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novel touchscreen enrichment across temperament and time

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An abstract of
a thesis submitted to the Faculty of Emory College of Arts and Sciences
of Emory University in partial fulfillment
of the requirements of the degree of
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Abstract

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The provision of environmental enrichment encourages species-typical behavior, may reduce abnormal behaviors in captive animals, and is an important component of federally mandated provisions for captive non-human primate psychological welfare. Many practices and devices have been developed that promote these goals for primates in general; however, response to enrichment can vary widely between individual primates, and without food reinforcement primates can rapidly habituate to some enrichment devices. Technology-based enrichment, which can provide cognitive stimulation and give primates more control over their environment, may help address these concerns. Twelve singly-housed, female rhesus macaques of different temperaments were exposed to a novel, interactive touchscreen computer program, and their responses were recorded over a three week period. In this study, temperament did not affect tablet use or predict the overall occurrence of abnormal behavior. A subject's latency to engage with the tablet and duration of use during the first exposure session did not predict use in later sessions. Monkeys exhibited no preference between the two initial activities. Overall tablet use decreased across the first two weeks of exposure, but the addition of a bubble screen saver, which increased visual complexity, corresponded to an increase in tablet use during the third week of exposure. Although temperament was not found to predict tablet use, almost all subjects engaged with the tablet during this study, and the pattern of use over time suggested that the complexity of a tablet device promotes a promising resilience to habituation.

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Introduction

Standards for the enrichment and care of primates housed in research facilities have increased over the past three decades, resulting in an improved general level of care for these animals. In response to a 1985 revision of the Animal Welfare Act, the United States Department of Agriculture now requires primates to be housed in environments that promote their psychological well-being through practices such as social grouping and environmental enrichment (1). The *Guide for Care and Use of Laboratory Animals* describes effective environmental enrichment as providing animals with sensory and motor stimulation, the opportunity to express species-typical behaviors, and a degree of control over their environment (14). For non-human primates (NHP) environmental modification may include social housing, foraging opportunities, and the provision of manipulable toys; the ultimate goal of these modifications is to promote psychological well-being through mental and physical stimulation and cognitive challenges (14). While psychological well-being remains difficult to define, the National Academy of Sciences suggests indicators such as the presence of species-typical behaviors and the absence of maladaptive, self-injurious behaviors or chronic signs of distress as useful measures (5).

Enrichment in captive environments can take many forms. Socially enriched environments may allow NHPs physical or visual/auditory contact with conspecifics, or incorporate positive interactions with human caretakers (21). Pair housing has been shown to benefit rhesus macaque (*Macaca mulatta*) psychological well-being by both measures of increasing species-typical behavior and decreasing abnormal behavior (2; 19; 36); pair-housed macaques may also cope better with environmental stress (17). As most NHP species live in complex social groups in their natural environment, many consider the social housing of captive NHPs to be the single best form of enrichment (12; 24).

Other forms of enrichment may supplement social housing, or enrich an animal's environment when social housing is not possible. Nonsocial forms of enrichment include feeding, physical, sensory, and occupational enrichment (12). Wild NHPs spend a larger portion of their day foraging and eating relative to those in captivity, and a wide range of devices have been designed to increase the time captive primates spend procuring food (37). Foraging enrichment has been shown to increase species-typical behaviors such as foraging, play, and exploration (8; 18); foraging devices have also been associated with decreases in the occurrence of abnormal behaviors (3; 19). Non-feeding physical enrichment devices, such as perches or toys, have also been shown in some cases to produce improvements in these two behavioral measurements of NHP psychological wellbeing (4; 22). However, both feeding and physical enrichment devices have limitations. While many studies have demonstrated the potential psychological benefits enrichment devices may offer NHPs, other studies have found no reduction in abnormal behaviors (15; 34). Even the documented beneficial effects of foraging devices may last only until the associated food is consumed (28). Further, NHPs often interact less with physical enrichment devices over prolonged exposure, and this habituation limits the benefits offered by any single device over time (18; 23; 39).

Sensory enrichment aims to introduce the greater complexity of sensory stimuli associated with natural environments into the laboratory, but has mixed results with regards to psychological well-being (12). One study found visual enrichment in the form of NHP video tapes produced no measurable benefits to singly-housed macaques' psychological well-being (34). However, video tapes have successfully engaged the interest of socially housed macaques in a laboratory environment (6); some macaques have been exposed to conspecific videos for 20 days or more without demonstrating habituation (30; 32).

While sensory enrichment adds more complex stimuli to an animal's environment, audio and visual media played at human caretakers' discretion does not permit the control thought to be beneficial to psychological well-being (14). Occupational enrichment provides NHPs with the option to engage in physical exercise or cognitive tasks (12). The nature of interactive computer programs provides NHPs with a cognitive challenge and control, two important components of psychological welfare (40). While using technology-based enrichment is not a species-typical behavior, the cognitive challenges provided by these tasks can mimic the dynamic conditions that encourage problem solving behavior in wild primates. When presented with interactive computer tasks, monkeys permitted to select the task order consistently outperformed those that had no control over the task order (31; 41), indicating a more willing, and thus rewarding, engagement with the task. Similarly, in humans personal control has been found to predict both job performance and satisfaction (20). Interactive computer programs designed to increase in complexity over time have also demonstrated resistance to habituation in a variety of NHP species (25; 32; 33; 38).

Determining the best practices for implementing effective environmental enrichment protocols for captive NHPs continues to challenge behavioral managers. Even behavioral management practices that have demonstrated benefits in published studies are often applied to entire facility populations without accounting for temperament differences between individual animals (11). Although the precise definition of temperament remains contentious, Freeman and Gosling describe temperament as individual behavioral differences that appear to be maintained over time and across a variety of situations (16). An important aspect of temperament is a monkey's response to unfamiliar stimuli, which can be quantitatively assessed by measuring the amount of time a monkey takes to inspect a novel food item placed near its enclosure. Monkeys may be classified as having exploratory, moderate, or inhibited temperaments based on their latency to inspect a novel object (13). There are other methods for assessment, but response to a novel object is a practical way to operationalize the construct of temperament.

Novelty is considered an important element of environmental enrichment programs (14). However, even this principle may not be universally applicable, as a monkey's willingness to approach unfamiliar objects could influence the degree to which the monkey benefits from novel enrichment (11). Few studies have investigated the influence of temperament on behavioral management practices, but studies of positive reinforcement training (PRT) demonstrate a wide range of responses to training on the level of individual animals (35). PRT presents a cognitive challenge to animals, and a more exploratory temperament has been significantly associated with rhesus macaques' speed in learning behaviors via PRT (13). Conversely, when monkeys were presented with both passive and interactive activities on a touchscreen tablet, inhibited animals did not touch the device, while monkeys with exploratory or moderate temperaments did (29). These studies suggest that temperament could affect the psychological benefits macaques obtain from a variety of enriching activities.

