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Growing up with Google: How children's understanding and use of internet-based devices relates to cognitive development

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Children are increasingly exposed to devices that can access the internet, such as computers, smartphones, and tablets, beginning early in life. This review summarizes current evidence regarding the understanding and use of internet-based devices among children from birth through age 8, while highlighting gaps in the literature and opportunities for future research. The first section describes children's access to internet-based devices, and discusses the role that parents play in mediating children's access to internet-based devices. The second section describes children's developing understanding of how internet-based devices work and what they can do, and how capable children are of accessing information from the internet using these devices. The third section discusses potential implications of children's use of internet-based devices for children's cognitive development, with an emphasis on the development of memory, metacognition, and exploration.

KEYWORDS
Human cognition, Human development, Internet

1 | INTRODUCTION

A 2-year-old traces letters with her finger on a tablet touchscreen. A 4-year-old watches videos on YouTube. A 6-year-old asks a voice-controlled digital assistant whether eagles eat snakes. These scenarios have become common in many homes, yet little is known about how each of these children thinks about the internet-based devices that they see and use. Over the past few decades, the majority of research on children's understanding and use of technology has focused on older children and adolescents, and has emphasized issues such as social media use (e.g., Best, Manktelow, & Taylor, 2014; Wood, Bukowski, & Lis, 2016) and cyber safety (e.g., boyd & Marwick, 2009; Mishna, Cook, Saini, Wu, & MacFadden, 2011). However, in many communities, children are exposed to computers, tablets, smartphones, and other internet-based technological devices starting at birth, and they begin using these devices not long afterwards. Thus, it is essential to understand what children think about internet-based devices and how they come to comprehend these devices' capabilities and limitations, in addition to the influence that early and prolonged exposure to internet-based devices may have on children's cognitive development. This article reviews what is currently known about young children's understanding of and use of internet-based devices, highlights critical gaps in the literature, and outlines directions for future research.

This review focuses on technology use and understanding among children from birth to age 8. This period of development is important because children are actively exploring and learning about the world around them as their cognitive and social skills rapidly develop. As with other domains such as literacy (National Early Literacy Panel, 2008) and numeracy (e.g., Jordan, Kaplan, Ramineni, & Locuniak, 2009), early experiences with technology may form the basis for later behaviors and competence. Additionally, the fact that the first generation of children who have been exposed to internet-based devices from birth is only now approaching adolescence, and that there are still communities where internet-based devices are not widely available, presents a unique opportunity for studying how emerging technologies and rapid access to information potentially influence child development.

For the purpose of this review, internet-based devices are defined primarily as technological devices that can access the internet (e.g., computers, tablets, smartphones). These devices include text- or

touch-controlled devices (e.g., iPads) that can access information from websites and applications, as well as voice-controlled digital assistants such as Siri and Alexa. As technology has improved, the appearance and capabilities of the devices have changed, as have factors such as the speed of internet access or ease of device use. Nevertheless, internet-based devices share common characteristics of being interactive (i.e., responsive to the user) and drawing information or content from the internet. Beyond describing how children spend their time on internet-based devices, this review does not focus on children's use of device-based applications (i.e., apps) for activities such as playing games, taking photos, or watching videos. Instead, this review focuses on internet-based devices as a means of obtaining information from the World Wide Web via search engine apps or websites. Furthermore, it does not focus on children's understanding and use of social media as social media blurs the boundary between the internet and other human beings (e.g., when a child uses a device to communicate with another person, the information being obtained is coming directly from the other person, not the internet), and because thus far, the data suggest that children under age 8 rarely engage in non-gaming social media activities (e.g., Ofcom, 2019; Rideout, 2017). Finally, this review is not intended to be exhaustive. Rather, it draws from cognitive science, education, human-computer interaction, and other fields to broadly describe what is currently known about children's understanding and use of internet-based devices, and how children's experiences with internet-based devices may relate to other aspects of cognitive development.

2 | CHILDREN'S ACCESS TO INTERNET-BASED DEVICES

According to the UN International Telecommunications Union, as of late 2017, more than half of the global population had access to the internet (ITU, 2017), with the percentage being much higher in developed nations. A 2018 survey of American adults found that nearly 77% of respondents went online daily, and only 10% of respondents (primarily elderly individuals) did not use the internet at all (Perrin & Jiang, 2018). It is telling that surveys of internet use over the past few decades have shifted from asking whether individuals use the internet to how frequently they do so, and that nearly 40% of American adults ages 18–29 reported being online "almost constantly" in the 2018 survey. As the number of adults with access to the internet and their frequency of internet use increases, so does the likelihood that young children are exposed to devices that can access the internet.

Parent surveys and case studies have documented that exposure to caregivers using mobile internet-based devices begins in infancy (e.g., Harrison & McTavish, 2018; Kildare & Middlemis, 2017) and that an estimated 98% of American children ages 0–8 live in homes with devices that can access the internet (Rideout, 2017). Moreover, on average, American children spend over an hour a day using computers or mobile devices (Rideout, 2017). This high rate of technology exposure and use is not limited to children in high-income families. Even in lower-income American communities, the data indicate that most children are exposed to mobile devices before their first birthday and that the majority of 4-year-olds have at least one mobile internet-enabled device (e.g., a tablet) of their own (Kabali et al., 2015). Similar patterns of early access to technology have been observed in Europe, where in some countries the majority of children are online by age 3 or 4 (Holloway, Green, & Livingstone, 2013), and in Australia (Huber, Highfield, & Kaufman, 2018) and South Korea (Korea Internet & Security Agency, 2012). Recent evidence suggests that even in the least developed countries, over 30% of individuals' ages 15–24 have internet access (ITU, 2017). Thus, on a global scale, children's access to the internet has been steadily increasing and can be expected to continue doing so.

Whether or not children have the opportunity to use internet-based devices in their first few years of life is largely determined by the adults around them. Parents mediate children's access to internet-based devices by enabling and/or restricting their child's technology use (see Livingstone et al., 2017; Livingstone & Helsper, 2008). Enabling mediation strategies involve sharing the experience of using a device or accessing the internet together with the child. For example, a parent can observe their child playing an online game or have a discussion with the child about what link to click on a Google search. Restrictive mediation involves limiting the child's access or engagement with internet-based devices, including setting time limits on how long the child can use a device or restricting their access to certain websites. Research suggests that caregivers use restrictive strategies more frequently as children become more capable of using internet-based devices independently (i.e., the children grow older; Nikken & Jansz, 2014). Importantly, though, the two major mediation strategies are not exclusive and parents use both to different degrees and at different times (Livingstone et al., 2017).

