Quantifying Curiosity and Exploratory Play on Touchscreen Tablets

Madeline Pelz[1], Amanda Yung[1,2], and Celeste Kidd[1,2]
1 Brain and Cognitive Sciences, 2 Center for Vision Sciences
University of Rochester, Rochester, NY
{mpelz, ckidd}@bcs.rochester.edu, ayung@cvs.rochester.edu

ABSTRACT

Children are driven by curiosity to learn about novel objects and concepts through exploration of their environments, and the results of these behaviors are crucial to cognitive development. This study seeks to examine how exploration changes as children mature, and how experience with touchscreen tablets affects their exploration of novel environments. Two participant groups, one drawn from a sample of U.S. children in New York, and one from the Tsimane' farming-foraging group in Bolivia, were presented with a novel touchscreen game (Toca Kitchen Monsters) that provided a constrained environment in which they could explore freely. Age and touchscreen experience was highly predictive of the rate at which participants discovered novel objects within the environment.

1. INTRODUCTION

Curiosity is fueled by the intrinsic rewards that are felt when information is gained and uncertainty about the environment is reduced [2]. This motivation to explore our surroundings is crucial to learning and development. Children are driven by natural curiosity to explore their environments from a very young age [4]. They are constantly forming and testing hypotheses about how different people and things in their environment function in relation to each other. Despite its importance, much of the past research on curiosity and exploration has lacked tightly controlled experimental designs, and instead relies more on the qualitative analysis of play (as described in [1]).

One theory of curiosity refers to an "information gap" that exists between the information we know and the knowledge that we want to gain [3]. This phenomenon can lead to epistemic curiosity that drives exploration and learning about specific objects in the environment. Touchscreens allow for even very young children to confidently control on-screen objects, which enables them to manipulate and interact with objects that they are curious about in a way that would not be possible with a traditional mouse.

IDC '15, June 21-24, 2015, Boston, Massachusetts, United States

In this study, we examine curiosity in the context of the touchscreen game "Toca Kitchen Monsters," which contains multiple novel characters and objects for children to explore. This game contains many different interactive objects in order to inspire uncertainty and spark the desire to learn. This provides a rich environment that has the potential to provide useful insight into patterns of curiosity and exploration in the real world.

Having the ability to quantify aspects of curiosity and exploratory play would be extremely beneficial to understanding how these behaviors change across development. In the current study, we use data gathered while participants interacted with this game in order to assess how children's curiosity and exploration in a digital environment change as a function of age and touchscreen experience.

To balance out the widespread exposure to touchscreens in the U.S., this study was carried out using a unique cross-cultural participant pool consisting of children from the U.S. as well as participants from the Tsimane', a farming-foraging group in Bolivia that has no experience with touchscreen technology.

2. METHODS

2.1 Participants

A total of 145 children participated in this study (ages 18-146 months, $M = 59.6$). 121 children (ages 21-146 months, $M = 57.9$) participated in the study in the Rochester Baby Lab, and 24 children (ages 18-144 months, $M = 68.1$) in the Tsimane' villages of Campo Ballo, Puerto Coda, Iuasichi, Cara Lara, Las Minas, and Limoncito.

Participants were excluded from data analysis if he/she played under the criterion of 5 minutes of play (U.S., N=13, Tsimane', N=3), if a parent was present in room (U.S., N=3), or if he/she had played the game previously (U.S., N=3).

2.2 Materials

All participants were run using a first-generation iPad mini with the home button locked in order to prevent participants from exiting the application. A modified version of the "Toca Kitchen Monsters" application by the game development studio Toca Boca was utilized, in which touch data was saved directly onto the tablet. Children were allowed to play the game for a maximum of 10 minutes.

The application consists of two monster characters, a refrig-

erator containing eight food items (broccoli, carrot, lemon, meat, monsterfood, mushroom, sausage, and tomato), and a kitchen containing five appliances (saucepot, pan, microwave, knife, and blender), as well as salt and pepper. The food can be chosen and prepared using the appliances, and then fed to the monster in order to get feedback on his likes and dislikes. An example of what the screen might look like during gameplay can be found in Figure 1.