With the goals of maximizing both behavioral management resources and the benefits of enrichment to individual animals, this pilot study investigated rhesus macaques' response to a novel touchscreen tablet computer program. The user-directed interactivity and variable complexity intrinsic to computer programs offer a promising opportunity to address individual temperament and habituation, two issues that can impede enrichment efficacy. Monkeys were previously assessed for temperament using their response to a novel object to categorize their temperament as exploratory, moderate, or inhibited. I provided monkeys with different temperaments the opportunity to interact with multiple activities on a computer tablet. Based on the data collected during exposure sessions, I aimed to determine whether temperament impacted an individual animal's tablet use, what factors could contribute to the success of a tablet enrichment program, and whether tablet use improved animal welfare. Specifically, I tested the following hypotheses:

1. If temperament affected tablet enrichment use, then exploratory animals would display lower visual and touch latency and higher overall tablet use relative to moderate and inhibited animals.
2. If either the paint or music initial activity more effectively engaged animal interest, animals would spend a higher percentage of time interacting with one activity over another.
3. If individual animals' tablet use is relatively stable across time, then the percent of time each animal interacted with the tablet during the first exposure session would correlate with the percent of time it used the tablet during subsequent sessions, which could enable behavior managers to efficiently predict an individual animal's tablet use.
4. If the environmental control and cognitive challenge offered by tablet enrichment promotes psychological wellbeing, then the percent of time animals engaged in

abnormal and anxiety-related behavior would decrease during tablet exposure sessions.

5. If the dynamic nature of tablet enrichment offers resistance to habituation, tablet use would not decrease across exposure weeks.

Methods

Subjects. Subjects were 12 adult, female rhesus macaques ranging from 5 to 17 years of age (mean = 11 years) housed at the Yerkes National Primate Research Center (Atlanta, GA). From monkeys previously temperament tested by Behavioral Management Unit (BMU) personnel, subjects were selected to evenly represent each temperament type; the observer was blinded to all temperament test results until after data collection was complete.

Study approval. The BMU directs enrichment programs for the primate colony and regularly conducts research to assess how these programs may be contributing to the quality of animal care. New enrichment devices are evaluated for their benefits to psychological well-being; this study fell within the scope of the current Institutional Animal Care and Use Committee (IACUC) approval for management of the primate colony, so a separate IACUC approval was not required for this particular evaluation.

Housing. Singly-housed subjects were selected to prevent social partner influence from affecting the subject's tablet use. Animals live in cages that meet federal standards for their size and weight in indoor, climate-controlled rooms; singly-housed monkeys cannot physically interact with other individuals, but have continuous visual, auditory, and olfactory access to other monkeys in the room. Water is available ad libitum, and formulated food biscuits are provided twice daily.

Enrichment. All macaques have continuous access to enrichment in the form of a manipulatable object, a foraging device, and a perch. Monkeys are also provided with a variety of fresh produce five days a week, foraging material daily, destructible enrichment items such as paper, and other enrichment devices that encourage species-typical behavior.

Temperament testing. Each subject had been previously temperament tested and assigned a temperament of either exploratory, moderate, or inhibited. The Yerkes temperament test procedures were based on those developed by the Oregon National Primate Research Center (13). To conduct the temperament test, a BMU personnel member unfamiliar to the subject would enter the room and allow the animal to acclimatize to observer presence for 5 minutes. The observer then hung a novel object on the monkey's cage directly above the food slot, permitting the animal to easily access the object. The animal's initial response to the object was recorded as touch, inactive, fear, anxiety, or other. Latency to inspect and latency to touch the object was also recorded. Animals classified as exploratory touched the object within 10 seconds, moderate animals displayed touch latency between 11-180 seconds, and inhibited animals did not touch the object within the 3 minute time frame.

Tablet device. The Windows® 7 Professional HP Slate 500 tablet was loaded with the CHOICE Solo Enrichment© program (7; 9). This tablet program is designed with the goal of promoting psychological well-being by giving animals more control over their environment. From the home screen of this program, animals can select from lighting, video, music, and paint activities; within these activities animals can choose from three light colors, video clips, songs, or four paint colors. This program allows researchers to select not only which activities the animal can access, but also how many options within each activity are available. In this study I provided all options in the paint and music activities. The paint activity provided visual stimulation but did not provide any auditory enrichment. The music activity provided both auditory and visual stimulation in the form of a black screen with a dynamic green line that moved with the music.

A case was designed to attach the tablet securely to the cage and protect it from damage. The entire tablet was enclosed in two pieces of plexiglass with a window cut-out to allow monkeys to access the touchscreen; the plexiglass pieces were connected by metal hinges and secured closed with a latch the monkeys could not open. Two hooks at the top allowed the case to hang with the touchscreen resting against the outside of the cage door, and another adjustable-length hook on the bottom prevented the monkeys from knocking the device off the cage.

Experimental design. Three cohorts of animals underwent a 5-week study-period, and each animal participated in eight 30-minute observation sessions. During the first week each animal was observed for a single, 30-minute pre-exposure session. During each week of the 3-week exposure period subjects were exposed to the novel touchscreen enrichment for two 30-minute sessions. In the first session of each week the tablet was set to the paint program, and in the second session the observer started a song on the music selection screen. Each observation began with either a blank paint canvas or playing one of the three song choices, and monkeys had access to both programs throughout the observation. In addition to the interactive CHOICE Solo© program, during week 3 of exposure the Windows bubble screensaver displayed moving, multicolored bubbles on the screen after one minute of inactivity. The visually stimulating screensaver was added during week 3 after the first cohort of subjects showed signs of habituation to the tablet during week 2; subjects from all three cohorts experienced the same conditions throughout the exposure phase. During the last week each animal was observed for a single, 30-minute post-exposure session to look for changes in overall activity or behavior.

Data collection. Two types of data were collected and assessed for this project: focal animal data recorded during pre-exposure, exposure, and post-exposure observations, and behavioral monitoring one-zero sampling data collected routinely by behavioral management personnel. Prior to focal animal data collection, the observer achieved >85% inter-observer reliability with a trained observer on the behavioral ethogram. The BMU's comprehensive ethogram records species-typical, social, enrichment use, anxiety-related, and abnormal behaviors (see selected behaviors in the Appendix). The additional behaviors of visual use, active physical use, and passive physical use of the novel device were added to the ethogram for this project. Visual use was recorded when the animal's face was oriented toward the tablet and the animal was gazing directly at the tablet. The subject was engaged in active physical use when any body part was both in physical contact with the device and actively moving; active physical use was scored immediately when the animal touched the novel device and turned off when the animal broke contact for more than 3 seconds. If the body part was not actively moving for more than 3 seconds but was still in physical contact with the device, the behavior was considered passive physical use.