The likelihood that parents will mediate their child's use of internet-based devices has been linked to parent characteristics, including parent age (Lauricella, Wartella, & Rideout, 2015; Livingstone et al., 2017) and education level (Valcke, Bonte, De Wever, & Rots, 2010), and the parent's comfort using technology (Livingstone et al., 2017). Parenting style is also predictive of the extent to which parents mediate their child's technology use, such that children of more authoritarian parents spend less time using mobile devices and the internet (Hwang, Choi, Yum, & Jeong, 2017; Valcke et al., 2010). Another factor related to parent mediation of children's device use is how often parents use internet-based devices themselves and how they feel about it. A 2015 survey of a representative sample of American parents examined the relation between parent device use and attitudes and the amount of time children ages 0–8 spent using computers, smartphones, and tablets (Lauricella et al., 2015). Not surprisingly, parents who spent more time using devices themselves and had more positive attitudes toward device use had children who spent more time using devices, though the influence of parent attitudes toward device use depended on the child's age and the type of device. Children under age 5 spent more time using computers if their parents viewed computer use positively. There was no relation between parent attitudes and computer use among children ages 6–8, yet 6- to 8-year-olds spent more time using tablets and smartphones if their

parents viewed those devices positively. Hence, parent opinions influence children's access to technology, but the extent of their influence varies based on factors such as age and the type of device. As Lauricella et al. propose, when children become old enough to access devices on their own, the ways in which parents influence their children's device use necessarily shift.

Although both parents and older children sometimes report concerns about the amount of time they spend using technology (Kildare & Middlemis, 2017), parents generally have a positive attitude toward their children's use of internet-based technology (Nikken & Jansz, 2014). In a study of American parents of children ages 2–7, the majority of parents believed that using technological devices would benefit their child and prepare them for the workforce (Vittrup, Snider, Rose, & Rippy, 2016). To this end, parents reported a willingness to disregard guidelines recommending that young children's media use be restricted. Parents' positive attitude toward technology also extends specifically to internet use. For example, parents of elementary school children in Singapore report that internet use is beneficial for their children, citing its value for finding information (e.g., using Google to obtain information for school assignments; W. Shin, 2015). These positive attitudes carry-over into educational decisions, as parents who hold positive views of internet use in their child's preschool and elementary school classrooms seek out schools that will provide these opportunities (Chen & Tu, 2017).

Besides viewing their children's use of internet-based technology positively, parents frequently view their children as being adept at using internet-based devices. For example, Vittrup et al. (2016) found that 62% of parents of young children in their sample endorsed the statement that "children today naturally understand how to use computers and related technologies at the preschool age." However, interviews with the children suggested parents overestimated their abilities. Regardless of whether parents' opinions of their children's technological skills and understanding are accurate (and the research suggests that they are not; see also Metzger, Flanagin, & Nekmat, 2015), these findings may help explain why some parents report that they allow children as young as age 3 or 4 to use internet-based devices largely independently (Kabali et al., 2015) and that they are not very aware of their children's online activities (Vittrup et al., 2016). If parents interpret their child's ease at using internet-based devices (e.g., their ability to access a desired website or manipulate objects on a touchscreen with their fingers; see Cristia & Seidl, 2005) as indicative of a genuine understanding of how the device works or the ability to navigate the internet, then parents may be less likely to mediate their child's interactions with internet-based devices. Consequently, understanding how well children comprehend the nature and functions of internet-based devices and how adept children are at using these devices could help inform parents' decisions about whether to monitor and support children when they are using technology, and potentially influence parent attitudes toward granting young children access to internet-based devices.

3 | CHILDREN'S UNDERSTANDING AND USE OF COMPUTERS AND OTHER INTERNET-BASED DEVICES

Although children may have extensive exposure to internet-based devices and use these devices independently, they do not necessarily understand how these devices work or what they can do. Children's understanding of internet-based devices involves two elements: understanding the device's physical nature and inner workings (i.e., hardware) and understanding the device's functions and capacities (see Rücker & Pinkwart, 2016). Although these elements are inter-related, acquiring an understanding of each one may involve different types of experiences and judgments.

Because of their long-term presence in children's homes and classrooms, computers have been the focus of much of the research on children's understanding of technological devices. Although computers may sometimes behave in ways that imply sentience or agency (e.g., by producing spoken language), children quickly come to grasp the difference between computers and other living entities. By age 5, children indicate that computers are not alive, nor do they experience mental states, desires, or emotions (Mikropoulos, Misailidi, & Bonoti, 2003; Subrahmanyam, Gelman, & Lafosse, 2002). Young children also indicate that computers require electricity to work and that they rely on "wires," so that if the wires are unplugged or improperly connected, the computer will not work (Mertala, 2019; Rücker & Pinkwart, 2016). That said, even older children may have difficulty comprehending that a computer's capabilities are determined by internal components, such as memory capacity and CPU speed. For example, although older children sometimes agree that computers have a "brain" in the figurative sense, they may struggle to identify its location (e.g., indicate that it is in the monitor rather than the CPU; Scaife & Van Duuren, 1995). Rücker and Pinkwart (2016) propose that children learn about the physical nature of devices such as computers through observations of how adults handle computer dysfunction (e.g., watching a parent discover that a computer is unplugged) and through observations of other types of mechanical devices, such as watches or cash registers. Hence, as digital devices increasingly replace their mechanical counterparts and their inner workings become more opaque (and less accessible when they malfunction), it may become more challenging for children to understand the physical components of computers and other internet-based devices.

One could argue that understanding the physical nature of technological devices is not important for children as long as they know how to use these devices and what these devices can and cannot do. By the time they enter elementary school, children realize that the capacity of technological devices, such as computers, is limited to certain types of tasks. For instance, in a study that took place prior to the advent of social media, 5- and 8-year-olds expressed surprise when a computer answered a biographical question about them (van Duuren, Dossett, & Robinson, 1998). Likewise, when judging what kinds of questions should be directed toward a computer or person, 5-year-olds indicate that questions involving emotional or moral judgments

should not be directed toward a computer; however, not until age 7 do children strongly prefer to consult a computer rather than a human for answers to computational or obscure factual questions (Danovitch & Keil, 2008). Unfortunately, because a wide range of methodologies have been used to probe children's thinking about computers, it is difficult to draw definitive conclusions from these studies. Many studies of children's understanding of computers are also limited in their scope because they were undertaken before internet access became widely available (e.g., Scaife & Van Duuren, 1995; van Duuren et al., 1998), did not directly reference the internet when describing the computers (e.g., Danovitch & Keil, 2008), or they failed to take into account children's prior experience with the internet. Consequently, research is needed to determine whether children hold similar views of modern internet-based devices.

A recent study of children's judgments about computers and other types of internet-based devices suggests that children continue to view devices as having a restricted range of functions and that children's judgments are primarily driven by their personal experiences using devices for specific purposes. Eisen and Lillard (2017) asked American children ages 4–6 and a group of college students to identify seven objects, including a tablet, smartphone, and a book, and then to indicate whether each device could be used for certain purposes. Nearly all of the children accurately identified the tablet and smartphone, and they consistently indicated that the tablet and smartphone could be used for playing games, watching movies, and taking pictures. Yet, children were less likely than adults to say that tablets and smartphones could be used for work or for learning. In addition, when asked to choose the best device for learning specifically about dogs, children were most likely to choose the book. These findings suggest that even as the capabilities of technological devices have expanded and these devices have become more accessible to young children, children may still think of devices as being capable only of the functions for which they have personally used them (e.g., playing games), and younger children may struggle to see internet-based devices as multifunctional. Thus, despite being familiar with devices such as computers and tablets, children often do not understand how they work or what they can do, and it may take extensive experience using them for children to grasp their range of capabilities.

