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How Does a Toddler Experience Digital Media? A Case Study of a 28-Month Old Child Learning to Use the iPad

Marina A. Zhukova*

University of Houston, Houston, TX, USA

Laboratory of Translational Developmental

Sciences, Saint-Petersburg State University, Saint-Petersburg, Russia

ORCID: <https://orcid.org/0000-0002-3069-570X>

e-mail: marina.zhukova@times.uh.edu

Hechmi Kilani**

Genetic and Neurobehavioral Systems: Interdisciplinary Studies,

University of Houston, Houston, TX, USA

ORCID: <https://orcid.org/0000-0002-2424-2165>

e-mail: hechmi.kilani@times.uh.edu

Jessica L. Garcia***

Genetic and Neurobehavioral Systems: Interdisciplinary Studies,

University of Houston, Houston, TX, USA

ORCID: <https://orcid.org/0000-0003-1905-3658>

e-mail: jessica.garcia@times.uh.edu

Mei Tan****

Texas Institute of Measurement, Evaluation and Statistics,

University of Houston, Houston, TX, USA

ORCID: <https://orcid.org/0000-0001-6408-6091>

e-mail: Mei.tan@times.uh.edu

Paul D. Parell*****

Yale University, New Haven, CT, US;

Khan Academy, San Mateo, CA, US

ORCID: <https://orcid.org/0000-0002-6169-5403>

e-mail: pdparell@gmail.com

Sascha Hein*****

Department of Education and Psychology,

Freie Universität Berlin, Berlin, Germany

ORCID: <https://orcid.org/0000-0002-5358-704X>

e-mail: Sascha.Hein@fu-berlin.de



Elena L. Grigorenko*****

Moscow State University of Psychology and Education, Moscow, Russia

Saint-Petersburg State University, Saint-Petersburg, Russia

University of Houston, Houston, TX, USA

Baylor College of Medicine, Houston, TX, USA

Yale University, New Haven, CT, USA

ORCID: <https://orcid.org/0000-0001-9646-4181>

e-mail: elena.grigorenko@times.uh.edu

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***Marina A. Zhukova**, Graduate Research Assistant; University of Houston, Houston, TX, USA; Associate research scientist; Laboratory of Translational Developmental Sciences, Saint-Petersburg State University, Saint-Petersburg, Russia, ORCID: <https://orcid.org/0000-0002-3069-570X>, e-mail: marina.zhukova@times.uh.edu

****Hechm Kilani**, Graduate Research Assistant, Genetic and Neurobehavioral Systems: Interdisciplinary Studies, University of Houston, Houston, TX, USA, ORCID: <https://orcid.org/0000-0002-2424-2165>, e-mail: hechmi.kilani@times.uh.edu

*****Jessica L. Garcia**, Graduate Research Assistant, Genetic and Neurobehavioral Systems: Interdisciplinary Studies, University of Houston, Houston, TX, USA, ORCID: <https://orcid.org/0000-0003-1905-3658>, e-mail: jessica.garcia@times.uh.edu

*****Mei Tan**, Graduate Research Assistant, Texas Institute of Measurement, Evaluation and Statistics, University of Houston, Houston, TX, USA, ORCID: <https://orcid.org/0000-0001-6408-6091>, e-mail: Mei.tan@times.uh.edu

*******Paul D Parell**, Graduate, Yale University, New Haven, CT, US, Product manager, Khan Academy, San Mateo, CA, US, ORCID: <https://orcid.org/0000-0002-6169-5403>, e-mail: pdparell@gmail.com

*******Sascha Hein**, PhD, Professor, Department of Education and Psychology, Freie Universität Berlin, Berlin, Germany, ORCID: <https://orcid.org/0000-0002-5358-704X>, e-mail: Sascha.Hein@fu-berlin.de

*******Elena L. Grigorenko**, PhD, Leading scientist, Moscow State University of Psychology and Education, Moscow, Russia; Principal investigator, Saint-Petersburg State University, Saint-Petersburg, Russia; Professor, University of Houston, Houston, TX, USA; Professor, Baylor College of Medicine, Houston, TX, USA; Professor, Yale University, New Haven, CT, USA, ORCID: <https://orcid.org/0000-0001-9646-4181>, e-mail: elena.grigorenko@times.uh.edu



Digital media is becoming increasingly prevalent in households and classroom settings lowering the age of first exposure to technology; however, little is known about how children experience digital media and how their experiences relate to learning and social engagement. In this case study, we followed a 28-month-old boy in a naturalistic setting for 5 weeks, videotaping the process of his interactions with the iPad. Using a combination of video coding, screen recordings, and a formal academic assessment we evaluated the effects of digital media on specific learning outcomes, child affective states associated with gains in digital literacy, and the role of social interaction in the process of digital media exposure. We found that the number of errors predicted a significant amount of the variance in the child's levels of frustration, attentiveness, help-seeking behaviors, and persistence. Two main types of affect, confusion and attentiveness, predicted gains in his iPad proficiency, providing important insights into the role of emotions in digital learning. With increased levels of iPad proficiency, we observed an inconsistent pattern of child social engagement. This study is the first, to our knowledge, to use a combination of qualitative observation data, standardized assessment, and quantitative analysis of a child's behavior in the process of digital literacy learning.