Prior to each observation session, the observer would sit quietly and allow the subject to acclimate to her presence for 2-3 minutes. During the pre- and post-exposure phases, data collection would begin immediately after this acclimation period; during the exposure phases, the observer would either open the paint program or initiate a song in the music program, attach the tablet to the outside of the cage door, and then begin collecting data. Focal animal sampling data were collected via continuous sampling using Noldus Pocket Observer© software to assess overall activity, as well as frequency and duration of species-typical versus abnormal/tension-related behaviors. The observer maintained non-threatening body posture and avoided direct eye contact throughout the observation period. Once the exposure sessions were complete, the observer immediately removed the tablet from the cage.

Although I hoped to collect tablet use data to assess which aspects of the CHOICE Solo© program best engaged the subjects, due to technical difficulties I was only able to obtain data from a few exposure sessions. These data were insufficient to analyze subjects' tablet use.

As part of their standard behavior monitoring program, the BMU conducts behavioral monitoring observations in each room for an average of 10 minutes a minimum of three times per week. During these observations, trained staff allow animals to acclimate to observer presence for several minutes, then record the presence/absence of abnormal and fear-related behaviors for each animal using a one-zero sampling technique. Observers must achieve 85% agreement on all target behaviors, and periodic inter-observer reliability checks are performed to maintain this standard. I analyzed these one-zero sampling data from the three weeks prior to exposure, during the exposure phase (to assess abnormal behaviors outside of exposure sessions), and for the three weeks following exposure to determine whether the frequency of abnormal behavior changed across this time period.

Data Analysis. The Observer© software initially analyzes and outputs the latency and total duration of every behavior recorded for each observation session. Data were then transferred into Microsoft Excel for further analysis. Statistical analyses were conducted using IBM SPSS Statistics©. Due to the small sample size, the durations of active physical use, visual use, and total abnormal behavior were first analyzed for normal distribution by conducting Shapiro-Wilk tests, assessing the degree of skewness, and visually assessing histograms and QQ plots for normality. The data were not found to be normally distributed. Therefore, nonparametric tests were selected to analyze the data. Overall, statistics were selected for each comparison based on whether the variable of interest consisted of repeated or independent measures, the scale of measurement, and the number of data groupings (e.g. by temperament).

All tests had an alpha level of $p = 0.05$. For one-zero sampling data, the number of abnormal behaviors recorded was divided by the number of observation sessions to produce an index score. For focal animal sampling data, behavior durations are reported as a percentage of total observation time. Independent-Samples Kruskal-Wallis Test was used as the non-parametric ANOVA equivalent to test for significant differences in a continuous dependent variable across three or more independent groups (Hypotheses 1, 2, 4). Related-Samples Wilcoxon Signed Rank Test was used as a non-parametric t-test equivalent to determine whether the population median of differences between two matched samples differed (Hypothesis 2). Kendall's tau was used to test for correlations between two variables (Hypothesis 3). Related-Samples Friedman's Two-Way Analysis of Variance by Ranks was used as the non-parametric repeated measures ANOVA equivalent to test for differences in a continuous dependent variable over 3 or more time points (Hypotheses 4, 5); Dunn-Bonferroni test was used to perform post hoc pairwise comparisons.

Results

All subjects visually inspected the tablet, and 11 out of 12 subjects touched the tablet at some point during the study period. Subjects visually inspected the tablet an average of 12.33% of the observation (range 3.14 – 30.25), and, on average, were actively physically engaged with the tablet 3.34% of the observation (range 0.00 - 10.33). The percent of time animals were observed engaging in abnormal behavior during the 5 week study period was relatively low (M = 1.01%, SD = 1.21). Anxiety behaviors were observed an average of 3.35% of observation time (SD = 1.87).

Use across temperament. Although the one animal that did not touch the tablet during the study was classified as inhibited, I found no statistically significant results indicating that a subject's temperament affected her overall duration of tablet use. The distribution of active physical use duration (Kruskal-Wallis, $H(2) = 1.423$, $p = 0.491$), passive physical use duration ($H(2) = 1.443$, $p = 0.486$), and visual use duration ($H(2) = 0.808$, $p = 0.668$) did not differ across temperament types. Additionally, temperament did not affect visual latency ($H(2) = 0.500$, $p = 0.779$) or touch latency ($H(2) = 2.458$, $p = 0.293$) in the first exposure session, although touch latency varied widely across individuals (Fig 1).

Use across activities. For all subjects, the active physical use duration median of differences between the two initial activities of paint and music did not differ significantly (Wilcoxon, $Z = 36.0$, $p = 0.790$). Active physical use duration did not change significantly across temperaments for exposure sessions beginning with paint (Kruskal-Wallis, $H(2) = 2.036$, $p = 0.361$) or music ($H(2) = 0.819$, $p = 0.664$); there was also no significant difference in visual use duration across temperaments for paint ($H(2) = 1.077$, $p = 0.584$) or music ($H(2) = 0.346$, $p = 0.841$).

Initial use to predict later use. I performed a Kendall's tau correlation to determine whether a subject's tablet use duration during the first exposure session corresponded to her use in later sessions (sessions 2 – 6). There was no significant correlation between active physical use duration (r_τ = 0.208, p = 0.362) or visual use duration (r_τ = 0.061, p = 0.784) during the first exposure session and tablet use duration during the remainder of the exposure phase.

Abnormal and anxiety-related behavior across time and temperament. No statistically significant changes in abnormal or anxiety-related behavior duration were found across the five week study period. Across all subjects the most frequently observed anxiety-related behaviors were scratching (M = 2.41%, SD = 1.18) and yawning (M = 0.61%, SD = 0.87), and the most frequently observed abnormal behavior was hair plucking (M = 0.81%, SD = 1.22). The duration of anxiety-related behaviors showed a trend toward decreasing across pre-exposure, exposure, and post-exposure periods (Friedman's test, $\chi^2(2)$ = 0.667, p = 0.097, Fig 2). There was no significant difference in abnormal behavior duration across temperament types during the exposure phase (Kruskal-Wallis, $H(2)$ = 3.277, p = 0.194).

The one-zero behavioral monitoring data showed no significant change in abnormal behavior before, during, and after tablet exposure (Friedman's test, $\chi^2(2)$ = 2.000, p = 0.368). Only one subject was observed performing abnormal behavior during pre-exposure weeks (one instance of hair plucking), and no abnormal behaviors were observed for any subject during the exposure and post-exposure phases.

Use across time. Although there were no statistically significant differences in tablet use when the subjects were divided by temperament, the study group as a whole displayed interesting usage changes over time. There was a significant difference in the distribution of active physical use duration across exposure weeks (Friedman's test, $\chi^2(2) = 9.571$, $p = 0.008$); pairwise comparisons showed that this result was due to an increase in active use duration from exposure week 2 to week 3 (Dunn-Bonferroni test, $Z = -1.125$, $p = 0.018$, Fig 3). Further, there was a significant difference in the distribution of visual use duration across exposure weeks ($\chi^2(2) = 10.667$, $p = 0.005$), due to a decrease in duration from exposure week 1 to week 2 ($Z = 1.333$, $p = 0.003$, Fig 4). Based on visual inspection of graphs, the pattern of tablet use duration across time appeared to be consistent across temperament types (Fig 5).