Figure 1: Screenshot from "Toca Kitchen Monsters" showing the kitchen appliances selection screen following the selection of Monster #1.

2.3 Data Analysis

Data consisting of the location, timing, target object, and duration of each touch was automatically recorded and saved directly onto the tablet. Analyses were performed on the first 5 minutes (300s) of data collected from each participant, which was constrained by the length of time that the younger participants were able to fully maintain attention on the task.

2.3.1 Discovery Rate

Discovery rate is defined as the total number of unique objects found, divided by the length of gameplay (300s). This measure was used as a way to quantify the exploratory behavior of each child so that this behavior could be compared across participants. It can also be interpreted as a measure of the breadth of curiosity about objects in the environment.

2.3.2 Touchscreen Experience

Each participant's experience with touchscreens across different contexts was calculated using survey data collected at the time of the study. The surveys were used to calculate average minutes per day of touchscreen use as the measure of their level of experience for these analyses. Note that this is a rate measure—*not* a cumulative measure of touchscreen experience, so it is not necessarily confounded with age. Two U.S. participants did not complete the survey, so for regressions including experience as a factor, total N=121.

3. RESULTS

3.1 Discovery rate increases with age

Two linear mixed-effects models were run to assess the effect of age on discovery rate in the two cross-cultural populations. As illustrated in Figure 2, U.S. children discover more as they get older ($t = 8.26$, $p < .001$)(Table 1). This is also true of the Tsimane' participants ($t = 4.088$, $p < .001$) (Table 2, Figure 3).

Table 1: Predicting Discovery Rate from Age (U.S.)

Predictor	Coefficient	Std. Error	t-value	p-value
Age	1.61E-02	1.95E-03	8.26	6.25e-13***

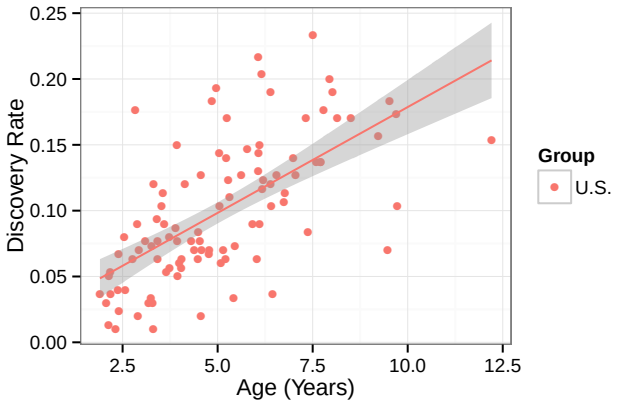

Figure 2: Discovery rate increases with age in U.S. participants (N=102).

Table 2: Predicting Discovery Rate from Age (Tsimane')

Predictor	Coefficient	Std. Error	t-value	p-value
Age	5.93E-03	1.45E-03	4.09	6.26e-4***

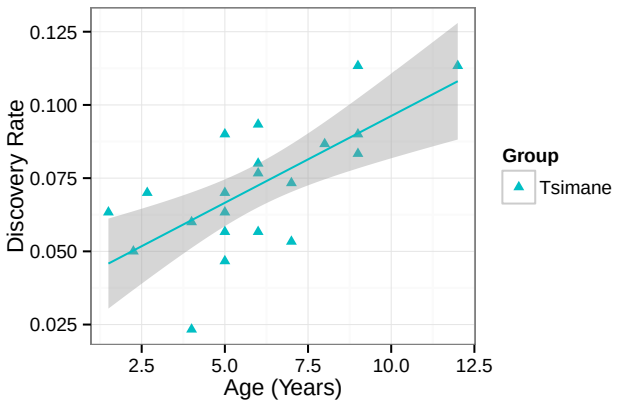

Figure 3: Discovery rate increases with age in Tsimane' participants (N=21).

3.2 Discovery Rate Increases with Touchscreen Experience

While age and discovery rate in both of the populations show a positive linear relationship, Tsimane' children showed decreased exploration overall as compared to the U.S. group (t = -4.146, $p < .001$) (Table 3). This suggests that in addition to age, other factors are also be driving these differences. One possibility is the difference in exposure to touchscreen technology between these two groups.