Keywords: toddler, technology, digital literacy, iPad

INTRODUCTION

Tablet technologies are the most novel addition of digital media to children's environments, as they can be used both as an active and passive technology and require fine motor skills to allow for navigation. The impact of these features on the development of young children currently remains understudied. Compared to the research on tablet use and socializing in adolescence, middle childhood (6 to 12 years old) is considered understudied and toddlerhood (0 to 3 years of age) considered overlooked [1].

The American Academy of Pediatrics recommends that children under the age of 2 should not have any screen time except for video chat [2]. Children between the ages of 2 and 5 years should watch no more than 1 hour of high-quality children's programming per day. However, children under the age of 3 are engaging with this media in various ways alone and with their parents [2]. With today's COVID-19 pandemic, these guidelines might not be as realistic. A recent meta-analysis [3] supported the current pediatric guidelines (mentioned above) on media use by children under the age of 12. The authors analyzed publications from 1960 through March 2019 that included a measure of screen use, a measure of language skills, and statistical criteria that could be transformed into an effect size. Screen use in this context included the use of television, movies, or DVDs on devices such as tablets or television, as well as background television. Forty-two studies (11 of which are from within the past 5 years) accounted for 18,905 participants. A greater quantity of screen use was associated with lower language skills ($r=-0.14$ for screen time, and $r=-0.19$ for background TV), while a better-quality screen use ($r=0.13$ for educational programs, and $r=0.13$ for co-viewing with caregivers) was associated with stronger language skills. A later onset of exposure to digital technology was also associated with stronger language



skills ($r = 0.17$). These findings support that reducing screen exposure, selecting high-quality content, and co-use (how often caregivers joined their children while exposed to screens) of the media are beneficial for children under the age of 12.

Interactions between children and parents when screen-time is involved also plays an important role in children's development. Technology-enhanced storytelling is associated with improved parent-child interaction [4]. To promote learning when using technology and to make a positive difference when learning with digital technologies, adults should be proactive: be present, supportive, and monitor the child's choices, for the technologies to create a positive, learning experience [6]. A study examining the relationship between Internet use and interpersonal communication [7] found that Internet use was significantly correlated ($r = -.13, p < .01$) with decreases in face-to-face family communication, and a decrease in desire for such exchanges ($r = -.120, p < .01$). The study supports the displacement hypothesis by demonstrating that media use, specifically daily Internet use, lowers the time that family spends together and lessens the desire to socialize [7]. In general, it is suggested that screen media, has disruptive effects on the quantity and quality of parent-child interactions. Media use can also be positive, depending on the content of the media used: for example, a longitudinal investigation found that preschool children's viewing of "Sesame Street" suggests a positive effect on children ages 3 to 5 and their vocabulary skills [8]. Other studies suggest that tablet use positively affects fine motor development [9] and promotes visual-spatial skills [10]. Learning from media is associated with cognitive and academic enhancement when programs are age-appropriate and guided by curriculums. Parents are able to maximize positive effects and minimize negative effects of media use by carefully selecting the material to be educational and avoiding purely entertainment and violence focused material. [11]. Learning from media use relies on cognitive demands of a task and a child's cognitive resources which encourages the use of apps that are able to interactively guide attention to important information. For more challenging information, parents are encouraged to use noninteractive video demonstrations for a short term [12].

Digital media is becoming increasingly prevalent in the households and classroom settings lowering the age of first exposure to technology; however, little is known about how children experience digital media and how their experiences relate to learning and social engagement. This case study aims to explore the processes a child goes through to learn to use an iPad, having been introduced to it for the first time at the age of 2 years and 4 months old. We investigate the effects of digital media on specific learning outcomes, child affects associated with gains in digital literacy which refers to proficiency in manipulating and navigating a digital device, and the role of social interaction in the process of digital media exposure.

We hypothesized that the child's performance on an iPad application would increase over time, as well as his digital literacy. We also hypothesized that frustration and confusion would predict the frequency of help-seeking behaviors. In addition, we expected to see a decrease in social interactions and an increase in digital proficiency over time as the child would rely less on a caregiver in problem solving. The findings of Craig and colleagues [13] showed evidence that the level of confusion is critical for optimal learning. Guided by these



results, we hypothesized that confusion and attentiveness would predict child's positive learning outcomes and explain gains in digital literacy and academic knowledge.

METHOD

Participant/Sample

The case subject, Ryan, is a Caucasian male who was 28 months (2 years and 4 months) old at the time of his first iPad exposure. Ryan is raised in a bilingual Russian-English household. He began attending English-based preschool since the age of 18 months. The data presented here were collected while Ryan was with a childcare provider (hereafter, babysitter) outside of his home; he visited the babysitter's house for 3 to 4 hours each time 2 to 3 times per week during the course of the study.

Study Design

During the course of five weeks, Ryan was given the iPad to play with 3 times each week. The researcher and a babysitter sought to assure that the device held his attention for at least 20 minutes per session. In each session, Ryan's interaction with the iPad was videotaped and the iPad's screen recordings were acquired to facilitate formal behavioral coding. Ryan was not given any specific instructions as the focus of the study was on free exploration of digital media. Following Ryan's exposure to the iPad the video recordings of his sessions were coded for a variety of behavioral and performance factors. Further, Ryan's behavior was analyzed to gauge his affect, behavioral characteristics, caregiver interactions during the iPad interactions, and types of manipulations. During the iPad sessions the child was accompanied by a babysitter and/or a researcher (depending on the selected day of recording), who were not given specific instructions and interacted with the child the way they normally would.