The percent of time the subjects spent manipulating the tablet case or hardware without utilizing the touchscreen function changed significantly across exposure weeks ($\chi^2(2) = 13.217$, $p = 0.001$, Fig 6); pairwise comparisons showed a significant decrease in novel object hardware manipulation in week 2 ($Z = 1.167$, $p = 0.013$) and week 3 ($Z = 1.333$, $p = 0.003$) relative to week 1. In contrast, the manipulation of other enrichment items (e.g. toys and forage boards) did not change across exposure weeks ($\chi^2(2) = 0.298$, $p = 0.862$, Fig 7).

Discussion

I first hypothesized that temperament could be used to predict tablet use. Although total tablet use varied between individuals, the data overall did not show any statistically significant variation across temperament types. In a similar study that presented macaques with touchscreen enrichment, inhibited animals did not touch the tablet (29). My data did not corroborate this finding, as 3 of 4 inhibited subjects in my study touched the tablet at least once. Another recent study found no interaction between temperament determined by novel object test and non-feeding enrichment use

(27). While studies have previously shown temperament to be a good predictor of behavioral management practices such as social pairing (26) and PRT success (13), my results indicate that temperament may not predict usage of a novel touchscreen device, suggesting that other factors likely account for individual animals' variable enrichment use.

Even more interesting, the temperament type assigned based on novel object touch latency was not a good predictor of latency to touch the tablet (another novel object). When initial touch latency is examined individually (Fig 1), the fact that 4/4 exploratory, 2/4 moderate, and 2/4 inhibited animals touched the tablet in the first session is generally consistent with their temperament classifications. However, one inhibited animal rapidly touched the tablet during the first exposure session. With small sample sizes, individual variability can impact the statistical significance of results; this inhibited animal's performance may have been enough to disrupt an otherwise significant result. While temperament is considered to be stable across time (16), trait measurements can vary across different testing conditions (10). An outside factor could have impacted this inhibited animal's performance during either the novel object temperament test or initial tablet exposure to produce these conflicting results.

With the goal of optimizing the future implementation of touchscreen enrichment programs, next I analyzed whether a monkey's usage duration varied across initial tablet program selected. Another tablet study indicated that monkeys preferred interactive activities over passive screens (29), but both the paint and music activities presented in my study were interactive. While the focal animal data did not indicate a difference in tablet use duration across initial activities, some monkeys did learn to switch between activities during sessions. Thus, the initial program selection did not always reflect actual activity use. Since I was not able to analyze tablet use data recorded by the CHOICE Solo© program, I was unable to determine with certainty whether monkeys preferred one activity over the other.

My third hypothesis tested whether a monkey's tablet usage duration during the first exposure could predict her tablet use over time. If tablet use during the first exposure correlated with overall use, monkeys could be efficiently screened for participation in future tablet enrichment programs. Considering the expense and time required to provide computer-based enrichment to captive primates, a method of determining which animals would benefit most from this enrichment would be useful to effectively allocate behavioral management resources. Unfortunately, I found no significant correlation between initial and overall use. Further research will be required to maximize the benefits of touchscreen enrichment to individual animals.

A common goal of enrichment programs is to decrease the occurrence of abnormal and anxiety-related behaviors. My fourth hypothesis addressed whether exposure to the tablet produced this behavioral change, a common measurement of psychological well-being (12; 14). Likely due to the small sample size and low rate of abnormal and anxiety-related behavior occurrence, no significant changes in either category were found in response to tablet exposure. The decline noted in anxiety-related behaviors across pre-exposure, exposure, and post-exposure phases was likely due to subjects' habituation to observer presence (Fig 2). As video enrichment has been shown to decrease abnormal behavior in macaques (30), incorporating the video activity feature of the CHOICE Solo© program may produce a similar effect. Another consideration is that subjects were selected for my study based on temperament; if I had selected subjects who exhibited high levels of abnormal behavior, the tablet enrichment might have significantly reduced abnormal behavior.

While habituation to environmental stressors is likely beneficial to primates in a laboratory environment, habituation to environmental enrichment devices can be a frustrating problem for behavioral management programs. My final hypothesis tested whether the percent of time subjects interacted with the tablet decreased across the exposure phase. The subjects' significant decrease in visual use duration from exposure week 1 to week 2 suggests that they began to habituate to the two activities presented on the tablet (Fig 4), but during week 3 the dynamic bubbles screen saver added a new element to engage their interest. The increase in active physical use duration (Fig 3) suggests that this novel element that increased the visual stimulation successfully enticed the monkeys to interact more with the tablet.

Because all monkeys were exposed to the screensaver during week 3, the increase in physical use could have resulted from some factor other than the addition of the screensaver. Due to the investigations of temperament, small sample size, and limited study period, a control group for the addition of the screensaver during exposure week 3 was not included in this study. However, the amount of time the monkeys spent interacting with the tablet case – all portions of the novel enrichment device that did not possess technological, touch-screen functionality – could be used as another measure of the subjects' interest in the device. Similar to a non-technological enrichment device, the case had plexiglass, metal hooks, and screws that many subjects attempted to bite or detach. In contrast to the subjects' increased active tablet use duration from exposure week 2 to week 3, their physical manipulation of the other parts of the tablet device decreased over time (Fig 6). In addition, the subjects' percent of time spent manipulating non-novel environmental enrichment devices did not change significantly over the study period (Fig 7). These results support the conclusion that the monkey's increased physical engagement with the tablet during week 3 occurred due to the addition of the bubbles screensaver, a novel visual element, rather than any physical feature of the device.

Nearly all subjects physically engaged with the tablet at some point during the study, which was encouraging from a behavioral management perspective. Data obtained directly from the CHOICE Solo© program was insufficient to quantitatively assess overall tablet use; however, individual monkeys were observed to play multiple songs during a single session, switch between activities, and paint on the blank canvas. These observations suggest that several monkeys learned to use the interactive features of the CHOICE Solo© program without food reinforcement. Technology-based occupational enrichment has been shown in several other instances to engage NHPs, and this form of enrichment may offer advantages over physical devices such as toys. The continuous novelty of conspecific videos can maintain macaque interest over extended periods (30; 32), and interactive computer programs that increase in complexity over time have resisted habituation in chimpanzees (33) and orangutans (25; 38). My results suggest that technology-based occupational enrichment could offer similar benefits to singly-housed, adult female rhesus macaques.

Future Directions

This small pilot study did not find any indication that temperament could be used to predict tablet use, or that individual monkeys could be quickly screened for inclusion in a tablet enrichment program. Traits that correlate consistently with enrichment use have yet to be uncovered, but such predictors would be very helpful when allocating limited behavioral management resources.

