Harnessing the science of learning to promote real educational apps:

A proposed contribution for *Psychological Science in the Public Interest*

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We are in the midst of a vast, unplanned experiment, surrounded by digital technologies that were not available but five years ago. At the apex of this boom is the introduction of applications ("apps") for tablet-based and smartphone devices. The iPad® was introduced in 2010 and according to Apple (2013a), as of May 16, 2013, consumers downloaded over 50 billion apps. There are over 500 million active accounts in the App Store and in a single month (December 2012), there were over two billion downloads. More than 775,000 apps have been developed for iPhone®, iPad® and iPod touch® users. A majority of all Americans (56%; Smith, 2013) already own a smartphone and more than a third already have a tablet (34%; Zickuhr, 2013), with anticipated increased adoption in the future (Rainie, 2012). By 2015, $38 million dollars of revenue will be generated by mobile apps alone (Shuler, 2012). More generally, it is estimated that US consumers spent $431 billion on technology-related products and services in 2012 (US Bureau of Economic Analysis, 2013). It is clear- today's technology is rapidly changing the nature of adults' day-to-day and even minute-to-minute experiences, and this has clear economic impacts.

This is not just a culture-change for adults, however. Children, even toddlers and infants, are a major part of this market. Over 20,000 apps are classified as education- and learning-based (Apple, 2013b). More than 25% of parents report that they have downloaded apps for their children (Common Sense Media, 2011). The Preschool/Toddler set is the most popular target in the app store with 72% of the top paid apps (Shuler, 2012). While this influx allows for near instantaneous delivery of new products, it means that the ability to scientifically evaluate a specific product or its educational value is nearly impossible. There is simply not the time, money, or resources available to evaluate each app as it enters the market. Thus, the development of so-called "educational apps" is largely unregulated and untested.

In this proposed piece for *Psychological Science in the Public Interest*, we plan to use science as a solution to this problem. We will first outline the current climate for learning in a digital world. Despite warnings from the American Academy of Pediatrics (2010), screen time for most children is a reality. The challenge is to use what we have learned through the science of learning to spur the development of high-quality screen time that can enrich children's lives. This piece seeks to meet this challenge. We will build upon decades of work examining the ways in which children learn best and will abstract a set of principles from the science of learning with two ultimate goals. First, we aim to guide researchers, educators, and designers in evidence-based app development. Second, the creation of an evidence-based guide will contribute to setting a new standard for evaluating existing children's apps. In short, we hope to better align the design and use of educational apps with known processes of children's learning and development.

This piece will touch briefly upon many types of "screen time" that have been shown to affect children before focusing primarily on the impact of touch-screen tablets and phones on the youngest age group. Our initial broad perspective will range from "passive" television viewing to active and interactive digital media that engage children on a variety of levels, from those requiring children to be physically active (such as motion-controlled video games or mobile apps for use anywhere), to those that are guided by children's input and responses. We will also examine digital media that promote children's interaction with caregivers as a part of the in-app experience.

We will concentrate on the use of apps by young children (from infancy to age 8) for four reasons. First, the intuitive interactions afforded by touch-screen devices make app content potentially accessible even to very young pre-readers. Second, the widespread use and popularity of educational apps suggests that many developers target this age group. Third, less than 20% of a child's waking time is spent in school (LIFE Center, 2005). Given the amount of time that children spend with digital media and the surge in educational apps' popularity, it suggests that at least some apps are being used in an attempt to supplement learning outside of school. Apps present a significant opportunity for out-of-school informal learning. Fourth, school readiness is predictive of later achievement (Duncan et al., 2007).

The potential impact of apps on a child's emergent literacy and numeracy skills cannot be overlooked. Yet little research has evaluated the potential benefits or drawbacks of app use. Crucially, our article will not endorse particular products or apps. Rather, we will utilize 'lessons learned' from successful apps within the context of our framework.

The importance of considering the development of principles for app use

We take inspiration and guidance from several decades of study of another medium – television. Like apps, the widespread adoption and use of television among infants and toddlers resulted in many programs claiming to create 'baby geniuses.' Millions were spent but when the empirical research was completed, results showed either no learning or an actual decrease in learning when young children watched television (Christakis, 2009, DeLoache et al., 2010; Richert, Robb, Fender, & Wartella, 2010; Roseberry, Hirsh-Pasek, Parish-Morris, & Golinkoff, 2009; Zimmerman, Christakis, & Meltzoff, 2007). One take-home message of this research was that the lack of contingency between the television characters and the children themselves was a hindrance to learning. Apps have the potential to add this contingency back to children's interactions with media.