Measures

Formal assessments were used to acquire a holistic profile of Ryan's developmental background and academic readiness: The Mullen Scales of Early Learning, MSEL [14], The Clinical Evaluation of Language Fundamentals—4th edition, CELF-4 [15], The Infant-Toddler Social and Emotional Assessment, ITSEA [16], The Conner's Early Childhood Form [17] and the Bracken School Readiness Assessment - Third Edition, BSRA-3 [18]. The school readiness scale was administered three times: to acquire a baseline for Ryan's development prior to iPad exposure, after two weeks of iPad interactions and finally at posttest one week after the iPad sessions discontinued. All assessments were conducted in English.

iPad Application

While the child explored a few applications, for the purpose of the analyses we focused on the Doodle Dots application, as it was the application consistently played throughout the sessions for at least three minutes per sitting. Doodle Dots is a free iPad application released by developer PBS KIDS Sprout in August of 2011. Within the app, children respond to verbal prompts from the game's narrator in order to connect dots and complete a picture. If the wrong dot is selected, the child receives negative feedback (e.g. «That's not a green dot!»), but



there is no limit to the number of incorrect responses allowed or the amount of time needed to connect the dots. The game can be played in 4 modes: numbers, colors, shapes, and fruit.

Video Coding

The video coding system was developed to address Ryan's affect, behavioral characteristics, and caregiver-child interactions during iPad play, and the types of iPad manipulations used. Videos were selected based on their length with a minimum duration of 3 minutes and the length of a coding sequence was based on a single doodle completion. The frequencies of Ryan's behaviors and affects were coded individually, allowing for overlaps. All coding rubrics are summarized in the appendix. The Specific Affect Coding System was used for descriptions of affect facial changes [19]. For the caregiver's behavior, the coding was based on selected categories from the Dyadic Parent-Child Interaction Coding System [20]. Three additional categories (pointing, problem solving, and redirection) were added to the rubric to reflect the specific facilitation of the child's iPad interactions. To analyze the child proficiency on the iPad use, we utilized a 5-point Likert scale developed by J.P. Hourcade, S.L. Mascher, D. Wu, L. Pantoja [21] to rate the ability to operate the device from low (1 point) to very high (5).

RESULTS

Correlations and regressions were completed to test our hypotheses and demonstrate the relative impact of variables on each other. Required assumptions were tested and met for each analysis.

Inter-Rater Reliability

There were five videos recorded throughout the observation period with a mean duration of 6.32 minutes ($SD = 4.14$; $min = 3.57$ minutes, $max = 13.38$ minutes). Coding was carried out by two independent graduate student coders who double-coded two out of nine videos. Interrater reliability was computed as an intraclass correlation coefficient (ICC) for each category of the analysis. For child affect and behavior, an ICC of .75 with a 95% CI [.54 to .89], $F(16,596) = 3.99$, $p < .001$ was achieved. For iPad manipulations the average ICC was .69 with a 95% CI [.41 to .87], $F(16,144) = 3.201$, $p < .001$. The average ICC for the caregiver rubric was .76 with a 95% CI [.57 to .89], $F(16,432) = 4.227$, $p < .001$. For iPad navigation proficiency, the average ICC was .86 with a 95% CI [.62 to .95], $F(16,16) = 4.227$, $p < .001$.

Skill Development

Assessments suggested that Ryan was typically developed in the areas of visual reception and social-emotional development. In language development, Ryan's expressive language was in the Low Average range of ability, which may be due to his bilingual status.

Because Ryan's age fell out of the norming range for the Bracken School Readiness Assessment (BSRA-3), composite scores and percentiles could not be computed and, thus, mastery percentage was used as an indicator of progress. A graphical representation of his mastery across the three time points can be viewed in Figure 1. Ryan's performance distinctly improved in all but one of the measured categories from T1 to T2. His scores then



dropped somewhat from the intermediate assessment to the final assessment, though his performance was still higher than what was observed at the baseline assessment. Given the lack of additional data points the statistical significance of these fluctuations were not studied, and thus these results should be viewed with an understanding that these fluctuations may represent normal variations in skill development typical with this age range.

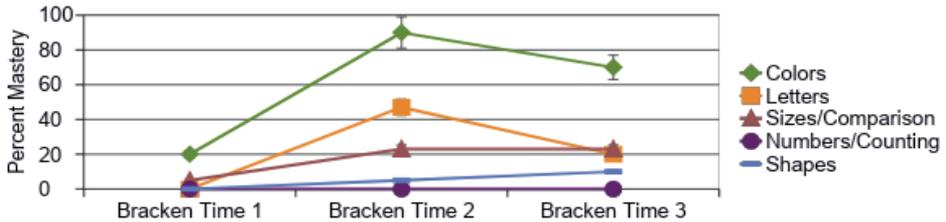


Figure 1. Changes in percent mastery across three administrations of the Bracken School Readiness Assessment, Third Edition (BSRA-3)

Errors

It was initially hypothesized that Ryan would perform better with the game over time. His performance on the game and learning over time was measured on two metrics: academic performance assessed in the number of errors made, and navigation proficiency. For each doodle completed, Ryan received a score from 0 to 5 on how adept he was at navigating the app and following the instructions, which served as his navigation proficiency index. Contrary to the hypothesis, a regression analysis revealed that the number of errors made in the game did not appear to decrease significantly over time, $R^2 = .07$, $F(1,48) = 3.74$, $p = ns$. Time point appeared to be a significant predictor of Ryan's ability to proficiently navigate the application ($R^2 = .11$, $F(1,53) = 6.32$, $p = .01$), though the negative correlation between the two variables ($r = -.33$) indicates that as time progressed, Ryan became less proficient in his use of the app, demonstrating lower accuracy of manipulations.