For the CHOICE Solo© program in particular, this study did not find any indication that either the paint or music applications was more successful at engaging animals. However, this study did not include the video or light applications; either of these programs might be more or less successful at engaging animals in general, or animals of specific temperaments. Increased behavioral management interest in this form of enrichment will likely encourage the development of other interactive games or programs to interest animals. Incorporation of more dynamic cognitive challenges, such as problem-solving tasks that increase in complexity over time, may provide even greater benefits to primate psychological well-being. Further, the potential to provide technology-based rewards such as conspecific video clips for these tasks could promote physical health by reducing the need for food rewards, since obesity is often a concern in laboratory-housed primates.

Based on the trends observed in tablet use duration across exposure weeks, increasing the complexity of technology-based enrichment on a weekly or bi-weekly basis could help maintain enrichment use levels over long periods of time, and further studies could certainly optimize the rate of increase.

The one-time investment in purchasing a tablet may enable facilities to engage animals over much longer periods of time than single-function, physical enrichment devices. In a laboratory environment that restricts mobility, non-food based enrichment that is resilient to habituation continues to be a promising option for behavioral management programs going forward.

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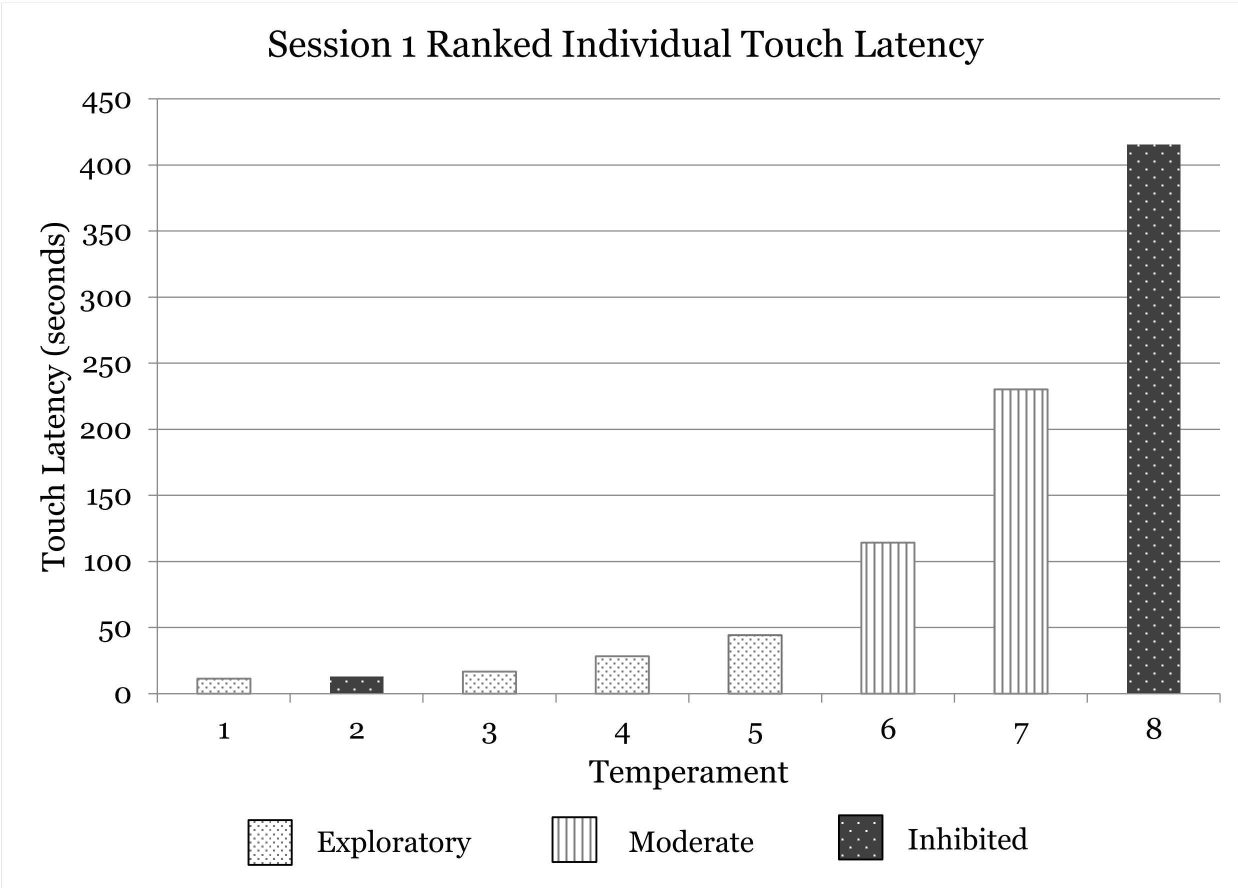


Figure 1. Touch latency during the first exposure session varied widely across individual subjects. Four animals (two moderate, two inhibited) did not touch the tablet during the first exposure session.

