Counting Coconuts and Apples: Young Children ‘Kinect-ing’ *Sesame Street* and Mathematics

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Abstract: The ability to count objects is a crucial skill for young children. We report on an experimental study that utilized a *Kinect Sesame Street TV* intervention designed to support two types of counting activities. Our quantitative analysis is supplemented by our preliminary qualitative analyses, and the complexity of these contexts for mathematical learning is unpacked with the assistance of literature from the fields of mathematics education and cognitive science. We conclude by making recommendations for interactive educational design in general.

Introduction

A foundational skill that young children need to develop for mathematics learning is counting. The Common Core State Standards for Mathematics Kindergarten standards state that students should learn the number names and count sequence, and be able to count objects (National Governors Association Center for Best Practices, 2010). The National Council of Teachers of Mathematics include in the pre-kindergarten to second grade-band the requirement that all students learn to count with understanding, be able to determine the size of sets of objects, and use numbers to count quantities (2000). Being able to count and connect the counting specifically to specific objects is a crucial part of learning to mathematize the world, as well as continue in further mathematics learning trajectories. This project focuses specifically on supporting 3 and 4 year-old children in counting by using a *Sesame Street* episode made interactive by the Microsoft Kinect. In the following section, we review literature on videogames and learning, and embodied cognition and mathematics. We then further describe the relationship between the Kinect and *Sesame Street*, before transitioning to Methods.

Considerably varied research indicates that videogames can be powerful vessels for learning (Barab, Gresalfi, & Ingram-Goble, 2010; Fisch, Lesh, Motoki, Crespo, & Melfi, 2011; Gee, 2003; Squire, 2011; Steinkuehler & Duncan, 2008). By leveraging some elements of videogame design and making the traditionally televised one-way information flow into an interactive learning experience, the *Sesame Street* Kinect series has the potential to increase the engagement and learning of its participants. In particular, this multimodal design aligns with embodied cognition research that suggests that cognition and action are intertwined (Shapiro, 2011). Theories of embodied cognition contend that thinking and learning are not based on amodal symbol systems, but rather are inextricably woven into action and perception systems (Barsalou, 1999, 2008). Researchers examining the relationship of action and gesture to mathematics learning have found promising results (Alibali & Goldin-Meadow, 1993; Glenberg, Jaworski, Rischal, & Levin, 2007; Nathan, Kintsch, & Young, 1992), including interventions in which actions and gestures are designed to be related to successful solving of specific conjectures (Dogan, Williams, Walkington, & Nathan, accepted; Walkington et al., accepted; Walkington, Srisurichan, Nathan, Williams, & Alibali, 2012). In summary, physical action can influence mathematical cognition, and consequently, using the Kinect in conjunction with episodes designed to support mathematical learning may leverage action as a way to support cognition.

In 2010 Microsoft Studios released the Kinect, an Xbox peripheral device for motion-sensing input. Since it’s release, Microsoft has worked on ways to engage audiences beyond their traditional core gamer, producing titles like *Dance Central*, *Kinect Sports*, *Disneyland Adventures*, and *Nike+ Kinect Training* to engage kids and families. Among the products that Microsoft has released to push the boundaries of a traditional gaming and the television viewing experience is Kinect TV (2012), with initial product lines that include a uniquely developed set of *Sesame Street* interactive television episodes.

Sesame Street is a proven television format with an extended media legacy of success. The format has been shown to produce learning gains in younger viewers across studies over the last forty years, including a longitudinal study that supports the findings of learning gains (Ball & Bogatz, 1970; Bogatz & Ball, 1971, Fisch & Truglio, 1991). For the developers of *Kinect Sesame Street TV*, the goal was to extend an already successful media. The designers wanted to design from a firm research base to make sure that the added Kinect interactivity wouldn’t break the potential for learning gains found in the linear television format (Rothschild, internal Microsoft white paper, 2012). This included understanding situated learning theory and the role of learning in the context of relevant activity (Gee, 2003; Barsalou, Niedenthal, Barbey, & Ruppert, 2003), and viewing the potential learning through a lens of embodied cognition, connecting concepts to a learner's own perceptions which includes relationships between the content and themselves/their own bodies (Glenberg, Jaworski, Rischal, & Levin, 2007; Glenberg, Brown, & Leven, 2007).