Affect and Behavior

Aimed at getting a snapshot of the affects and behaviors that a normally developing child experiences when first introduced to a tablet, Ryan's affects and general behaviors were coded. A depiction of the relative occurrence for each affect state, and how Ryan's affect changed over time can be viewed in Figures 2 and 3, respectively. When he was first introduced to Doodle Dots, Ryan would alternate between frustration and confusion. Ryan then reverted to attention seeking behaviors via verbalizations, eye contact, or pointing at the source of the issue. Over time, Ryan's help-seeking lessened in frequency as his frustration reduced.

As shown in Figure 4, eye contact and smiling were the most frequent behaviors that Ryan demonstrated throughout the sessions, both of which typically co-occurred with delight. However, Ryan was also noted to seek eye contact in instances of confusion. Persistence was prominent during the times Ryan got bored and started losing interest. We expected to observe a reduced need for assistance as Ryan's navigation proficiency increased. Interestingly, Ryan sought help regardless of his proficiency level. As can be



viewed in Figure 5, several of the behaviors were noted to decrease over time, particularly those of a social nature.

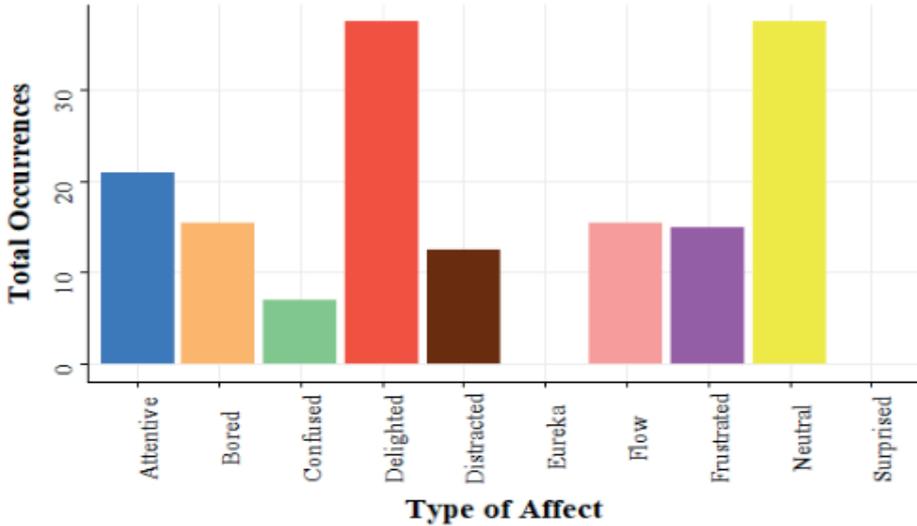


Figure 2. Total occurrences of coded affect states across all time points

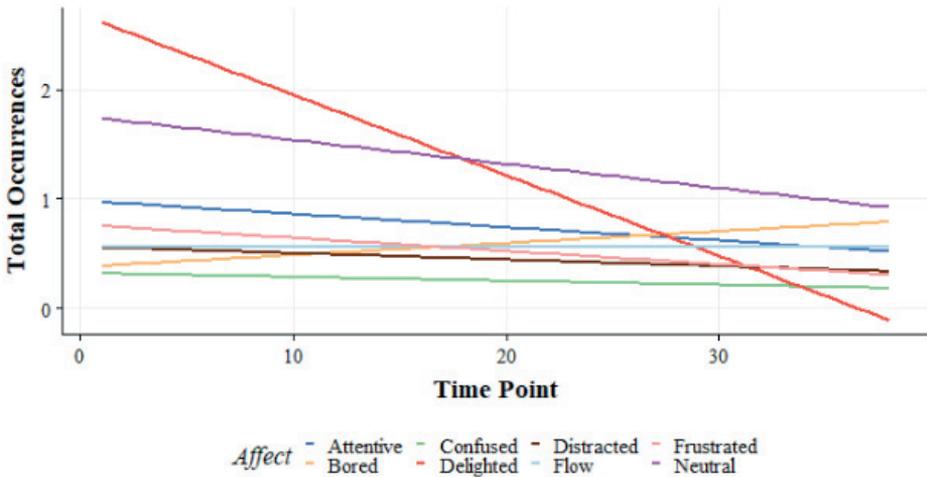


Figure 3. Changes in affect states over time estimated using linear regression. Two types of affect (“eureka” and “surprised”) were not included given their lack of occurrence