4 | CHILDREN'S UNDERSTANDING AND USE OF THE INTERNET

In order to fully understand how internet-based devices work and how to use them effectively, children must acquire an understanding of the internet itself. The first step in the process of understanding the internet is to realize that it exists—a fact that is not always apparent to young children. In a study of Australian preschoolers with experience using internet-based devices, less than half of children indicated familiarity with the internet even when alternate terms like "online" or "the web" were used (Edwards et al., 2016). That said, by the time they are in kindergarten, children in the United States and Jordan nearly unanimously report having heard of the internet or reference it in some way (Dodge, Husain, & Duke, 2011; Oliemat, Ihmeideh, & Alkhawaldeh, 2018). Nevertheless, familiarity with the internet does not necessarily imply an understanding of what it is or how it is used. In a recent study, Finnish 5- to 7-year-olds who were familiar with the term "internet" often did not know what it meant and could not accurately identify which computer-based activities require an internet connection (e.g., checking the weather forecast; Mertala, 2019). As Mertala proposes, one factor that may contribute to children's lack of familiarity with the internet is that children do not have experience taking actions to get online on most modern devices. Unlike in earlier eras when users had to set up and sign on to a connection, many devices now passively connect to the internet when Wi-Fi is available. As cellular networks and Wi-Fi accessibility continue to become faster and more ubiquitous, it may be more difficult for children to realize that the internet is a separate entity from the devices used to access it.

Even when children realize that the internet exists and have some sense of its usefulness, they are still unlikely to understand how it works. Understanding the structure of the internet presents multiple challenges due to its complexity and its unusual nature as a virtual artifact made up of both technical and social components (see Yan, 2009). In a ground-breaking series of studies, Yan (2005, 2006, 2009) examined children's and adults' understanding of the technical and social complexity of the internet. Based on responses to questions about the internet (e.g., How big is the internet? What kinds of good things can the internet do for us? etc.) and prompts to draw the internet, Yan classified participants' understanding of the internet into one of four categories, ranging from a minimal understanding (e.g., viewing the internet as a single computer) to a sophisticated scientific understanding (e.g., viewing the internet as a network of networks). The results of Yan's studies suggest that most children have acquired an adult-like understanding of the technical complexity of the internet by ages 11–12, and that they have an adult-like understanding of the social complexity of the internet by ages 13–14. That said, having an adult-like understanding is not equivalent to having the most sophisticated level of understanding; older adolescents and adults rarely demonstrated completely accurate models of how the internet works, and their understanding tended to be perceptually driven rather than conceptually driven (see Yan, 2009). Furthermore, across these studies, children's understanding of the internet was most strongly predicted by age, rather than experience using the internet, exposure to formal education about the internet, or other demographic factors (i.e., gender). Based on these data, Yan argues that forming an accurate and complete concept of the internet is a particularly difficult task, and as such, the development of children's and even adults' understanding may lag several years behind their acquisition of concepts involving other unobservable or abstract entities (e.g., the universe, God). This proposal is also supported by recent findings that middle school children frequently conceptualize search engines in an anthropomorphic, rather than a technological, fashion (e.g., depicting Google as a person or workers; Kodama, Jean, Subramaniam, & Taylor, 2017). Taken together, these findings imply that as technology

continues evolving and the distinction between the internet's technical and social components continues to blur, it may become even more difficult for children to form an accurate and coherent understanding of the internet.

5 | CHILDREN'S UNDERSTANDING AND USE OF ONLINE INFORMATION SEARCHES

Given their limited understanding of how the internet works, it may not be surprising that children struggle to effectively use the internet for one of its primary functions: obtaining information. Using a semi-structured interview where children in kindergarten through second grade were asked about the internet and given the opportunity to demonstrate their skills on a laptop computer, Dodge et al. (2011) found that most children did not identify the internet as an information source, and even when they did, they were rarely capable of using it to obtain information on their own. Although children tend to use the same search engines as adults, they face many challenges finding and evaluating information (Large, Nesset, & Beheshti, 2008). Children do not have a solid grasp of what kinds of information are available on the internet or where to find it, sometimes leading them to make egregious errors or conduct misguided searches (e.g., searching for information about the vice-president on a website dedicated to the fictional character SpongeBob Squarepants; Druin, Foss, Hutchinson, Golub, & Hatley, 2010).

A substantial body of research has documented the obstacles children face when formulating search queries and identifying appropriate results (e.g., Foss et al., 2012; Gossen, Höbel, & Nürnberger, 2014; Duarte Torres, Weber, & Hiemstra, 2014; Madrazo Azbiazu, Dragovic, Anuyah, & Pera, 2018). For instance, an analysis of Yahoo! search queries and web behavior among children ages 6–7, 8–9, and 10–12 revealed that younger children's searches lasted for a shorter time than older children's searches, and that younger children typed in shorter queries (i.e., fewer terms in the search bar), and were more likely to use natural language (i.e., phrasing queries in the form of a question), which can be problematic for some search engines (Duarte Torres et al., 2014). They were also more likely to undo auto-corrections by the search engine and to click on whatever item or link was most prominent in the search results, even if it was an advertisement. These findings raise questions about how the introduction of sophisticated search engine software that supports natural language queries and offers better suggestions for search terms may influence children's capacity to obtain information from the internet (Madrazo Azbiazu et al., 2018). Likewise, the introduction of voice-controlled digital assistants, such as Alexa and Siri, to many homes has removed spelling and other literacy-based barriers to children's information searches, making it possible for younger, preliterate children to search the web independently. In the coming years, it will be informative to see how the increasing accessibility of internet searches and more frequent experience conducting these searches influences the development of children's understanding of the internet's structure and function.

6 | DEVELOPING TRUST IN THE INTERNET

In order to effectively use internet-based devices to find information, children must determine whether to trust the information that these devices provide. By adolescence, internet users are aware that not all the information they find online is credible or accurate (e.g., Jung, Walsh-Childers, & Kim, 2016; St. Jean, Greene Taylor, Kodama, & Subramaniam, 2017), yet they are still vulnerable to believing false information found online (Metzger, Flanagin, Markov, Grossman, & Bulger, 2015). Moreover, adults show a good deal of trust in internet search engines and confidence in their own ability to use search engines to find the most relevant information (Pan et al., 2007; Purcell, Rainie, & Brenner, 2012).