In this piece, we will take a science-to-implementation approach and ask what other factors are important for learning and crucial to include in apps for children. This approach has only rarely been taken in the development of new apps. A small number of developers, often affiliated with bigger toy/media companies, have in-house research labs and have used these types of science-based approaches with compelling, but preliminary, results (Chiong & Shuler, 2010). One strong example of a science-based approach is that of the Go Go Games suite of apps. These apps are rooted in science and specifically target perceptual skills in children with Autism Spectrum Disorder. Critically, the apps do not just present choices but use algorithms that tailor the difficulty of the tasks to improve children's skills. In this way, future apps will likely be individually adaptive, adjustable to what individual children know and can do.

The comprehensive principles we will offer will be grounded in science but placed within the context of app use. Some of the principles will describe general mechanisms of learning that apply throughout childhood. Chi's (2009) taxonomy of learning outlines the types of experiences that maximize learning outcomes and classifies them as "active," "constructive," and "interactive." Our principles will expand this analysis by examining app-based learning activities. Apps present a unique and powerful learning opportunity that may, in fact, cut across two or more of these types of experiences. Research already tells us that children learn better when they are active and not passive, when they are constructive, and finally when they are

interactive and working with others – especially others who can scaffold their learning attempts and follow their interests (Fisher, Hirsh-Pasek, Newcombe, & Golinkoff, 2013; Fisher, Hirsh-Pasek, Golinkoff, Singer, & Berk, 2011). Apps that currently do this will be highlighted and we will offer guides for app developers to increase app effectiveness. If society were more aware of what makes for better educational experiences, perhaps developers could do a better job.

A discussion of principles of learning invariably leads to treatment of specific domains. For example, the types of experiences that promote the development of executive functioning, numerical cognition, theory of mind, social cognition, and language development will be discussed as models for bringing the lessons of the basic research home to practice. Consider language development. Research has indicated that children learn new vocabulary best when they are active and interactive around word meanings; simply repeating definitions is not as effective as *extending* word meanings to new examples and learning when a given word does not apply (the principle of contrast – as when we teach children that a whale is not a fish and why). The findings of research in any domain in developmental science can be adapted to teaching concepts in meaningful ways.

The social context within which children use electronic devices is often ignored as a secondary factor to the technology, but can be as important as the interactions between the child and device itself. For example, recent research on "joint media engagement" illuminates the learning potential of collaborative interactions around a wide range of media (Takeuchi & Stevens, 2011 for a review). Again, consider the scientific study of learning from television. Research finds that infants' learning from television is impacted by the nature of the interaction between the parent, child, and DVD (Fender, Richert, Robb, & Wartella, 2010). Among digital media for young children, "Alien Assignment" from the Fred Rogers Center exemplifies the potential of apps to scaffold educational interactions between parents and children. These findings, as well as many others from the science of learning, can apply to how we design and use apps in ways that support children's learning potential.

The designers of new child-focused apps do not begin with a blank slate. Instead, they are impacted by current trends in technology and design, their own interaction with technology, and their experience and intuitive sense of how learning happens. While this is understandable, their approach is often tainted by misconceptions about learning and education. The potential danger of this type of approach can again be seen in the 'baby geniuses' movement. Despite marketers' explicit and implicit claims of effectiveness, scientific study (e.g., DeLoache et al., 2010; Richert, et al., 2010; Zimmerman, et al., 2007) revealed that young children were not learning effectively from infant television and DVDs. Today, only a handful of apps are designed with an eye towards how children actually learn. When they are, positive results have been obtained. For example, a recent study found that interacting with a vocabulary-focused app results in increased vocabulary of up to 31% for young low-income children in just a 2-week period (Corporation for Public Broadcasting, 2011). We will utilize 'lessons learned' from successful apps within the context of our framework.