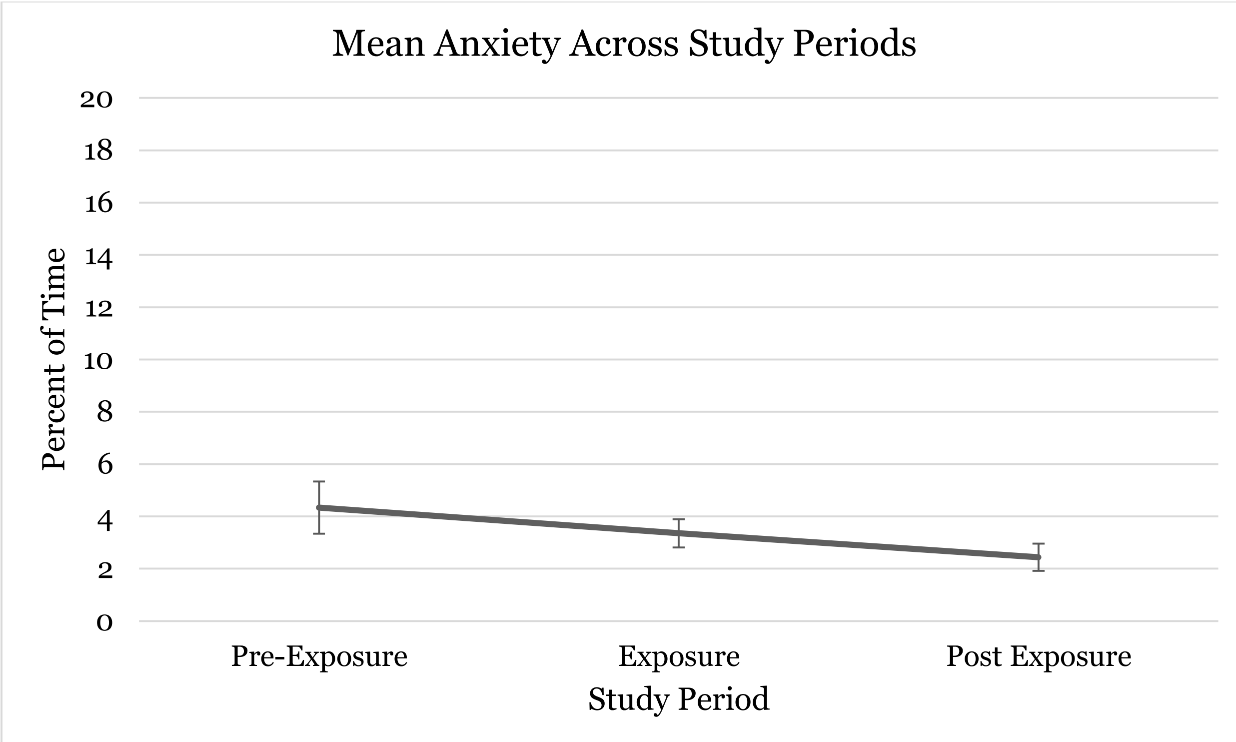


Figure 2. The percent of time monkeys exhibited anxiety-related behavior during focal animal observation sessions did not change significantly across the pre-exposure, exposure, and post-exposure phases of this study (Friedman's test, $\chi^2(2) = 0.667$, p = 0.097), but did display a decreasing trend across these phases.

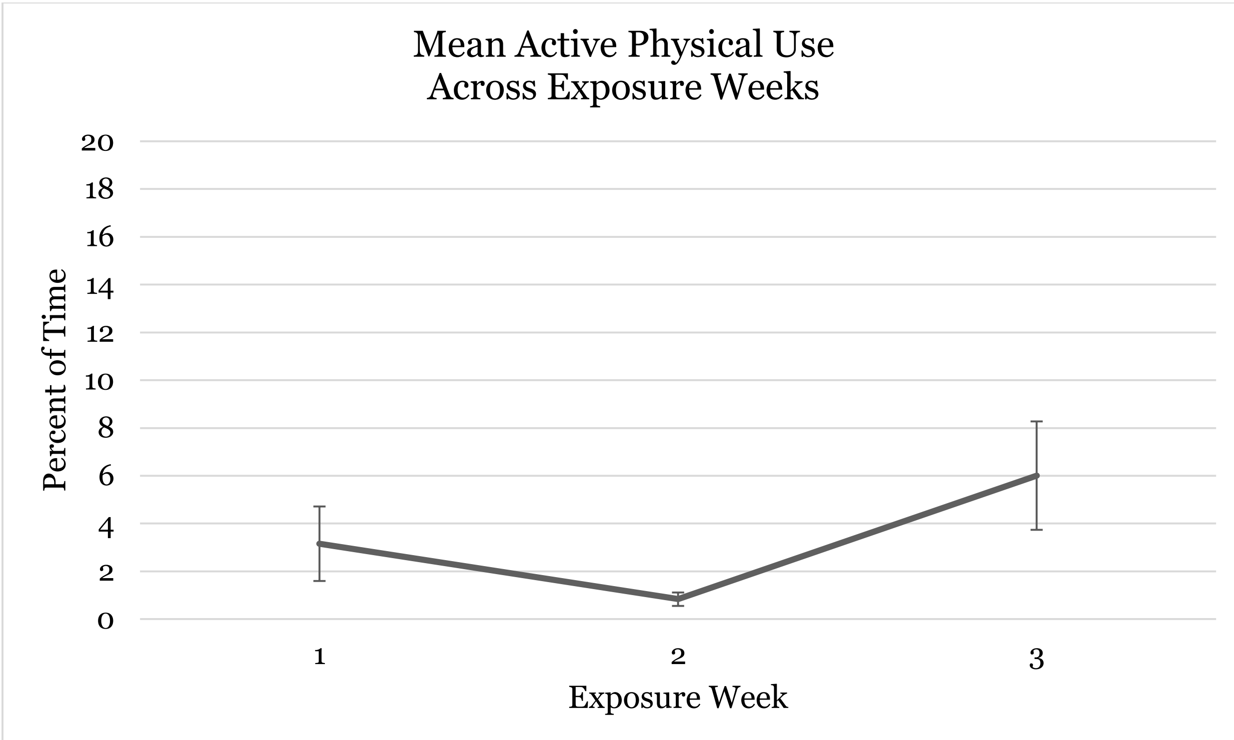


Figure 3. Focal animal data indicated that monkey's active physical tablet use changed across exposure weeks (Friedman's test, $\chi^2(2) = 9.571$, $p = 0.008$), with a significant increase from week 2 to 3 (Dunn-Bonferroni test, $Z = -1.125$, $p = 0.018$).