Insights into the development of children's trust in the internet may be gained from research into the development of children's trust in human informants (see reviews by Harris, 2012; C. M. Mills, 2013). Developmental psychologists have demonstrated that as early as age 3 or 4 children are capable of evaluating informants based on characteristics such as prior accuracy (e.g., Koenig, Clément, & Harris, 2004), benevolence (e.g., Johnston, Mills, & Landrum, 2015), and intent (e.g., Vanderbilt, Liu, & Heyman, 2011). An open question, then, is whether children apply the same heuristics that they use to evaluate human sources to evaluate nonhuman ones such as internet-based devices. Classifying internet-based devices as informants may be particularly challenging for young children because these devices share some properties, such as interactivity, with human sources and some properties with information-containing artifacts, such as books. However, unlike human sources, internet-based sources do not select information based on pedagogical intent or their understanding of the information-seeker's goals (see Csibra & Gergely, 2009; Landrum, Eaves Jr, & Shafto, 2015); instead, search engines select information based on factors such as prior browsing history, the user's location, and website popularity. Due to the differences between humans and internet-based devices, children may be uncertain whether the criteria they use to evaluate human sources apply to internet-based devices and they may even be wary of internet-based sources. Alternatively, internet-based sources may be easier for young children to evaluate than human informants if children view internet-based sources as more consistent or reliable because they are not subject to factors such as changing moods that can sometimes make human informants unreliable.

Using a paradigm similar to those used to measure children's trust in human informants, Danovitch and Alzahabi (2013) found that preschoolers tracked a computer's prior accuracy and trusted information from a previously accurate computer more than from a previously inaccurate one. In fact, they seemed to evaluate the computer's accuracy with more ease than children in other studies evaluated human informants (e.g., Koenig et al., 2004). In addition, despite anecdotal reports that children treat internet search engines as omniscient (see Richler, 2015), recent findings from the United States and China suggest that 5- and 6-year-old children are skeptical of information retrieved from the internet and that, in some cases, they prefer to

seek out factual information from a person than the internet (Danovitch, Noles, & Shafto, under review; Wang, Tong, & Danovitch, 2019). In these studies, not until at least age 8 do children start showing a preference to seek out information from the internet and, even then, they do not show strong trust in the results of internet searches. Another recent study supports that children also approach *novel* internet-based devices skeptically: when children were allowed to ask questions of a novel voice-controlled search device, some children chose to test the interface with questions for which they already knew the answer (Yarosh et al., 2018). Although further research is needed to understand the mechanisms underlying children's trust in internet-based devices, these early findings suggest that children's trust in information obtained from internet-based devices may take significant time and experience to develop.

7 | EFFECTS ON COGNITIVE DEVELOPMENT

The increase in children's early and prolonged access to internet-based devices raises important questions about the effects of exposure and use of internet-based devices on children's cognitive development. (There are also important questions about the effects on social and emotional development, but these are beyond the scope of the current paper.) Some commentators have argued that prolonged access to the internet diminishes cognitive capacity and intelligence (Bauerlein, 2008; Carr, 2011; Greenfield, 2015). Others, such as the author Nora Ephron, have wondered if "Google will mean the end of conversation as we know it" (Ephron, 2008) as individuals spend more time seeking answers from computers and less time seeking them from other people. These popular fears are echoed by internet users who indicate that internet use has impaired their memory and concentration (Näsi & Koivusilta, 2013) and who feel stressed by the amount of information available online (i.e., experience "information overload"; Horrigan, 2016). That said, empirical research on the cognitive effects of internet-based device and internet use has been inconclusive and yielded inconsistent outcomes (e.g., Orben & Przybyzki, 2019; see also reviews by K. L. Mills, 2016; Wilmer, Sherman, & Chein, 2017), and research with young children has rarely been conducted at all. Children are clearly capable of learning from internet-based devices, just as they are capable of learning from books or television (see Troseth & Strouse, 2017). The question is whether using internet-based devices enhances or diminishes children's learning relative to other media, including face-to-face interactions. This section describes potential effects of internet-based device use on three fundamental, interrelated features of children's learning: memory, metacognition, and exploration.

Much of the popular concern about the effects of accessing vast amounts of information online focuses on memory. In what was coined the "Google effect" on memory, Sparrow, Liu, and Wegner (2011) demonstrated that college students showed diminished memory for trivia statements that they knew could be accessed on a computer. Adults who search for information on the internet also remember less of the information than those who search in a printed encyclopedia, and show diminished activation of brain areas associated with the formation of long-term memories (Dong & Potenza, 2015). The detrimental effects of internet-based device use on memory have been shown to extend to devices that are used for other functions as well. For example, recent evidence suggests that using a hand-held device to take photos or share experiences on social media diminishes memory for the experience, both immediately and 1 week later (Tamir, Templeton, Ward, & Zaki, 2018). Although reduced memory for factual and autobiographical information may seem like a negative consequence of technology use, some have proposed that offloading memories to the internet can be beneficial because it allows for more efficient allocation of cognitive resources. Therefore, using internet-based devices can support better memory for information that cannot be offloaded (e.g., Storm & Stone, 2015) or allow for more creative thinking and problem solving (Clowes, 2013; Sparrow & Chatman, 2013).

Because young children are in the process of developing effective memory strategies and rapidly acquiring semantic knowledge (see Bjorklund, Dukes, & Brown, 2009 for a review), it is crucial to examine how use of internet-based devices may influence memory development. One possibility is that children may not feel compelled to remember information that can be accessed via a device, delaying the development of effective strategies for organizing and remembering information. For example, children no longer need to memorize their friends' phone numbers. As a result, they may have fewer opportunities to learn and deploy strategies such as rehearsal or clustering. Alternatively, it is possible that because access to internet-based devices makes remembering some factual information unnecessary, children may be able to devote more cognitive resources to remembering or understanding more complex information that cannot be easily retrieved from the internet, such as procedures or relations between concepts. Given that children's access to internet-based devices is likely to continue increasing in the coming years, cross-sectional and longitudinal studies are needed to investigate the development of children's memory for information that can and cannot be accessed on the internet.

Besides potentially influencing the formation and maintenance of memories, using the internet to obtain information may distort metacognitive judgments, leading adults to inflate estimates of their knowledge and understanding even when they do not have access to the internet (Hamilton & Yao, 2018; Ward, 2013a, 2013b). For instance, in a series of experiments, Fisher, Goddu, and Keil (2015) found that adults who searched for answers to questions on the Internet reported an inflated sense of how well they could explain the answers to different, unrelated questions compared to adults who did not perform searches. Moreover, this overestimation effect was specific to questions that could be answered through an internet search; it did not extend to information that was not available on the internet (e.g., personal autobiographical information). This illusion of knowledge could have major repercussions when it comes to learning, particularly for children.