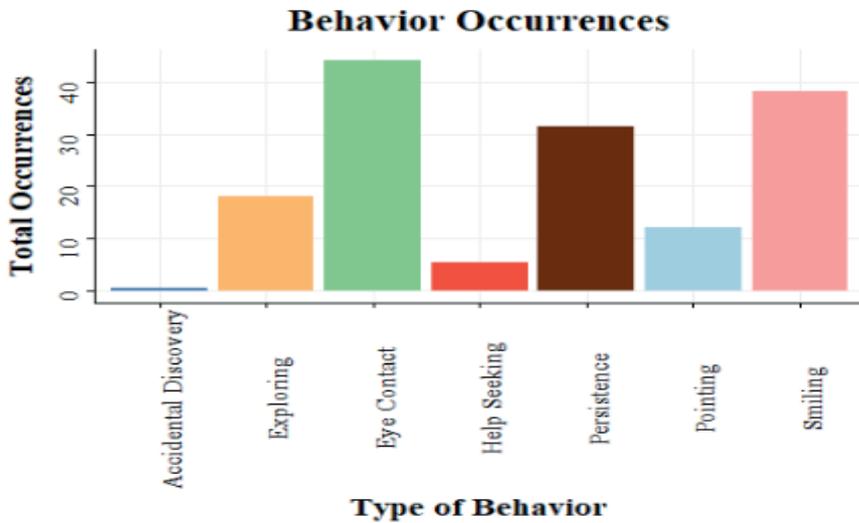


Figure 4. Total occurrences of coded child behaviors across all time points

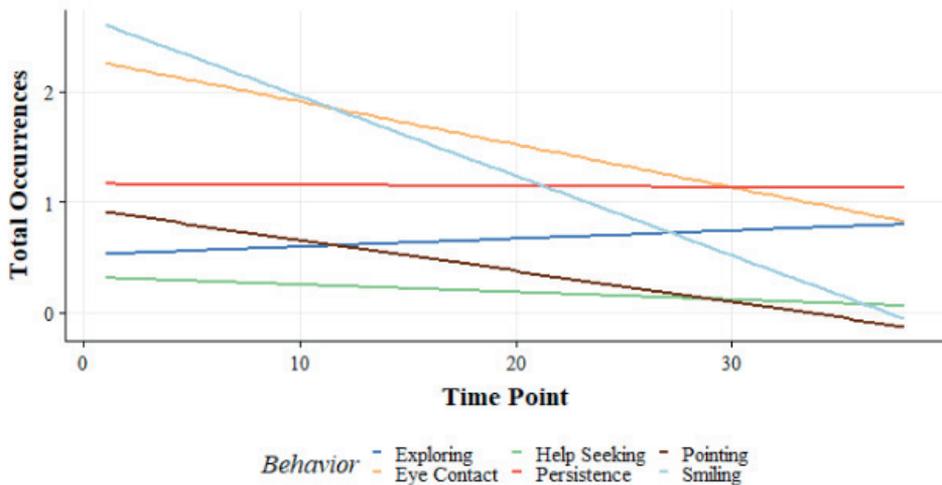


Figure 5. Changes in child behaviors over time estimated using linear regression. One type of behavior (“accidental discovery”) was not included given its infrequency of occurrence

Digital Literacy

The appropriateness and efficiency of iPad manipulations were used as the main metrics to characterize overall index of child’s digital literacy. We conceptualized the appropriateness of manipulations as all manipulations that can be applied to a tablet and lead to meaningful outcomes. All iPad manipulations were mastered by Ryan either independently or through



the observation of the caregiver. Most of Ryan's actions were purposeful and reflected a good understanding of the required actions from the early stages of his iPad interactions. His task performance indicated that some of the concepts were more difficult than others, with shapes producing on average more errors after controlling for the number of times played.

Digital literacy metrics suggested that Ryan started out showing moderate skill in navigating the iPad, and speed and precision of his manipulations increased over time. Some of the inappropriate and ineffective manipulations that were observed included hitting the iPad with a palm or fist, which was typically associated with frustration and boredom. Initially, we hypothesized that Ryan's proficiency in iPad manipulations would increase over time. However, contrary to our prediction, the frequency of inappropriate manipulations increased. One potential explanation could be that Ryan explored iPad functionality by trying out a new behavior repertoire. Another explanation is increased boredom. Over time, Ryan appeared to grow tired of the familiar app and expressed his boredom and frustration in inappropriate manipulations (e.g., sloppiness). In line with this hypothesis is the observation that Ryan began more frequently switching categories in Doodle Dots app (e.g., from colors to fruit) as time went on and was browsing for desired doodles for periods of time longer than that spent completing the actual tasks.

Relation between affect, behavior, and digital performance

Correlational analysis revealed that the number of errors Ryan made on Doodle dots were significantly related to the frequency of affect states, including frustration ($r = .32$, $p = .02$), attentiveness ($r = .47$, $p < .001$), help-seeking ($r = .27$, $p = .05$), and persistence ($r = .42$, $p < .001$). All correlations were positive, which indicates that as errors increased, so did the measured affects and behaviors. It was hypothesized that two types of affect, confusion and attentiveness, would predict navigation proficiency. A multiple regression confirmed this hypothesis, $R^2 = .48$, $F(3,51) = 15.75$, $p < .01$. It was noted that both confusion ($\beta = .40$, $p < .01$) and attentiveness ($\beta = .17$, $p = .01$) significantly predicted variance in navigation proficiency, whereas the interaction between the two affects did not ($\beta = .12$, $p = ns$). Finally, it was predicted that child help seeking would predict navigation proficiency, though analyses revealed this association to be non-significant.