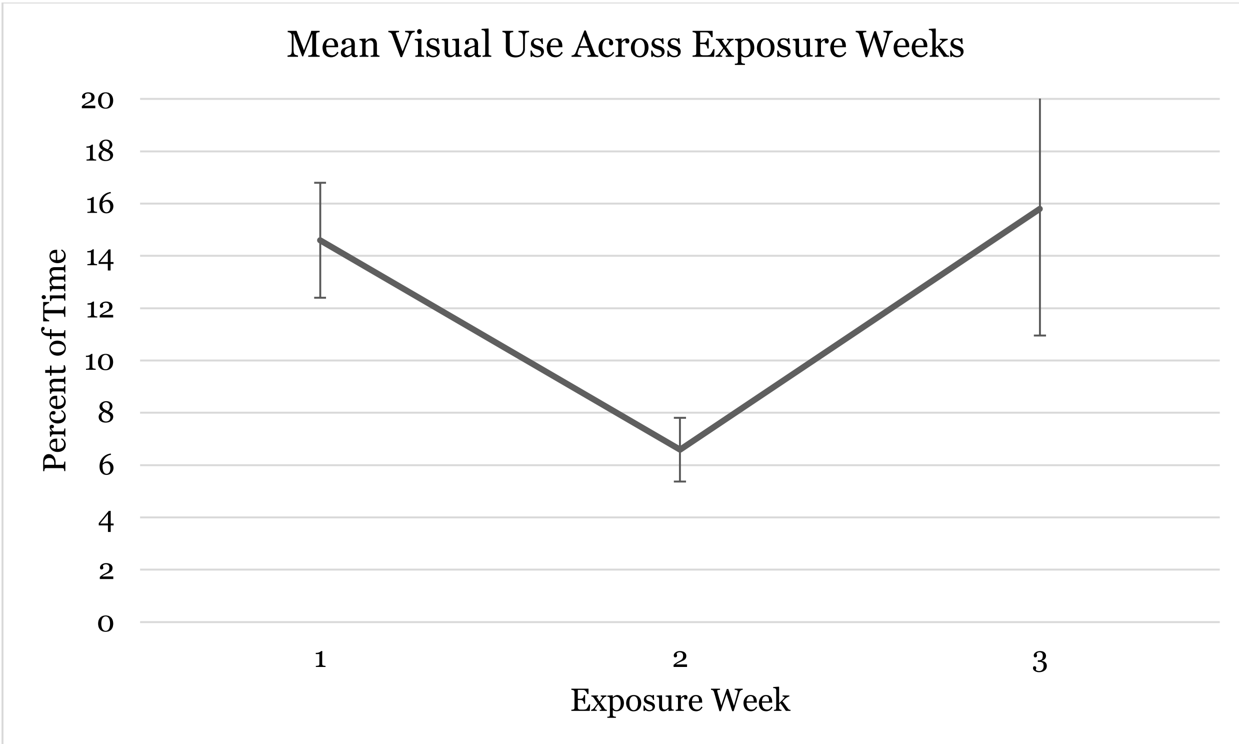
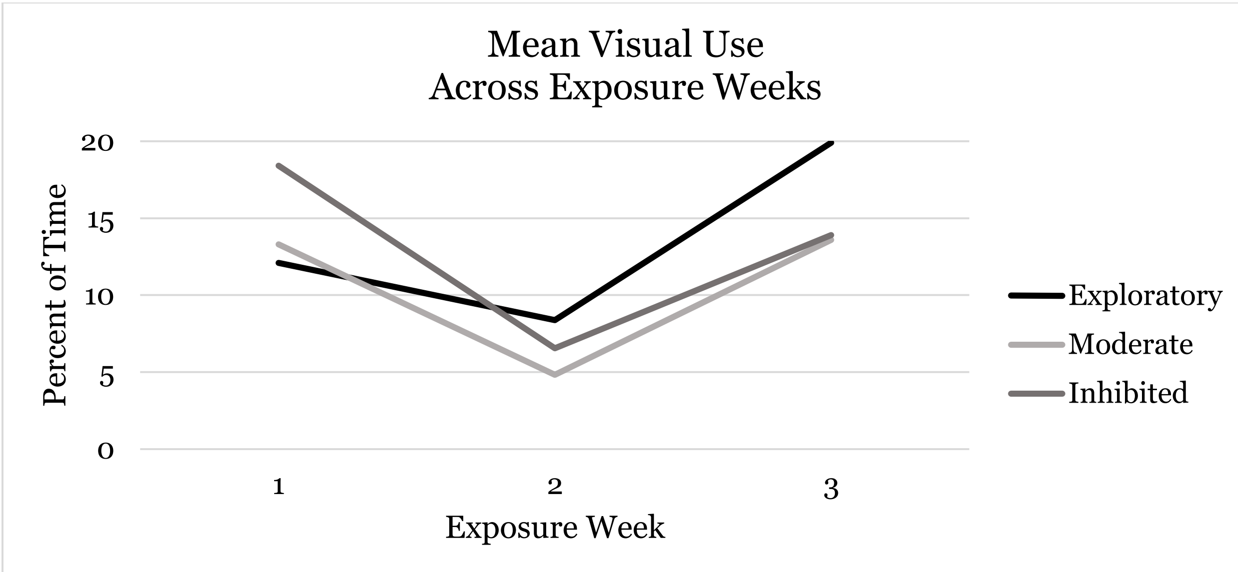


Figure 4. Focal animal data indicated that monkey's visual tablet use changed across exposure weeks (Friedman's, $\chi^2(2) = 10.667$, $p = 0.005$), with a significant decrease from week 1 to 2 (Dunn-Bonferroni test, $Z = 1.333$, $p = 0.003$).



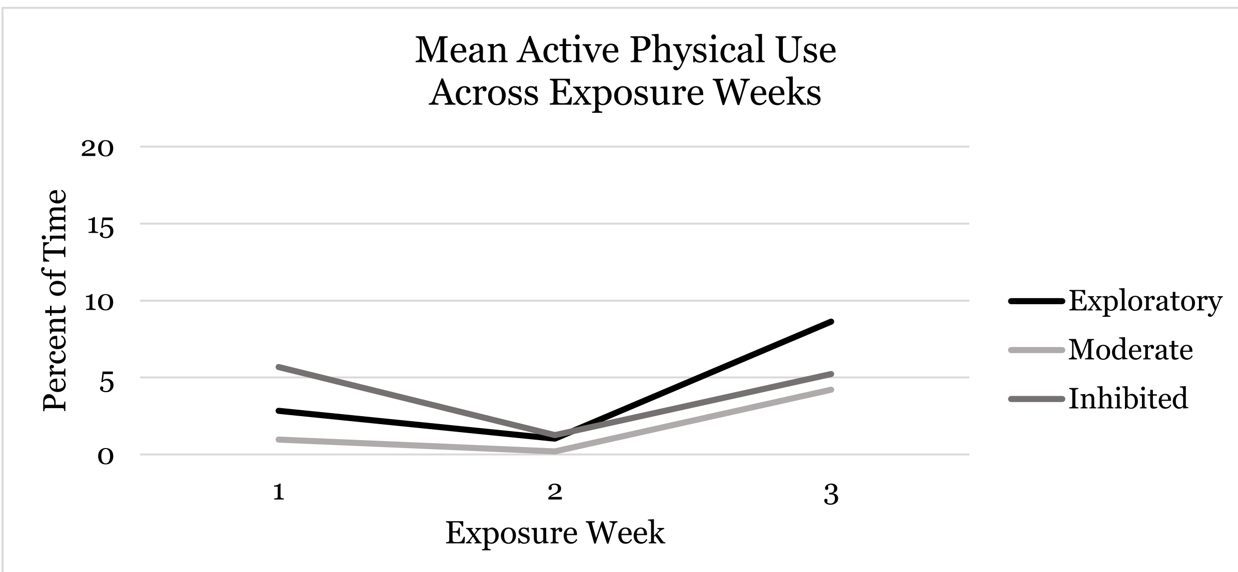


Figure 5. Based on focal animal data collected during exposure sessions, monkeys displayed similar patterns of visual and active physical tablet use across all temperament types.