Children are notorious for overestimating their knowledge and abilities (e.g., C. M. Mills & Keil, 2004; H. Shin, Bjorklund, & Beck, 2007; Spinath & Spinath, 2005). Does using internet-based devices further inflate children's overoptimistic views of their own knowledge and, consequently, their willingness to defer to more knowledgeable individuals

(Aguiar, Stoess, & Taylor, 2012; Danovitch, Fisher, Schroeder, Hambrick, & Moser, in press)? Children (and adults) are relatively optimistic about their ability to evaluate the information they find online (Metzger, Flanagin, & Nekmat, 2015). Although these findings are suggestive, no studies have examined whether the direct experience of finding answers on the internet influences children's judgments of how much they know. If children are vulnerable to similar effects of internet search as adults, then prolonged experience with online information searches may alter the typical developmental timeline for the emergence of more realistic metacognitive judgments during the elementary school years. Furthermore, recent findings that the effects of using internet-based devices on adults' metacognition are positively correlated with familiarity and attachment to the specific device used to search the internet (Hamilton & Yao, 2018) suggest that children who frequently use the same internet-based device or who own a device may be more vulnerable to overestimating their knowledge. Although there is some debate over whether overestimating knowledge and skills is necessarily detrimental to children's learning (see Bjorklund, 2007), understanding whether internet use influences children's metacognition could potentially elucidate the mechanisms underlying internet-induced changes in adult metacognition as well.

Finally, if internet access inflates children's evaluation of their own knowledge, then it may subsequently diminish their curiosity and motivation to acquire new information (see Ward, 2013b). Curiosity and exploration are essential components of children's learning (see Lowenstein, 1994; Sobel & Letourneau, 2018) and children are intrinsically motivated to understand how the world works. Children can explore the world through their direct actions and observations, or by seeking information from others, and they are motivated to gain information to fill gaps in their knowledge (Danovitch & Mills, 2018). For instance, children explore more and ask more questions when faced with ambiguous evidence (e.g., Schulz & Bonawitz, 2007) or incomplete explanations (e.g., Frazier, Gelman, & Wellman, 2009). If internet use artificially inflates children's sense of knowledge or understanding about a topic, then they may be less motivated to seek out additional information about that topic. Internet experience may also be detrimental to learning and exploration if children become accustomed to finding information quickly and easily, and thus give up more quickly when they encounter obstacles or more complex problems. Alternatively, using internet-based devices could have a positive effect on children's exploration and learning by facilitating access to information that children cannot easily obtain on their own or from other people.

Research exploring the volume and types of questions children direct toward internet-based sources could be a useful means of exploring these possibilities. Moreover, examining how children's initial success at finding information on the internet influences further information seeking behaviors would elucidate the potential relation between internet use and self-directed learning, a question which may be particularly relevant as new voice-controlled devices and more sophisticated search engines make children's searches more likely to succeed. In addition, future studies should examine how exposure to internet-based devices potentially influences children's attitudes toward *what* can be learned. In comparison to previous generations, children who have used internet-based devices throughout their lives may be more optimistic about their likelihood of finding answers to questions and thus be more willing to tackle challenging scientific or philosophical problems.

8 | CONCLUSIONS

As internet-based devices such as computers, tablets, and smartphones become more widely available and easier to use, children are more likely to encounter and use these devices at younger ages. Although children as young as toddlers may seem adept at using internet-based devices, their understanding of these devices may take many years to develop. Hence, a child's ability to activate a device or conduct an internet search should not be interpreted as an indication that the child understands how the device works or that they can effectively evaluate the information it provides. Although parents play an important role in mediating children's access to technology, it is important to keep in mind that children's understanding of internet-based devices develops in conjunction with other cognitive skills: cognitive development influences children's use and understanding of devices, and children's experience using devices may influence their cognitive development.

Despite the increasing presence of internet-based devices in children's daily lives, there remain many open questions about how children's concepts of technology and the internet develop, and how internet-based devices may influence the ways children think about and explore their environment. As described in this review, specific questions include how children's understanding of internet-based devices originates, and how children's concepts may be changing as technology advances. They also include how experience obtaining information online influences children's memory, metacognitive judgments, and interest in learning and exploration. These open questions present unique and timely opportunities for researchers. For instance, most of the research to date on the cognitive effects of technology and internet use has been conducted with adults from WEIRD populations (see Henrich, Heine, & Norenzayan, 2010), and little is known about whether the findings generalize to other populations, including children. As access to internet-based devices rapidly spreads to children in low- and middle-income countries, researchers could capitalize on this opportunity to study the effects of using internet-based devices among cohorts of children who first encounter these devices at different ages. Such research could shed light not only on the long-term consequences of technology use, but also on how children's cognitive functions and learning behaviors change and adapt as their means of accessing information change, and on what we can expect as the first generation to grow up with early and prolonged access to the internet matures into adults.

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REFERENCES

Aguiar, N. R., Stoess, C. J., & Taylor, M. (2012). The development of children's ability to fill the gaps in their knowledge by consulting experts. *Child Development*, *83*, 1368–1368. https://doi.org/10.1111/j.1467-8624.2012.01782.x

Bauerlein, M. (2008). *The Dumbest Generation: How the digital age stupefies young Americans and jeopardizes our future (or, don't trust anyone under 30)*. New York, NY: Penguin.

Best, P., Manktelow, R., & Taylor, B. (2014). Online communication, social media and adolescent wellbeing: A systematic narrative review. *Children and Youth Services Review*, *41*, 27–36. https://doi.org/10.1016/j.childyouth.2014.03.001

Bjorklund, D. F. (2007). *Why youth is not wasted on the young: Immaturity in human development*. Malden, MA: Blackwell.

Bjorklund, D. F., Dukes, C., & Brown, R. D. (2009). The development of memory strategies. In M. L. Courage & N. Cowan (Eds.), *The development of memory in infancy and childhood* (pp. 145–175). Hove, England: Psychology Press.

boyd, d., & Marwick, A. The conundrum of visibility. *Journal of Children and Media*, *3*(4), 410–414. https://doi.org/10.1080/17482790903233465

Carr, N. (2011). *The Shallows: What the internet is doing to our brains*. New York, NY: W. W. Norton & Company.

Chen, R.-S., & Tu, C.-C. (2017). Parents' attitudes toward the perceived usefulness of Internet-related instruction in preschools. *Social Psychology of Education*, *21*, 477–495. https://doi.org/10.1007/s11218-017-9424-8

Clowes, R. W. (2013). The cognitive integration of e-memory. *Review of Philosophy and Psychology*, *4*, 107–133. https://doi.org/10.1007/s13164-013-0130-y

Cristia, A., & Seidl, A. (2015). Parental reports on touch screen use in early childhood. *PLoS One*, *10*, e0128338. https://doi.org/10.1371/journal.pone.0128338

Csibra, G., & Gergely, G. (2009). Natural pedagogy. *Trends in Cognitive Sciences*, *13*(4), 158–153. https://doi.org/10.1016/j.tics.2009.01.005

Danovitch, J. H., & Alzahabi, R. (2013). Children show selective trust in technological informants. *Journal of Cognition and Development*, *14*, 499–513. https://doi.org/10.1080/15248372.2012.689391

Danovitch, J. H., Fisher, M. E., Schroder, H. S., Hambrick, D. Z., & Moser, J. S. (in press). Intelligence and neurophysiological markers of error monitoring relate to children's intellectual humility. *Child Development*. https://doi.org/10.1111/cdev.12960

Danovitch, J. H., & Keil, F. C. (2008). Young Humans: The role of emotions in children's evaluation of moral reasoning abilities. *Developmental Science*, *11*, 33–39. https://doi.org/10.1111/j.1467-7687.2007.00657.x

Danovitch, J. H., & Mills, C. M. (2018). Understanding when and how explanation promotes exploration. In M. Saylor & P. Ganea (Eds.), *Active learning from infancy to childhood: Social motivation, cognition, and linguistic mechanisms* (pp. 95–112). Cham, Switzerland: Springer International Publishing. https://doi.org/10.1007/978-3-319-77182-3_6

Danovitch, J. H., Noles, N. S., & Shafto, P. (under review). *The development of trust in information from the internet*. Manuscript submitted for publication.