Relation between affect and social behaviors

We hypothesized that social interactions with the caregiver would decrease over time. The results of the regression analysis generally supported this hypothesis. Specifically, it was found that time, as measured by each progressive doodle completed in the game, predicted a significant level of the variance in pointing ($R^2 = .20$, $F(3,51) = 13.51$, $p < .001$), smiling ($R^2 = .46$, $F(3,51) = 46.03$, $p < .001$), and eye contact with the caregiver ($R^2 = .12$, $F(3,51) = 7.42$, $p = .010$). The results of the correlational analyses indicate a moderate negative relation between time and each of these social behaviors ($r = -.45$, $-.68$, $-.35$, respectively) which indicates that these social behaviors decreased over time.

It was also predicted that Ryan's affect, particularly frustration and confusion, would predict frequency of help seeking behaviors. It was found that confusion and the interaction between confusion and frustration predicted a significant amount of the variance in help



seeking behaviors, but frustration alone did not, $R^2 = .21$, $F(3,49) = 4.45$, $p = .01$. We have also found that delight predicted eye contact with the caregiver $R^2 = .34$, $F(1,53) = 26.98$, $p < .001$, $r = .58$.

Caregiver Behaviors

As shown in figure 6, the most frequent form of scaffolding was questions, followed by statements and acknowledgements. Caregiver's questions were primarily reiterations of the Doodle dots instructions ("Where is the blue dot?") or referred to the type of Doodle/category the child was interested in playing next. We observed that the most scaffolding was provided when the child was first introduced to the iPad, with caregiver's interference becoming minimal during the last sessions. Verbal praise was used to encourage the child's exploration and participation. Overall, the frequency breakdown of caregiver's behavior suggests minimal direct involvement (pointing, redirection, problem solving) and caregiver's preference to utilize indirect commands, verbal praises and statements as opposed to negative and direct commands with explicit instructions.

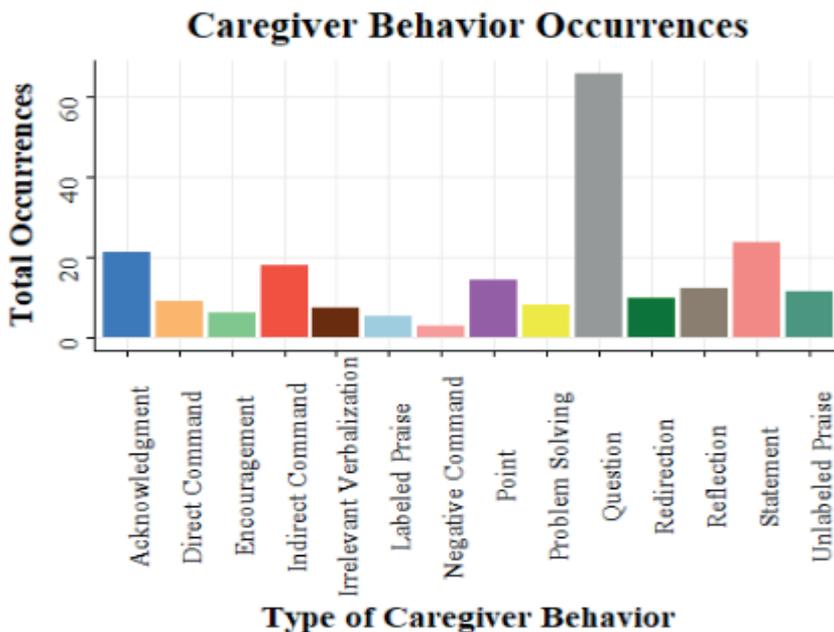


Figure 6. Total occurrences of coded caregiver behaviors across all time points

DISCUSSION

The current study utilized a set of single-case observations of a 28-month-old boy in the naturalistic setting over the course of 5 weeks in the process of his iPad interactions. This



study is the first, to our knowledge, to use a combination of qualitative observation data, standardized assessments and quantitative analysis of child's behavior in the process of digital literacy learning.

Results showed that Ryan's performance on the BSRA-3 distinctly improved from the pre-assessment to the intermediate assessment in the categories of colors, letters and sizes but the categories of numbers and shapes did not show significant improvement. His scores then dropped somewhat from the intermediate assessment to the final assessment, which we believe may be explained by the regression toward the mean. The increase in Ryan's performance on colors, numbers and shapes shaped our hypothesis of knowledge transference as we believed that the increases were due to the iPad application. When we analyzed the number of errors in Doodle Dots over time, results showed that there was no significant decrease in errors. These findings are most likely explained by the fact that Ryan grew bored with the repetitiveness of the task and committed more errors to skip the trial and get to the next Doodle.

A number of studies have shown that affect is not a byproduct of learning but an important factor shaping achievement [e.g., 22]. It has been shown that higher enjoyment and lower boredom predicts greater math achievement in 5th and 6th graders [23]. Another study found a negative association between boredom and learning gains [13]. Interestingly, other authors argue that boredom can be seen as an affect that leads to creativity and exploration [24].

Our findings on digital literacy acquisition show that contrary to our initial hypothesis, the number of functionally inappropriate manipulations did not decrease over time. We also observed an inverse effect with navigation proficiency, indicating that Ryan became less proficient with digital technology over time. We believe that these findings can be explained by Ryan's high persistence, and growing boredom and frustration as he was navigating the app.