Although the U.S. participants have a wide range of experience (1-246 minutes per day), all participants in this group reported some level of prior touchscreen experience. In comparison, participation in this study was the first time any of the Tsimane' participants had used a touchscreen tablet. It was demonstrated that experience is also a significant predictor of discovery rate beyond what is accounted for by age, with increased experience leading to increased exploration (t = 2.708, $p < .01$) (Table 4, Figure 4).

Table 3: Predicting Discovery Rate from Age and Participant Group

Predictor	Coefficient	Std. Error	t-value	p-value
Age	1.38E-02	1.64E-03	8.44	8.26e-14***
Tsimane'	-3.92E-02	9.46E-03	-4.15	6.35e-05***

Table 4: Predicting Discovery Rate from Age and Experience

Predictor	Coefficient	Std. Error	t-value	p-value
Age	1.25e-02	1.70e-03	7.36	2.74e-11***
Experience	2.12e-04	7.82e-05	2.71	0.0078*

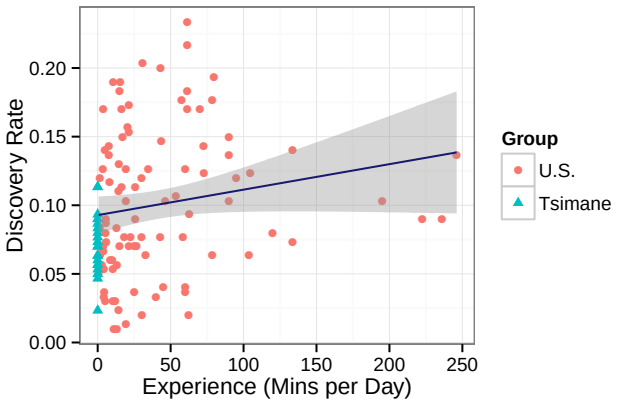

Figure 4: Discovery rate increases with touchscreen experience. Regression includes both Tsimane' and U.S. data (N=121). When participants with touchscreen experience >150 min per day are removed, the positive linear trend is strengthened.

Another way that we can visualize participants' touch data is by creating circular graphs of the objects with links drawn between them based on what was touched sequentially. Connections between objects are strengthened based on how often they occur consecutively in each participant's data. This allows us to observe differences in curiosity and information-seeking through repetitive play and the different pathways taken through the options in the game. Figure 5 is a visualization of the combined touch patterns of both the Tsimane' and U.S. groups (created using the igraph package in R).

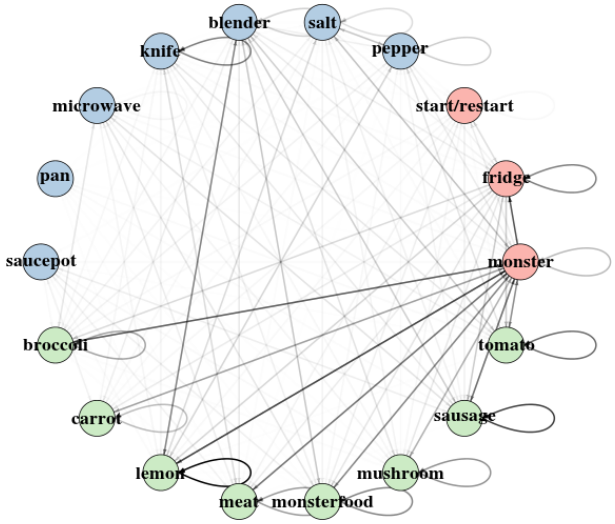

Figure 5: Visualization of combined Tsimane' and U.S. pattern of exploration of active objects shown as circles color-coded based on object category (red: scenes within the game, green: food items in refrigerator, blue: kitchen appliances/extras for food preparation).

4. CONCLUSIONS

Discovery rate is dependent on age and experience, and this difference relates to the group from which participants were sampled. In both the U.S. and Tsimane' participant groups, increasing age significantly predicted an increase in discovery rate. Regardless of experience, it seems that as children develop they become more widely curious about things in the environment, and choose to explore more broadly.

Increased touchscreen experience was also a significant predictor of an increase in discovery rate in this environment. The participants in the Tsimane' group had no previous experience with touchscreen tablets, regardless of age. This unusual participant pool allowed us to separate age from touchscreen experience and conclude that experience was also a factor driving this effect.