Dodge, A. M., Husain, N., & Duke, N. K. (2011). Connected kids? K—2 children's use and understanding of the internet. *Language Arts*, *89*(2), 86–98. Retrieved from http://www.jstor.org/stable/41804322

Dong, G., & Potenza, M. N. (2015). Behavioural and brain responses related to Internet search and memory. *European Journal of Neuroscience*, *42*(8), 2546–2554. https://doi.org/10.1111/ejn.13039

Druin, A., Foss, E., Hutchinson, H., Golub, E., & Hatley, L. (2010, April 10). *Children's roles using keyword search interfaces at home*. CHI '10 Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, 413–422.

Duarte Torres, S. D., Weber, I., & Hiemstra, D. (2014). Analysis of search and browsing behavior of young users on the web. *ACM Transactions on the Web (TWEB)*, *8*(2), 7. https://doi.org/10.1145/2555595

Edwards, S., Nolan, A., Henderson, M., Mantilla, A., Plowman, L., & Skouteris, H. (2016). Young children's everyday concepts of the internet: A platform for cyber-safety education in the early years. *British Journal of Educational Technology*, *49*(1), 45–55. https://doi.org/10.1111/bjet.12529

Eisen, S., & Lillard, A. S. (2017). Young children's thinking about touchscreens versus other media in the US. *Journal of Children and Media*, *11*, 167–179. https://doi.org/10.1080/17482798.2016.1254095

Ephron, N. (2008, January 13). The Chicken Soup Chronicles. *The New York Times*. Retrieved from https://www.nytimes.com/2008/01/13/opinion/13ephron.html

Fisher, M., Goddu, M. K., & Keil, F. C. (2015). Searching for explanations: How the Internet inflates estimates of internal knowledge. *Journal of Experimental Psychology: General*, *144*(3), 674. https://doi.org/10.1037/xge0000070

Foss, E., Druin, A., Brewer, R., Lo, P., Sanchez, L., Golub, E., & Hutchinson, H. (2012). Children's search roles at home: Implications for designers, researchers, educators, and parents. *Journal of the American Society for Information Science and Technology*, *63*, 558–573. https://doi.org/10.1002/asi.21700

Frazier, B. N., Gelman, S. A., & Wellman, H. M. (2009). Preschoolers' search for explanatory information within adult-child conversation. *Child Development*, *80*, 1592–1611. https://doi.org/10.1111/j.1467-8624.2009.01356.x

Gossen, T., Höbel, J., & Nürnberger, A. (2014). Usability and perception of young users and adults on targeted web search engines. In *Proceedings of the 5th Information Interaction in Context Symposium (IIiX '14)* (pp. 18–27). New York, NY: ACM. https://doi.org/10.1145/2637002.2637007

Greenfield, S. (2015). *Mind Change: How digital technologies are leaving their marks on our brains*. New York, NY: Random House.

Hamilton, K., & Yao, M. (2018). Blurring boundaries: Effects of device features on metacognitive evaluations. *Computers in Human Behavior*, *89*, 213–220. https://doi.org/10.1016/j.chb.2018.07.044

Harris, P. L. (2012). *Trusting what you're told: How children learn from others*. Cambridge, MA: Belknap of Harvard University Press.

Harrison, E., & McTavish, M. (2018). i'Babies: Infants' and toddlers' emergent language and literacy in a digital culture of iDevices. *Journal of Early Childhood Literacy*, *18*, 163–188. https://doi.org/10.1177/1468798416653175

Henrich, J., Heine, S. J., & Norenzayan, A. (2010). Most people are not WEIRD. *Nature*, *466*(7302), 29. https://doi.org/10.1038/466029a

Holloway, D., Green, L., & Livingstone, S. (2013). *Zero to eight: Young children and their internet use*. London, England: LSE London, EU Kids Online. Retrieved from http://eprints.lse.ac.uk/52630/1/Zero_to_eight.pdf

Horrigan, J. B. (2016). *Information overload.* Retrieved from: http://www.pewinternet.org/2016/12/07/information-overload/

Huber, B., Highfield, K., & Kaufman, J. (2018). Detailing the digital experience: Parent reports of children's media use in the home learning environment. *British Journal of Educational Technology*, *49*, 821–833. https://doi.org/10.1111/bjet.12667

Hwang, Y., Choi, I., Yum, J. -Y., & Jeong, S. -H. (2017). Parental mediation regarding children's smartphone use: Role of protection motivation and parenting style. *Cyberpsychology, Behavior and Social Networking*, *20*, 362–368. https://doi.org/10.1089/cyber.2016.0555

International Telecommunications Union. (2017). *ICT facts and figures 2017*. Retrieved from https://www.itu.int/en/itu-D/Statistics/Documents/facts/ICTFactsFigures2017.pdf

Johnston, A. M., Mills, C. M., & Landrum, A. R. (2015). How do children weigh competence and benevolence when deciding whom to trust?

Cognition, *144*, 76–90. https://doi.org/10.1016/j.cognition.2015.07.015

Jordan, N. C., Kaplan, D., Ramineni, C., & Locuniak, M. N. (2009). Early math matters: Kindergarten number competence and later mathematics outcomes. *Developmental Psychology*, *45*(3), 850. https://doi.org/10.1037/a0014939

Jung, E. H., Walsh-Childers, K., & Kim, H. S. (2016). Factors influencing the perceived credibility of diet-nutrition information web sites. *Computers in Human Behavior*, *58*, 37–47. https://doi.org/10.1016/j.chb.2015.11.044

Kabali, H. K., Irigoyen, M. M., Nunez-Davis, R., Budacki, J. G., Mohanty, S. H., Leister, K. P., & Bonner, R. L. (2015). Exposure and use of mobile media devices by young children. *Pediatrics*, *136*, 1044–1050. https://doi.org/10.1542/peds.2015-2151

Kildare, C., & Middlemis, W. (2017). Impact of parents mobile device use on parent-child interaction: A literature review. *Computers in Human Behavior*, *75*, 579–593. https://doi.org/10.1016/j.chb.2017.06.003

Kodama, C., Jean, B. S., Subramaniam, M., & Taylor, N. G. (2017). There's a creepy guy on the other end at Google!: Engaging middle school students in a drawing activity to elicit their mental models of Google. *Information Retrieval Journal*, *20*, 403–432. https://doi.org/10.1007/s10791-017-9306-x