The questions about the nature of learning with *Kinect Sesame Street TV* led to a research project conducted at Microsoft Studios in which researchers began to investigate the nature of participant experiences in two-way episodes and traditional builds, what concepts are learned in each context, and how interactivity may relate to concept learning. The episode follows *Sesame Street*'s emphasis on literacy and STEM, and includes a word of the day, a number of the day, and to connect to the interactive elements, a move of the day. The preliminary results show that all students that watched the episode in this study (both experimental and comparison groups) showed statistically significant learning gains when all the tests were collapsed. This paper goes deeper into a quantitative analysis of the questions specifically related to number knowledge, and presents the preliminary investigation of the number knowledge component of the episode studied within the frames of current math education and cognition research.

Methods

Forty-two three and four year-olds participated in the study. The group was composed of a mix of boys and girls from Seattle and its surrounding areas. The requirements for participant families were that they needed to have regular access to an Xbox 360 and Kinect in their home, that they had not previously viewed the episodes, and that the child was proficient with English. Data was predominantly collected at the Microsoft User Research Labs, and consisted of video footage, observation notes, pretests and posttests, and parent surveys (including demographic data). Participants were divided into two groups of twenty-one by a process of stratified random sampling, accounting for gender and known family annual income. One group of participants was designated as the *KINECT* group, in which *Kinect Sesame Street TV* experiences took place as designed with all interactions on. The other group was the *TRADITIONAL* group, in which all interactions in the episode were turned off and the participant experienced the same content as was in the episode, edited to a non-interactive, linear format.

Participants came in to the research lab with a parent or guardian, and participated in a pretest, watched the episode, then completed a midtest. The child and guardian left the lab with a copy of the episode in the format that they viewed (*KINECT* or *TRADITIONAL*) and then played the same episode at home over the next couple weeks. Parents logged their child's play and made observations. The child and a parent or guardian returned to the lab one more time to view the episode and then participate in a posttest. For the purposes of this paper, analysis is specifically targeting the questions regarding the number five (the number of the day for the episode), and comparing pre- and posttest scores for analysis.

Number Knowledge in the Episode

In the episode, the scene opens with Cookie Monster dropping a banana peel on the ground, which a bustling Grover then slips on, dropping his delivery of five coconuts. Grover then asks the audience member to please help him collect his five coconuts by throwing them into his box. For each throw, an image of the box is displayed with a visual of how many coconuts are now in the box. The number of coconuts in the box is displayed in the lower right corner of the box (See Figure 1 on the next page). Grover states, "Now I have *(number)* coconuts in the box." At the end, the box with five coconuts and the number five in the bottom right corner is displayed as Grover cheers, "Hooray! Now I have FIVE coconuts!" In the *KINECT* group, when the participants threw, the Kinect motion sensor would respond to their movement in the system, and the coconut would fly into the screen and into Grover's box, sometimes in silly and surprising ways (See Figure 2 on the next page). If the child did not throw the coconut, Cookie Monster would come into the scene having "found" one, and drop it into Grover's box. Grover would then ask the audience member to try throwing the next one. The *TRADITIONAL* group would get the verbal prompts from Grover to throw the coconut, however, their activity did not affect the way the show progressed, and for each coconut, the show would progress as if the child had made a successful throw.

Figure 1: Throwing coconuts into Grover's box.

Figure 2: Participant throwing coconut.

The Performance Assessment

The assessment activities were designed to feel playful and both match the spirit of the episode and align with the sorts of performance elicited in the show. The researcher began by asking the participant to pretend with her, pretending that they had been walking through an apple farm together (situating the activity). The researcher then declares, "Oh look! We found some apples on the ground!" and displays a page with five apples on it (See Figure 3 below). The researcher then asks, "Can you count how many apples we found?" and prompts with "Point to and count each apple that you see" if necessary. If the child counted to five, it was coded as correct; anything other than counting exactly to five was coded as incorrect.