Our findings show that during iPad interactions, the leading types of affects were delight and neutral, followed by attentiveness, boredom, flow and frustration. We have noticed that when flow co-occurred with attentiveness, Ryan was the most proficient with his manipulations and concept identification. These observations are corroborated by the findings of S. Craig, A. Graesser, J. Sullins, B. Gholson [13] showing that flow has a meaningful effect size on learning (Cohen's $d = .22$). A few papers have argued that confusion is a corner stone of productive learning as it has been linked to flow and learning gains. In line with these findings, our data showed that confusion and attentiveness (but not their interaction) predicted higher navigation proficiency. However, given the small number of instances that Ryan experienced confusion in the current study, our results should be interpreted with caution. Importantly, we noticed that when confusion was coupled with attentiveness Ryan was more likely to achieve the desired result in his iPad manipulations compared to instances, where confusion was linked to frustration or boredom. This observation is in line with the B. Kort, R. Reilly, R.W. Picard [25] model of constructive learning that shows confusion as an emotion driving positive learning, but frustration as a negative affect hindering learning processes.

The child's behavior involved several instances of help-seeking, which was not reduced as a function of digital proficiency. At the same time, we observed a decrease in other social behaviors over time. These findings point to the differential relationship between types of emotions and sharing. Our study shows that as positive affects become less socially



oriented over time, the child tends to rely on the caregiver only in instances of negative affect. These findings provide an important view on the role of caregiver as a mediator in digital literacy acquisition. We observed that the most frequent forms of scaffolding were questions, followed by statements and acknowledgements. Generally, indirect instructional approaches relying on praise, indirect commands and questions have been shown to be effective in boosting child's exploration, creativity and building self-esteem [26, 27]. We believe that in situations of carefully selected content, low caregiver interference is beneficial for digital literacy learning as it promotes children's creativity and exploration; however, our data shows that boredom and frustration are negatively associated with learning gains and in these instances caregiver's interference would be warranted.

The role of digital media in the lives of toddlers is currently being re-evaluated as families and educational institutions are facing new challenges with COVID-19. Even though the findings on the impact of digital media are controversial, experts agree that balance and moderation is the key to a positive experience with digital media and encourage parents to think more about the quality of the content and less about the quantity [28]. The E-AIMS Model which refers to the media that is that is Engaging, Actively Involved, Meaningful, and Social [29] encourages parents to choose content with clear story lines that children can understand and relate to, and to actively involve the child in the discussion about the content. This idea is also reflected in the guidelines suggesting that the child is developmentally ready for digital content as soon as they are able to talk about their experiences [30]. In our study we observed that Ryan was able to capitalize on his vocabulary to do so as the content corresponded to his current level of verbal skills (i.e., when the doodle was named after completion Ryan was able to repeat the word). At the same time the Doodle Dots application used in the study only partially aligns with the E-AIMS model as the application does not encourage social interaction. Monitoring for the difficulty of the content is an important aspect. The E-AIMS Model encourages parents to promote active involvement of a child instead of being in "autopilot" mode. We believe that the content selected in line with E-AIMS recommendations will allow for some flow experience, where after the initial state of confusion the child effortlessly completes a series of tasks quickly and effortlessly. The flow state promotes competence and has been positively linked to learning gains [31]. In our study we identified that when flow was co-occurring with attentiveness, Ryan was the most proficient with his manipulations and concept identification. We believe that when flow is coupled with a high attention allocation it should be considered an indicator of successful learning rather than autopilot mode. When the activity gets too familiar the child might transition into boredom and a more challenging task should be offered, reflecting the principle of the zone of proximal development. Our findings show that digital literacy acquisition is not linear.

The study has limitations. As an observational case study, external validity is limited and, caution should be taken in generalizing the results of these exploratory analyses until these findings are replicated. In addition, due to the ways in which the videos were coded, the temporal sequence of affects, behaviors, and app-related was not recorded and thus the researchers could not make any inferences about the directionality or causality between the



variables of interest. Future studies should employ the use of advanced software, which would allow to track the sequencing of these variables in order to make stronger inferences about the nature of their relationships. Another limitation is the lack of other educational applications that could have allowed the researchers to explore the extent to which these patterns can be found when the child is exploring other applications. Given that the child in the current study was not directed to use specific applications by the caregiver and was given free rein to explore, it may also be beneficial for future research to examine what drives children to choose specific applications, and subsequent learning experiences, over others.