Koenig, M. A., Clément, F., & Harris, P. L. (2004). Trust in testimony: Children's use of true and false statements. *Psychological Science*, *15*, 694–698. https://doi.org/10.1111/j.0956-7976.2004.00742.x

Korea Internet & Security Agency. (2012). *ICT use statistics of households and individuals in Korea*. Retrieved from: https://www.itu.int/ITU-D/ict/wtim12/documents/cont/029_E_doc.pdf

Landrum, A. R., Eaves, B. S., Jr., & Shafto, P. (2015). Learning to trust and trusting to learn: A theoretical framework. *Trends in Cognitive Sciences*, *19*, 109–111. https://doi.org/10.1016/j.tics.2014.12.007

Large, A., Nesset, V., & Beheshti, J. (2008). Children as information seekers: What researchers tell us. *New Review of Children's Literature and Librarianship*, *14*(2), 121–140. https://doi.org/10.1080/13614540902812631

Lauricella, A. R., Wartella, E., & Rideout, V. J. (2015). Young children's screen time: The complex role of parent and child factors. *Journal of Applied Developmental Psychology*, *36*, 11–17. https://doi.org/10.1016/j.appdev.2014.12.001

Livingstone, S., & Helsper, E. J. (2008). Parental mediation of children's internet use. *Journal of Broadcasting & Electronic Media*, *52*, 581–599. https://doi.org/10.1080/08838150802437396

Livingstone, S., Ólafsson, K., Helsper, E. J., Lupiáñez-Villanueva, F., Veltri, G. A., & Folkvord, F. (2017). Maximizing opportunities and minimizing risks for children online: The role of digital skills in emerging strategies of parental mediation. *Journal of Communication*, *67*, 82–105. https://doi.org/10.1111/jcom.12277

Lowenstein, G. (1994). The psychology of curiosity: A review and reinterpretation. *Psychological Bulletin*, *16*(1), 75–98.

Madrazo Azbiazu, I., Dragovic, N., Anuyah, O., & Pera, M. S. (2018). Looking for the movie Seven or Sven from the movie Frozen? A multi-perspective strategy for recommending queries for children. In *Proceedings of 2018 Conference on Human Information Interaction & Retrieval (CHIIR '18)*. New Brunswick, NJ: ACM.

Mertala, P. (2019). Young children's conceptions of computers, code, and the Internet. *International Journal of Child-Computer Interaction*, *19*, 56–66. https://doi.org/10.1016/j.ijcci.2018.11.003

Metzger, M. J., Flanagin, A. J., Markov, A., Grossman, R., & Bulger, M. (2015). Believing the unbelievable: Understanding young people's information literacy beliefs and practices in the United States. *Journal of Children and Media*, *9*, 325–348. https://doi.org/10.1080/17482798.2015.1056817

Metzger, M., Flanagin, A., & Nekmat, E. (2015). Comparative optimism in online credibility evaluation among parents and children. *Journal of Broadcasting & Electronic Media*, *59*, 509–529. https://doi.org/10.1080/08838151.2015.1054995

Mikropoulos, T. A., Misailidi, P., & Bonoti, F. (2003). Attributing human properties to computer artifacts: Developmental changes in children's understanding of the animate-inanimate distinction. *Psychology: The Journal of the Hellenic Psychological Society*, *10*, 53–64.

Mills, C. M., & Keil, F. C. (2004). Knowing the limits of one's understanding: The development of an awareness of an illusion of explanatory depth. *Journal of Experimental Child Psychology*, *87*, 1–32. https://doi.org/10.1016/j.jecp.2003.09.003

Mills, C. M. (2013). Knowing when to doubt: Developing a critical stance when learning from others. *Developmental Psychology*, *49*, 404–418. https://doi.org/10.1037/a0029500

Mills, K. L. (2016). Possible effects of internet use on cognitive development in adolescence. *Media and Communication*, *4*, 4–12. https://doi.org/10.17645/mac.v4i3.516

Mishna, F., Cook, C., Saini, M., Wu, M. J., & MacFadden, R. (2011). Interventions to prevent and reduce cyber abuse of youth: A systematic review. *Research on Social Work Practice*, *21*(1), 5–14. https://doi.org/10.1177/1049731509351988

Näsi, M., & Koivusilta, L. (2013). Internet and everyday life: The perceived implications of internet use on memory and ability to concentrate. *Cyberpsychology, Behavior and Social Networking*, *16*, 88–93. https://doi.org/10.1089/cyber.2012.0058

National Early Literacy Panel. (2008). *Developing early literacy: Report of the National Early Literacy Panel*. Washington, DC: National Institute for Literacy. Retrieved from http://www.nifl.gov/earlychildhood/NELP/NELPreport.html

Nikken, P., & Jansz, J. (2014). Developing scales to measure parental mediation of young children's internet use. *Learning, Media and Technology*, *39*, 250–266. https://doi.org/10.1080/17439884.2013.782038

Ofcom. (2019). *Children and parents: Media use and attitudes report 2018*. Retrieved from: https://www.ofcom.org.uk/__data/assets/pdf_file/0024/134907/Children-and-Parents-Media-Use-and-Attitudes-2018.pdf

Oliemat, E., Ihmeideh, F., & Alkhawaldeh, M. (2018). The use of touch-screen tablets in early childhood: Children's knowledge, skills, and attitudes towards tablet technology. *Children and Youth Services Review*, *88*, 591–597. https://doi.org/10.1016/j.childyouth.2018.03.028

Orben, A., & Przybyzki, A. (2019). The association between adolescent well-being and digital technology use. *Nature Human Behavior*, *3*, 173–182. https://doi.org/10.1038/s41562-018-0506-1

Pan, B., Hembrooke, H., Joachims, T., Lorigo, L., Gay, G., & Granka, L. (2007). In Google we trust: Users' decisions on rank, position, and relevance. *Journal of Computer-Mediated Communication*, *12*(3), 801–823. https://doi.org/10.1111/j.1083-6101.2007.00351.x

Perrin, A., & Jiang, J. (2018). *About a quarter of U.S. adults say they are 'almost constantly' online*. Retrieved from: http://www.pewresearch.org/fact-tank/2018/03/14/about-a-quarter-of-americans-report-going-online-almost-constantly/

Richler, J. (2015, February 16). *What children think of the internet (and why it matters)* [web log post]. Retrieved from https://parenting.blogs.nytimes.com/2015/02/16/what-children-think-of-the-internet-and-why-it-matters/

Rideout, V. (2017). *The common sense census: Media use by kids age zero to eight [PDF]*. San Francisco, CA: Common Sense Media. Retrieved from https://www.commonsensemedia.org/sites/default/files/uploads/research/csm_zerotoeight_fullreport_release_2.pdf

Rücker, M. T., & Pinkwart, N. (2016). Review and discussion of children's conceptions of computers. *Journal of Science Education and Technology*, *25*, 274–283. https://doi.org/10.1007/s10956-015-9592-2