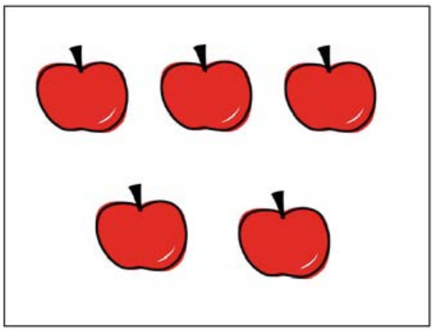

Figure 3: Enumeration activity.

Immediately following the enumeration activity, the researcher segued into the number application activity by telling the child that Cookie Monster loves apples, and that today they were going to help him cook! The participant helped decide what should be cooked (apple cookies, apple cake, applesauce, etc.), and the researcher brought out a bowl, seven foamcore apples, and an image of Cookie Monster, placing them in front of the child (see Figure 4 on the next page).

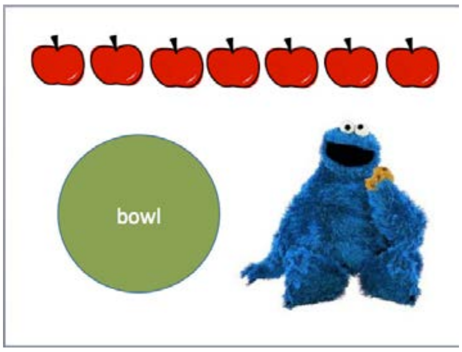

Figure 4: Number application activity.

The researcher then told the participant that Cookie Monster needed exactly five apples to make his recipe, and asked, “Can you put five apples in Cookie Monster’s bowl?” If the participant placed five apples in the bowl, it was coded as correct. Anything other than five apples in the bowl was coded as incorrect.

Results

In this section, we share the results we anticipated, and then share the actual results. We then explore more deeply why some of our expected results and actual results did not align, and propose an explanation of this divergence. We then make recommendations to field as a whole, in order to give insight into designs that more deeply support the desired types of learning.

Expected Results

As a consequence of playing the *Sesame Street* episode, we expected the children to improve in their ability to count to five, and to increase their understanding of how an individual object relates to a set of objects. In particular, we expected children to know that if—for example—one apple had already been counted, adding another apple would result in two apples total, and so on until five apples were reached. Based on the existing success of the *Sesame Street* platform and the earlier preliminary results of the overall assessment (Rothschild, internal Microsoft white paper, 2012), we theorized that both groups would show learning gains, with the possibility of the *KINECT* group showing greater gain due to increased activity and engagement.

Actual Results

The actual results did not unilaterally fulfill our expectations. Regarding our hypothesis that the *KINECT* group would perform better than the *TRADITIONAL* group, no significant difference was found between the two conditions according to Fisher’s Exact Test for the enumeration ($p > .05$) or the number application ($p > .05$) tasks. Furthermore, no significant difference was found when the conditions were collapsed ($p > .05$). However, the results of our preliminary qualitative analyses align quite well with literature on child development and mathematics learning, and suggest that the lack of significance is due to considerably different reasons for each test.

For the enumeration test, 38 children contributed complete data to our analysis. Of those 38 children, 28 were successful in enumerating five apples during the pre-test, indicating that counting to five was a skill that these participants were already quite competent at. At post-test, 32 participants were successful (which included all 28 who replied accurately during the pre-test). Given that nearly 75% of participants came into the study with the target skill, it is hardly unexpected that a ceiling effect occurred.

The number application test, on the other hand, suffered from no ceiling effect but similarly demonstrated few gains. 16 of the 38 participants were successful during the pre-test, and only 20 were successful during the post-test (again, all the participants who performed correctly during the pre-test continued to be correct in their post-test). Intriguingly, as an exact but nonverbal task, this performance assessment appears to be quite achievable, even for participants of this age (e.g., Baroody, Lai, & Mix), so the study did not accidentally include a task with achievable content but overly challenging performance demands (as Gelman & Meck (1983) so eloquently warn us about).

