., & Csikszentmihalyi, M. (2005). Middle school students' motivation and quality of experience: a comparison of Montessori and Traditional School Environments. *American Journal of Education, 111*(3), 341-371.

Shankland, R., Genolini, C., Franca, L. R., Guelfi, J., & Ionescu, S. (2010). Student adjustment to higher education: the role of alternative pathways in coping with the demands of student life. *Higher Education, 59*, 353-366.

Singh, D. (1970). Preference for bar pressing to obtain reward over freeloading in rats and children. *Journal of Comparative and Physiological Psychology, 73*(2), 320-327.