Scaife, M., & Van Duuren, M. A. (1995). Do computers have brains? What children believe about intelligent artifacts. *British Journal of Developmental Psychology*, *13*, 367–377. https://doi.org/10.1111/j.2044-835X.1995.tb00686.x

Schulz, L. E., & Bonawitz, E. B. (2007). Serious fun: Preschoolers engage in more exploratory play when evidence is confounded. *Developmental*

Psychology, *43*(4), 1045–1050. http://doi.org/10.1037/0012-1649.43.4.1045

Shin, H., Bjorklund, D. F., & Beck, E. F. (2007). The adaptive nature of children's overestimation in a strategic memory task. *Cognitive Development*, *22*, 197–212. https://doi.org/10.1016/j.cogdev.2006.10.001

Shin, W. (2015). Parental socialization of children's Internet use: A qualitative approach. *New Media & Society*, *17*, 649–665. https://doi.org/10.1177/1461444813516833

Sobel, D. M., & Letourneau, S. M. (2018). Curiosity, exploration, and children's understanding of learning. In M. Saylor & P. Ganea (Eds.), *Active learning from infancy to childhood: Social motivation, cognition, and linguistic mechanisms* (pp. 57–74). Cham, Switzerland: Springer International Publishing. https://doi.org/10.1007/978-3-319-77182-3_4

Sparrow, B., & Chatman, L. (2013). Social cognition in the internet age: Same as it ever was? *Psychological Inquiry*, *24*, 273–292. https://doi.org/10.1080/1047840X.2013.827079

Sparrow, B., Liu, J., & Wegner, D. M. (2011). Google effects on memory: Cognitive consequences of having information at our fingertips. *Science*, *333*, 776–778. https://doi.org/10.1126/science.1207745

Spinath, B., & Spinath, F. M. (2005). Longitudinal analysis of the link between learning motivation and competence beliefs among elementary school children. *Learning and Instruction*, *15*(2), 87–102. https://doi.org/10.1016/j.learninstruc.2005.04.008

St. Jean, B., Greene Taylor, N., Kodama, C., & Subramaniam, M. (2017). Assessing the digital health literacy skills of tween participants in a school-library-based after-school program. *Journal of Consumer Health on the Internet*, *21*(1), 40–61. https://doi.org/10.1080/15398285.2017.1279894

Storm, B. C., & Stone, S. M. (2015). Saving-enhanced memory: The benefits of saving on the learning and remembering of new information. *Psychological Science*, *26*(2), 182–188. https://doi.org/10.1177/0956797614559285

Subrahmanyam, K., Gelman, R., & Lafosse, A. (2002). Animate and other separably moveable things. In G. Humphreys (Ed.), *Category-specificity in Brain and Mind* (pp. 341–371). London, England: Psychology Press.

Tamir, D. I., Templeton, E. M., Ward, A. F., & Zaki, J. (2018). Media usage diminishes memory for experiences. *Journal of Experimental Social Psychology*, *76*, 161–168. https://doi.org/10.1016/j.jesp.2018.01.006

Troseth, G. L., & Strouse, G. A. (2017). Designing and using digital books for learning: The informative case of young children and video. *International Journal of Child-Computer Interaction*, *12*, 3–7. https://doi.org/10.1016/j.ijcci.2016.12.002

Valcke, M., Bonte, S., De Wever, B., & Rots, I. (2010). Internet parenting styles and the impact on Internet use of primary school children. *Computers & Education*, *55*, 454–464. https://doi.org/10.1016/j.compedu.2010.02.009

van Duuren, M., Dossett, B., & Robinson, D. (1998). Gauging children's understanding of artificially intelligent objects: A presentation of 'counterfactuals'. *International Journal of Behavioral Development*, *22*, 871–889. https://doi.org/10.1080/01650259838420

Vanderbilt, K. E., Liu, D., & Heyman, G. D. (2011). The development of distrust. *Child Development*, *82*, 1372–1380. https://doi.org/10.1111/j.1467-8624.2011.01629.x

Vittrup, B., Snider, S., Rose, K., & Rippy, J. (2016). Parental perceptions of the role of media in their young children's lives. *Journal of Early Childhood Research*, *14*, 43–54. https://doi.org/10.1177/1476718X14523749

Wang, F., Tong, Y., & Danovitch, J. H. (2019). *Who do I believe?: Children's epistemic trust in internet, teacher, and peer informants*. Poster presented at the Society for Research in Child Development Biennial Meeting, Baltimore, MD.

Ward, A. F. (2013a). *One with the cloud: Why people mistake the Internet's knowledge for their own*. (Unpublished doctoral dissertation). Harvard University, Cambridge, MA.

Ward, A. F. (2013b). Supernormal: How the Internet is changing our memories and our minds. *Psychological Inquiry*, *24*, 341–348. https://doi.org/10.1080/1047840X.2013.850148

Wilmer, H. H., Sherman, L. E., & Chein, J. M. (2017). Smartphones and cognition: A review of research exploring the links between mobile technology habits and cognitive functioning. *Frontiers in Psychology*, *8*, 605. https://doi.org/10.3389/fpsyg.2017.00605

Wood, M. A., Bukowski, W. M., & Lis, E. (2016). The digital self: How social media serves as a setting that shapes youth's emotional experiences. *Adolescent Research Review*, *1*(2), 163–173. https://doi.org/10.1007/s40894-015-0014-8

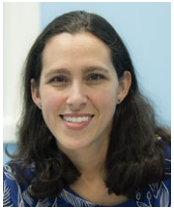
Yan, Z. (2005). Age differences in children's understanding of the complexity of the Internet. *Journal of Applied Developmental Psychology*, *26*, 385–396. https://doi.org/10.1016/j.appdev.2005.04.001

Yan, Z. (2006). What influences children's and adolescents' understanding of the complexity of the internet? *Developmental Psychology*, *42*, 418–428. https://doi.org/10.1037/0012-1649.42.3.418

Yan, Z. (2009). Limited knowledge and limited resources: Children's and adolescents' understanding of the Internet. *Journal of Applied Developmental Psychology*, *30*, 103–115. https://doi.org/10.1016/j.appdev.2008.10.012

Yarosh, S., Thompson, S., Watson, K., Chase, A., Senthilkumar, A., Yuan, Y., & Brush, A. J. (2018, June). Children asking questions: Speech interface reformulations and personification preferences. In *Proceedings of the 17th ACM Conference on Interaction Design and Children* (pp. 300–312). New York, NY: ACM.

AUTHOR BIOGRAPHY



Judith H. Danovitch is an associate professor of psychological and brain sciences at the University of Louisville. She earned her PhD in Developmental Psychology from Yale University in 2005. Dr. Danovitch's research program examines: (a) how children choose among information sources, and (b) what motivates children to seek out information. She is interested in how preschool and elementary school children develop an understanding of other people's knowledge and expertise, and how they apply their understanding of other people in order to evaluate nonhuman information sources, including computers and the internet. She is also interested in how children assess the information that they receive and whether their judgments vary depending on the nature of the information source. Her research has been funded by the National Institutes of Health, National Science Foundation, and the Templeton Foundation.

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