Reconciliation of Expectations and Findings

The results of the number application test were surprising and interesting. Our preliminary qualitative analysis indicates a nuanced complication: participants who enumerated five apples and *then* placed them simultaneously into the bowl were likely to be successful. However, participants who attempted to enumerate the apples one-by-one, placing each one into the bowl individually, were likely to be unsuccessful. Starkey (1992) offers illumination into this quandary (following the path of Gelman & Gellistel, 1978), by distinguishing between *numerical abstraction* and *numerical reasoning*:

> Numerical abstraction (or enumeration) comprises a set of abilities that are used to form representations of numerosities of sets. An example is verbal counting. Numerical reasoning comprises a set of abilities that are used to operate upon or mentally manipulate representations of numerosity. (p. 94)

Consequently, our preliminary results indicate that participants who used an enumeration strategy during this task tended to be successful, while other participants were unsuccessfully attempting to mentally represent both the desired set size (five) and the current set size (how many apples were already in the bowl, and not easily visually accessible). Young children tend to be successful at counting when they can move and touch the objects they are counting, and considerably less successful when they cannot do so and must consequently maintain a mental representation of the set in their minds (Gelman & Meck, 1983), as well as perform the numerical reasoning necessary to continue adding objects to the set.

Recommendations for Interactive Educational Design

Our design recommendations are broad, and go beyond the scope of this particular study. It is quite easy to examine the findings of the second performance assessment and make particular design recommendations. For example, based on the literature cited above, the finding that participants struggled to count five apples into the bowl is not surprising—and fixing it may be as simple as re-designing the intervention so that Grover responds slightly differently when catching a coconut. For example, when the third coconut lands, Grover could say, “Three! One, two, three!” (while pointing at the individual coconuts). This design may support the children in not only counting but in repeatedly being exposed to the relationship of one object to the full group of objects. Naturally, this recommendation needs empirical testing! Consequently, we go beyond this local recommendation and instead venture to make some recommendations for the field as a whole.

The interactive media industry is saturated with products and applications targeting basic math and literacy skills for early childhood. A strong conceptual foundation requires that children have the ability to move from basic knowledge to content application. This analysis shows that for an older preschool target audience, interactive media developers would be well advised to move beyond enumeration activities and look into supporting the transition from enumeration to number application. Additionally, this analysis shows that what may appear (particularly to adults) to be a simple cognitive progression may be riddled with complexities for a young child who is learning higher order number sense. Interactive media tools hold promise for providing meaningful learning experiences for children, but the complex nuances of learning, particularly in mathematics education, may require specific forms of scaffolding, like that suggested above. While it is quite simple to merely discard results that, like ours, show no significant difference between pre- and posttests, it is through qualitative analyses that we—as a field—can unpack the complications of learning and design more powerful interactive educational opportunities.

Conclusion

The preliminary results here indicate that while there were not significant learning gains between the pre- and post mathematics assessments, our preliminary qualitative analysis reveals intriguing findings can be explained in part by existing research in mathematics education and cognition. Our ongoing qualitative analysis examines the demonstrative behaviors of the study participants as they perform the required activities of the number knowledge assessment items. While this can provide the researchers with a deeper understanding of both participant engagement with a situated learning activity and the nuanced methods in which early learners demonstrate their knowledge of specific content, the suggestions for interactive media development proposed still stand. Interactive media is poised to dramatically change the field of learning, especially when pairing newly emerged technologies like the Kinect with tried-and-true educational interventions like *Sesame Street*. The results that are most useful for designers and mathematics educators, however, may be hiding behind a simple test that declares discouragingly: “No significant differences.”

References

Alibali, M. W., & Goldin-Meadow, S. (1993). Gesture-speech mismatch and mechanisms of learning: What the hands reveal about a child's state of mind. *Cognitive Psychology*, 25, 468-523.

Ball S., & Bogatz, G.A., (1970). *The first year of Sesame Street: An evaluation.* Princeton, N.J.: Educational Testing Service.

Barab, S.A., Gresalfi, M., & Ingram-Goble, A. (2010). Transformational play: Using games to position person, content, and context. *Educational Researcher*, 39(7), 525–536. doi:10.3102/0013189X10386593

Baroody, A. J., Lai, M. L., & Mix, K. S. (2006). The development of young children's early number and operation sense and its implications for early childhood education. In B. Spodek & N. Olivia (Eds.), *Handbook of research on the education of young children* (2nd ed.). Mahwah, NJ: Lawrence Erlbaum.