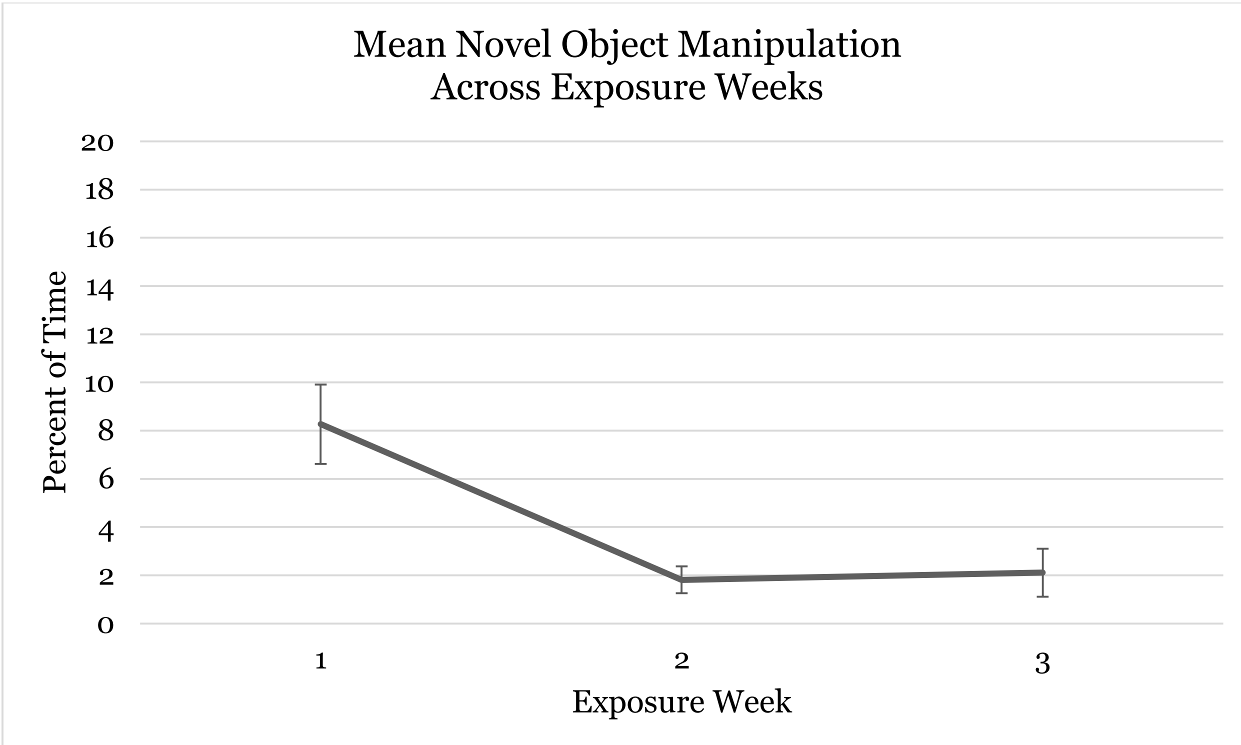


Figure 6. During focal animal observation sessions the mean percent of time subjects manipulated the hardware and tablet case without interacting with the touchscreen function of the enrichment device decreased significantly after week 1 (Friedman's test, $\chi^2(2) = 13.217$, $p = 0.001$).

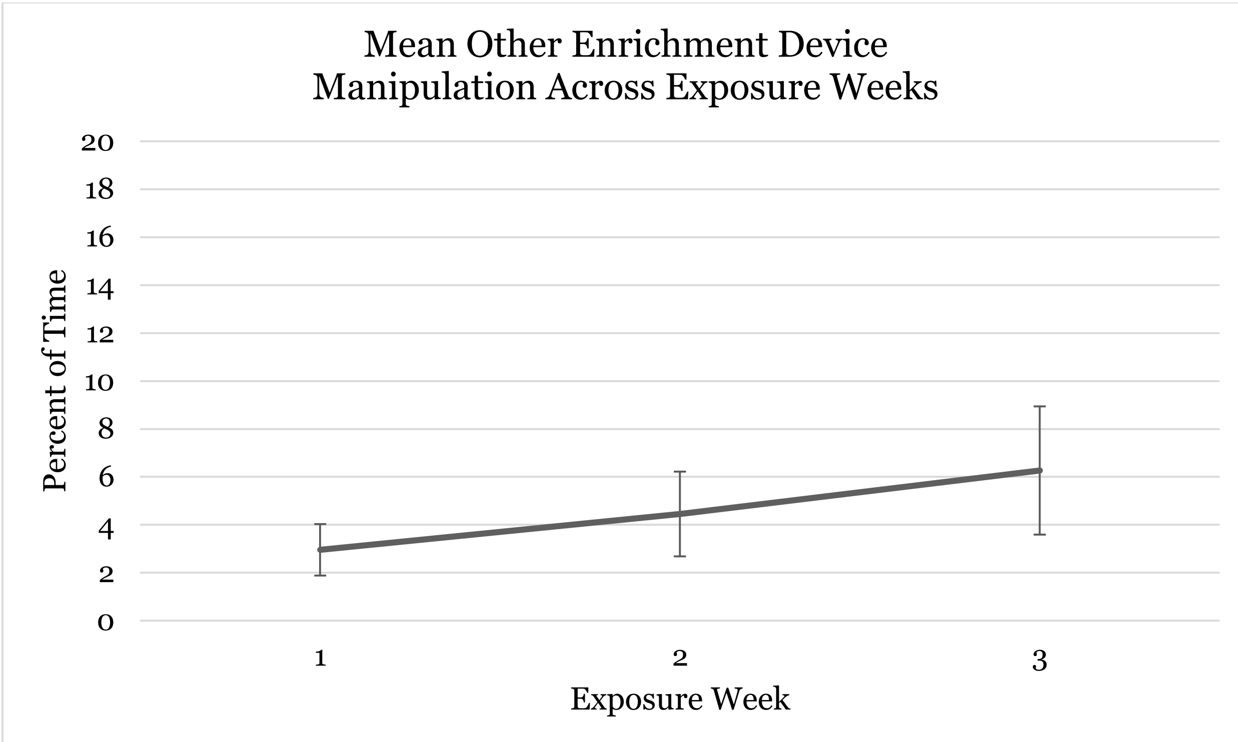


Figure 7. During focal animal observation sessions the mean percent of time subjects manipulated non-tablet enrichment devices did not change significantly across exposure weeks (Friedman's test, $\chi^2(2) = 0.298$, $p = 0.862$).

Appendix - Ethogram Behaviors of Interest

Abnormal Behaviors – differ in quality or quantity from those observed in wild conspecifics; abnormal behaviors recorded in this study included the following:

- **Eye Behaviors** – directed at the animal's own eye, such as poking or covering
- **Hair Plucking** – pulling out the animal's own hair; often repetitive and may or may not include ingestion of hair
- **Whole Body Stereotypy –** repetitive movement of the entire body that does not serve an obvious function, such as pacing, flipping, or repetitive swaying; keyed after the animal has engaged in three repetitions of behavior, and turned off when animal has ceased behavior for 3 seconds
- **Self-bite** – closing teeth rapidly and forcefully on the animal's own skin; may or may not break skin

Active Physical Use – any body part is in physical contact with the device and the body part is actively moving; active use is scored immediately as the animal touches the novel device and turned off when the animal breaks contact for more than 3 seconds, or switched to passive physical use when the body part is not moving for more than 3 seconds

Anxiety Behaviors – associated with stress or uneasiness; includes scratching, yawning, teeth grinding, and body shaking

Manipulate Object (MAO) – manual, oral, or pedal touching or handling of cage parts or items within the cage; modifier records what object subject is manipulating

Manipulate Object, Novel – MAO of plexiglass case, metal attachments, or any other portion of the tablet apparatus that does not include touching the tablet screen

Social Behavior without contact, Aggressive – includes hostile or threatening actions that do not involve physical contact; observer-directed aggression behaviors included animal cage shaking and open-mouth staring while directing gaze towards observer

Passive Physical Use - any body part is in physical contact with the device and the body part is not moving

Visual Use – animal's face is oriented toward the tablet and animal is gazing directly at the tablet