5. DISCUSSION

This paper serves as an example of the potential that touchscreen games have for aiding in the quantification of children's exploration and curiosity. With touchscreen tablets there are a number of possible measures that can be collected. This allows for the creation of more varied and intricate environments for children to explore than what would be attainable using other in-lab methods.

Visualizations of repetitive play suggest that there is no-

ticeable variation in the play patterns of different subjects (Figure 6). Some children loop back to the same objects over and over again, while others show a broader curiosity and find new paths to take through the options in the game. This repetitive behavior, described by Piaget (1954) as perseveration, has been observed to decrease with age [5]. Moving forward, the next step in analyzing how repetitive play behavior changes through development would be to determine ways to quantify it based on data collected from touchscreen play. This will allow for comparison of repetitive play across participants as well as provide opportunities to manipulate this effect in order to determine its features in different contexts.

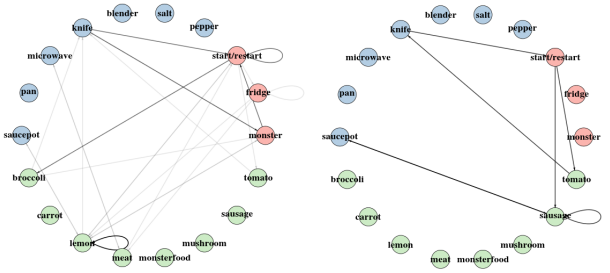

Figure 6: Qualitative comparison of individual search patterns (both from the U.S. sample) between a participant that sampled many of the available options in the game (left) and a participant that demonstrates a more repetitive pattern of play (right).

It has been previously demonstrated that children are more curious about objects in the environment that are surprising or that go against the assumptions created by the object categories that they belong to [6]. Based on the visualization of the path of exploration across groups, children showed a qualitatively higher curiosity for the lemon and the broccoli from among the food options. When playing the game, if the child attempted to feed the monster a piece of broccoli or a lemon, he spit out the food and refused to eat it. Although this wasn't an intentional aspect of the experimental design, the demonstrated preferences for these objects reveal an interesting effect of increased curiosity about objects that are dramatic or that go against the child's expectations. In future studies, this type of manipulation would be an interesting addition to an otherwise realistic touchscreen environment.

Further research assessing similar predictors measured from different novel environments could provide further insight into the changes in information-seeking that take place during development. The findings reported here lead to further questions about the origins of these behaviors. It is still unclear whether curiosity itself is changing through development, or if other aspects of cognition (e.g., memory) improve over time, leaving younger children to rely on repetitive play in order to learn successfully from the environment.

In addition to touchscreen games, it would be interesting to use similar environments in a cross-method comparison study. Touchscreen games could be combined with different methodologies such as eye-tracking or memory tasks in order to study more complicated questions about how altered levels of curiosity about certain objects can lead to different learning and memory for those objects. Curiosity is a complicated and multi-faceted concept, but these questions can be explored further by analyzing different aspects of quantifiable touchscreen play.

6. REFERENCES

[1] Bonawitz, E. B., van Schijndel, T. J., Friel, D., Schulz, L. (2012). Children balance theories and evidence in exploration, explanation, and learning. *Cognitive psychology*, 64(4), 215-234.

[2] Gottlieb, J., Oudeyer, P. Y., Lopes, M., Baranes, A. (2013). Information-seeking, curiosity, and attention: computational and neural mechanisms. *Trends in cognitive sciences*, 17(11), 585-593.

[3] Loewenstein, G. (1994). The Psychology of Curiosity: A Review and Reinterpretation. *Psychological Bulletin*, 116(1), 75-98.

[4] Piaget, J. (1952). The origins of intelligence in children (Vol. 8, No. 5). New York: International Universities Press.

[5] Piaget, J. (1954). The construction of reality in the child. *Journal of Consulting Psychology*, 19(1), 77.

[6] Schulz, L. E., Bonawitz, E. B. (2007). Serious fun: preschoolers engage in more exploratory play when evidence is confounded. *Developmental psychology*, 43(4), 1045.