Barsalou, L. W. (1999). Perceptual symbol systems. *Behavioral and Brain Sciences*, *22*(4), 577-609; disc. 610-60.

Barsalou, L. W. (2008). Grounded cognition. *Annual Review of Psychology*, *59*, 617-45.

Barsalou, L.W., Niedenthal, P.M., Barbey, A., & Ruppert, J. (2003). Social embodiment. In B. Ross (Ed.), *The Psychology of Learning and Motivation,* Vol. 43 (pp. 43-92). San Diego: Academic Press.

Bogatz, G.A., & Ball, S., (1971). *The second year of Sesame Street: A continuing evaluation.* Princeton, N.J.: Educational Testing Service.

Dogan, M.F., Williams, C.C., Walkington, C., & Nathan, M. (accepted). *Body-based examples when exploring conjectures: Embodied resources and mathematical proof.* Poster presentation to be conducted at the Research Pressession of the 2013 National Council of Teachers of Mathematics Annual Meeting and Exposition. Denver, CO.

Fisch, S.M., Lesh, R., Motoki, E., Crespo, S., & Melfi, V. (2011). Children's mathematical reasoning in online games: Can data mining reveal strategic thinking? *Child Development Perspectives, 5*(2), 88-92.

Fisch, S.M., & Truglio, R. T. (2001). *"G" is for growing: Thirty years of research on children and Sesame Street.* Mahwah, N.J.: Erlbaum.

Gee, J.P. (2003). *What video games have to teach us about learning and literacy.* New York: Palgrave MacMillan.

Gelman, R., & Meck, E. (1983). Preschoolers' counting: Principles before skill. *Cognition, 13*(3), 343–59.

Glenberg, A., Jaworski, B., Rischal, M., & Levin, J. (2007). What brains are for: Action, meaning, and reading comprehension. In D. McNamara (Ed.), *Reading comprehension strategies: Theories, interventions, and technologies* (pp. 221–238). Mahwah, NJ: Erlbaum.

Glenberg, A. M., Brown, M., & Levin, J. R. (2007). Enhancing comprehension in small reading groups using a manipulation strategy. *Contemporary Educational Psychology*, 32, 389-399

Kinect Sesame Street TV [computer software]. (2012). Redmond, WA: Microsoft Studios

Nathan, M., Kintsch, W., & Young, E. (1992). A theory of algebra-word-problem comprehension and its implications for the design of learning environments. *Cognition and Instruction*, **9**(4), 329-389.

National Council of Teachers of Mathematics (2000). *Principles and Standards for School Mathematics*. Reston, VA: Author.

National Governors Association Center for Best Practices, Council of Chief State School Officers (2010). *Common Core State Standards: Mathematics.* Washington D.C.: National Governors Association Center for Best

Practices, Council of Chief State School Officers. Retrieved from http://www.corestandards.org/the-standards/mathematics.

Shapiro, L. (2011). *Embodied Cognition.* New York: Routledge.

Squire, K. (2011). *Video Games and Learning: Teaching and Participatory Culture in the Digital Age.* Technology, Education--Connections (the TEC Series). New York: Teachers College Press.

Starkey, P. (1992). The earlv development of numerical reasoning. *Cognition*, 43, 93–126.

Steinkuehler, C., & Duncan, S. (2008). Scientific Habits of Mind in Virtual Worlds. *Journal of Science Education and Technology*, *17*(6), 530-543. Doi:10.1007/s10956-008-9120-8

Walkington, C., Nathan, M., Alibali, M., Pier, L., Boncoddo, R., & Williams, C. (accepted). *Projection as a mechanism for grounding mathematical justification in embodied action*. Upcoming paper session at the 2013 Annual Meeting of the American Educational Research Association, San Francisco, CA.

Walkington, C., Srisurichan, R., Nathan, M., Williams, C., & Alibali, M. (2012, April). *Using the body to build geometry justifications: The link between action and cognition.* Paper presented at the 2012 American Educational Research Association Annual Meeting and Exhibition. Vancouver, BC.

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