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Как ребенок осваивает электронные технологии? Анализ случая 28-месячного ребенка в процессе освоения iPad

Марина А. Жукова*

Хьюстонский университет, Хьюстон, США
Лаборатория междисциплинарных исследований развития человека
Санкт-Петербургский государственный Университет (Россия)
ORCID: <https://orcid.org/0000-0002-3069-570X>
e-mail: marina.zhukova@times.uh.edu

Хешми Килани**

Лаборатория междисциплинарных исследований генетики и
нейроповеденческих систем; Хьюстонский университет, Хьюстон, США
ORCID: <https://orcid.org/0000-0002-2424-2165>
e-mail: hechmi.kilani@times.uh.edu

Джессика Л. Гарсия***

Лаборатория междисциплинарных исследований генетики и
нейроповеденческих систем; Хьюстонский университет, Хьюстон, США
ORCID: <https://orcid.org/0000-0003-1905-3658>
e-mail: jessica.garcia@times.uh.edu

Мей Тан****

Техасский институт измерений,
оценки и статистики, Хьюстонский университет, США
ORCID: 0000-0001-6408-6091
e-mail: Mei.tan@times.uh.edu

Пол Д. Перэл*****

Йельский университет, Нью Хейвен, Коннектикут, США
Khan Academy, Сан Матео, Калифорния, США
ORCID: <https://orcid.org/0000-0002-6169-5403>
e-mail: pdparell@gmail.com

Саша Хайн*****

Департамент Образования и Психологии,
Свободный Университет Берлина, Германия
ORCID: <https://orcid.org/0000-0002-5358-704X>
e-mail: Sascha.Hein@fu-berlin.de

Елена Л. Григоренко*****

Московский государственный психолого-педагогический
университет, Москва, Российская Федерация
Санкт-Петербургский государственный университет,
Санкт-Петербург, Российская Федерация
Хьюстонский университет, Хьюстон, Техас, США



Бэйлорский медицинский колледж, Хьюстон, Техас, США
Йельский университет, Нью-Хейвен, Коннектикут, США
ORCID: <https://orcid.org/0000-0001-9646-4181>
e-mail: elena.grigorenko@times.uh.edu

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***Марина А. Жукова**, Кандидат психологических наук, Ассистент-исследователь, Хьюстонский университет (США); Научный сотрудник Лаборатории междисциплинарных исследований развития человека Санкт-Петербургский государственный Университет, Россия, ORCID: <https://orcid.org/0000-0002-3069-570X>, e-mail: marina.zhukova@times.uh.edu

****Хешми Килани**, Ассистент-исследователь Лаборатории междисциплинарных исследований генетики и нейроповеденческих систем; Хьюстонский университет, Хьюстон, США, ORCID: <https://orcid.org/0000-0002-2424-2165>, e-mail: hechmi.kilani@times.uh.edu

*****Джессика Л. Гарсия**, Ассистент-исследователь Лаборатории междисциплинарных исследований генетики и нейроповеденческих систем; Хьюстонский университет, США, ORCID: <https://orcid.org/0000-0003-1905-3658>, e-mail: jessica.garcia@times.uh.edu

******Мей Тан**, Ассистент-исследователь, Техасский институт измерений, оценки и статистики, Хьюстонский университет, Хьюстон, США, ORCID: <https://orcid.org/0000-0001-6408-6091>, e-mail: Mei.tan@times.uh.edu

*******Пол Д. Перэл**, Выпускник Йельского университета, Нью Хейвен, Коннектикут, США Менеджер по продукту, Khan Academy, Сан Матео, Калифорния, США, ORCID: <https://orcid.org/0000-0002-6169-5403>, e-mail: pdparell@gmail.com

*******Саша Хайн**, PhD, Профессор, Департамент Образования и Психологии, Свободный Университет Берлина, Германия, ORCID: <https://orcid.org/0000-0002-5358-704X>, e-mail: Sascha.Hein@fu-berlin.de

*******Елена Л. Григоренко**, PhD, доктор психологических наук, ведущий научный сотрудник, Московский государственный психолого-педагогический университет, Москва, Российская Федерация; главный исследователь, Санкт-Петербургский государственный университет, Санкт-Петербург, Российская Федерация; профессор, Хьюстонский университет, Хьюстон, Техас, США; профессор, Бэйлорский медицинский колледж, Хьюстон, Техас, США; профессор, Йельский университет, Нью-Хейвен, Коннектикут, США, ORCID: <https://orcid.org/0000-0001-9646-4181>, e-mail: elena.grigorenko@times.uh.edu



Электронные технологии набирают все большую популярность и представлены как в домашнем окружении, так и в образовательных учреждениях, снижая возраст первого контакта ребенка с электронными устройствами; при этом существует недостаток исследований, посвященных процессу освоения электронных технологий детьми дошкольного возраста и связи данного процесса с социальным взаимодействием. В данном исследовании мы рассматриваем случай 28-месячного ребенка в процессе обучения взаимодействию с планшетным компьютером. Данные взаимодействия регистрировались на видео в течение 5 недель. Используя комбинацию кодирования видеозаписей, анализа записей экрана и стандартизованного академического тестирования нами были проанализированы эффекты, оказываемые электронными технологиями на различные аспекты обучения, аффективное состояние ребенка, а также роль социального взаимодействия в процессе освоения технологий. Результаты исследования свидетельствуют о том, что количество ошибок предсказывало состояние фрустрации, уровень внимания ребенка, частоту обращения ко взрослому за помощью, а также настойчивость. Два ключевых состояния ребенка, затруднение и внимательность, были связаны с улучшением навыков пользования iPad. Полученные данные вносят важный вклад в понимание роли эмоционального компонента в процессе научения. По мере нарастания навыка пользования iPad, ребенок демонстрировал противоречивый паттерн социального взаимодействия. Данное исследование является первым, использующим комбинацию качественной оценки данных наблюдения, стандартизованного тестирования и количественного анализа поведения ребенка в процессе приобретения технической грамотности.

Ключевые слова: тоддлер, технологии, техническая грамотность, iPad.

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