Assisting the marketplace in developing the second wave of apps for use with children

The majority of apps in today's marketplace can be considered the first wave of the digital revolution. Developers have simply transferred games and puzzles to app format without

explicitly considering how children learn, or how the electronic medium can be harnessed to use its unique affordances to support learning. Consider how powerful apps might be if in the second wave, the wave we hope to help usher in, they actually used the findings from the science of learning to drive development and use. There is another potential outcome that might be transformative: If apps were well designed they might provide augmented experiences to the lives of low SES children and help reduce the long-standing achievement gap. This is more than a pipe dream - whole school districts are giving children tablets (Merion, PA). Without high-quality content and guidance for educators and families, tablets will never reach their full potential.

Assisting the marketplace in evaluating the first wave of apps for use with children

It is important that we also find ways to evaluate the apps that exist now. While there is no way to evaluate every app on the market in a scientific study in a research lab, these principles can be used to help create a guide to evaluate the merit of existing apps. Some preliminary steps have already been taken. For instance, Kathy Hirsh-Pasek and Roberta Golinkoff have already authored a piece for the *Huffington Post* that includes a general list of characteristics parents should look for when evaluating apps for their children. In his role at YogiPlay, Jim Gray produced a rubric for app assessment based on potential for engagement and learning. We will connect our guidelines to existing efforts such as Guernsey's 3 Cs framework that emphasizes content, context, and the child's own needs and background (Guernsey, 2011) and ratings systems, such as Common Sense Media's Learning Ratings.

Parents will not be omitted from consideration. The principles we generate will serve as a launching point for a comprehensive guide that can be used by parents. As a result of our efforts and the resulting publication in PSPI, we will be in a position to produce articles for dissemination in lay publications to empower parents to make better apps choices.

The Experienced, Accomplished, and Varied Team

We bring together developmental psychologists who have studied cognitive and language development and the effects of television as well as experts on the burgeoning electronic choices families face. Roberta Michnick Golinkoff (Professor at University of Delaware) and Kathy Hirsh-Pasek (Professor at Temple University) are accomplished researchers who focus on playful learning, language and literacy development, learning from television, and dissemination of psychological science. They have published in both academic and popular press outlets and developed a set of principles for learning language and literacy for the *California State Preschool Curriculum Framework*. Their work on language learning through television (Roseberry, et. al., 2009), video chat (Roseberry, Hirsh-Pasek, Parish-Morris, & Golinkoff, 2009), and electronic books (Parish-Morris, Mahajan, Hirsh-Pasek, Golinkoff, & Collins, in press) exemplifies the power of science to critically evaluate learning in digital formats. They have established a 'digital footprint' in blogs for the *Huffington Post* and *Psychology Today*. They are unique among developmental scientists for their keen interest and achievements in bringing developmental science out to the lay public. Jim Gray is a digital learning consultant, with an advanced degree in Interactive Media Design and a doctorate of Education, who was the Director of Learning at LeapFrog Enterprises. He has served as an adviser for PBS KIDS Next Generation Media and Stanford University's Program in Learning, Design, and Technology.

Michael Robb holds a Ph.D. in Psychology and is the Director of Education and Research at the Fred Rogers Center for Early Learning and Children's Media and oversees a website which is a digital resource for families and educators. Jordy Kaufman of Swinburne University in Australia, conducts behavioral and EEG/ERP research investigating early learning and children's media use. Finally, Jennifer Zosh is an Assistant Professor of Human Development and Family Studies at the Pennsylvania State University conducting research in early cognitive development, working memory, language development, parent perceptions of media use, and number development. She also serves as an Advisory Board member and social media consultant for Ultimate Block Party.

Over the next year, we will review the current climate for digital learning, mine the existing inter-disciplinary literature on cognitive development and the science of learning, and generate a set of comprehensive principles that can be used as a guide for tomorrow's apps and an evaluation tool for today's apps. We are not the only team with the goal of app evaluation. The difference is that our team is uniquely positioned to add a level of scientific rigor and knowledge to the evaluation of apps and the development of knowledge-based guides for app development.

In sum, we propose to develop a manuscript that is a collaborative effort by an interdisciplinary team of scientists who work in academe and in the real world of educational technology. We maintain that research from the science of learning can help harness the potential of digital technology. By drawing on what we know about how children really learn, we can inform all constituents who are consumers of these apps about how to improve them and how to judge their worth. The widespread and increasing use of apps by today's children suggests that this approach may help make learning opportunities more accessible to children than ever before. Our goal is to create a set of principles that will be useful to a variety of constituents for guiding the use and design of digital children's products for years to come.

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