Digital media and young children's learning: how early is too early and why? Review of research on 0-2 year olds

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Abstract

This chapter reviews available evidence and theoretical underpinnings for the benefits and limitations of media use in infants. An overview of available research evidence in relation to children's learning with four types of technology: videos, television (TV), touchscreens, and children's electronic toys is followed by a discussion of the potential health and developmental risks associated with early introduction of digital media. Gaps in research are identified in relation to key learning theories and the developmental stages through which children progress. A framework for educators, parents, and policy-makers is suggested, which takes into account children's learning needs and the available literature, to guide discussions around infants' technology use.
Keywords: infants, technologies, apps, videos, TV, Electronic toys, AAP, e-books, digital media, interactive media, electronics.

Introduction

Children's ages and developmental stages play an important role in how beneficial or harmful exposure to screen media might be. In this chapter, we focus on typically developing children aged 0-2 years, referred to as infants from hereafter, and four types of digital media: video, TV, tablets, and electronic toys.

For infants, anxieties around digital media use are most pronounced and vividly demonstrated in research and policy-making discussions. While concerns around children's use of technology are not new (e.g. TV has been called the 'boob tube' since the 1970s, and Postman (1982, 1994) worried that it would rob children of their childhood), concerns have been heightened as use of newer technologies (such as smartphones and tablets) by infants has been increasing steadily over the past 5 years. As an illustration, in the United States in 2011, only 10% of children under 2 years of age had ever used a mobile device (Common

Sense Media and Rideout 2011). This increased to 38% of 0-2 year olds in 2013 (Common Sense Media and Rideout 2013). A smaller study conducted in a low-income urban paediatric clinic in 2015 showed that almost all (97%) of 0-4 year olds had used a mobile device, 3/4 owned their own device, and most young children were primarily using mobile devices for entertainment, not educational, purposes (Kabali et al. 2015). When last examined, 0-2 year olds were estimated to use an average of 1 hour and 15 minutes of screen media per day (Wartella 2014), despite professional guidelines that children under 2 years of age avoid media use (American Academy of Pediatrics, AAP 2011).

While we acknowledge that many questions in relation to new technologies remain unanswered, we also perceive an urgency to provide parents and educators with guiding principles. Considering the rapid uptake of digital media by families in the Minority world (such as the UK, Australia, USA, and Canada), it is important to draw together the current available evidence on the affordances and limitations of digital media for infants and reflect on how to best support parents and educators in their decision-making around their use.

To frame this reflection in a broader exploration of the cognitive and socio-emotional development of infants, we first review the evidence on how infants learn more generally, followed by the key theoretical conceptualisations of children's learning.

How do children learn?

There are various ways to describe how children learn and given the idiosyncratic nature of development for each child, there are probably as many ways as there are children in the world. Developmental milestones, which are used clinically to screen for developmental delays and help parents understand what behaviours to expect and how to best support their

children's developmental trajectory, are one framework for considering how infants might interact with media. Milestones are not fixed points in time; they often overlap with each other and occur in parallel. Some children develop milestones at different times, different children develop in different patterns, and individual differences can be accentuated in different contexts. We revisit key developmental stages selectively, paying special attention to those milestones which are relevant for the chapter's discussion of the influence of new technologies on young children's development and for identifying the current research gaps.

0-3 months

Children between 0-3 months are in the process of developing their auditory abilities, which means that they react to loud noises, often with a distress response such as spreading out their arms or crying. They typically respond to close sounds, and develop their distance hearing abilities later on. Infants of 0-3 months develop motor strength and coordination principally in their trunk and neck, while distal extremity coordination (e.g. voluntary grasp and release of objects) has not yet matured. They attend to faces and eyes and can imitate basic facial expressions.

Children at this age would therefore process very little from screen technologies because of their immature auditory and visual processing. Cross-sectional associations between screen media use and excessive crying have been reported (Thompson, Adair, and Bentley 2013), suggesting that audio-visual stimulation from media may contribute to irritability and children's desire for attention from others, instead of a screen. On the other hand, parents of fussy infants may be putting them in front of digital media in an effort to calm them down. Future research should consider how the presence of features particularly salient for this age group might influence irritability, self-regulation, and social co-regulation, particularly for

infants with a low sensory threshold or high sensory reactivity. For instance, many infant apps include mirrors and high-definition images of colourful characters, but it is not known whether these features support or confuse children's understanding of self and others – a crucial development in these early months. There are also many technologies developed for this age group that include audio-recordings of voiceovers and music, but it is not known whether these audio features influence children's earliest stages of auditory processing.

4-6 months

At this age, motor coordination and strength matures so that infants can start to use their hands to voluntarily grasp objects, bring their feet to mouth when lying on the back, or sit unsupported. Children's hearing skills progress as well and they are now able to enjoy listening to familiar sounds and create babbling noises with different sound qualities (e.g. volume, pitch, and rate). They explore with touch and taste (or hand and mouth). They do not recognise that an image in the mirror is a reflection – they would reach out to it and experiment how it responds. They are fascinated with and enjoy exploring simple cause-and-effect toys and objects, such as rattles and other noisemakers (see Davies 2010).

These abilities mean that children would enjoy exploring simple cause and effect responses on the screen (e.g. tapping an area of a touchscreen and seeing how it changes colour or produces a sound), but they would not be expected to have the motor control to recreate this effect over and over. Future research needs to establish whether apps and technologies which elicit cause-and-effect response in children support their development of causality in other 3-dimensional play. Babies at this age enjoy the sensory experience and interact more with their own body (e.g. chewing their own hands or feet), so would explore digital devices in a largely sensorimotor manner. It would be interesting to find out whether children's physical

manipulation of technology can develop their emerging understanding of space, or whether displacement of 3-dimensional play by watching videos (i.e. 2-dimensional experiences) has a net detrimental influence on visual-spatial abilities.

7-9 months

Seven-to-nine-month-old children enjoy responding to sounds, objects, and people around them with imitation and their own sounds. Children of this age babble and respond to family members' names and familiar pictures. They love producing their own sounds such as clapping, and cooing and play games with a surprise effect (such as peek-a-boo, which takes advantage of their emerging understanding of object permanence).

There are many apps that record and play back to children the sounds they can make, such as gurgling, laughing, and babbling. However, as children at this age do not appear to understand audio- or video-recorded language the same way they do spoken speech (see Doupe and Kuhl 1999; Kuhl et al. 2006), they would not be expected to learn from, or understand, such apps. Child-directed in-person speech is the most important facet of language development at this age. Future research is necessary to determine whether the presence of child-directed and child-reflective speech in children's software helps their language development or displaces parent-child verbal interaction, as other interactive media have been shown to do (as discussed below). What we do not know is whether children benefit from such interaction at repeated exposure or whether the novelty effect is the crucial means for learning.

10-12 months

A one-year-old child can use their entire body to respond to music, including moving to rhythm and dancing. One-year-olds can also attend to new words and look for new and familiar objects when asked. First words also emerge during this time. Popular activities with this age group are often centred on the exploration of songs and pictures of their family, friends, and personal experiences in various contexts. Children love to look at family pictures over and over, pronounce the names of the people they recognise, and point to them with their finger. They now better understand that people in pictures do not have to be present physically for sounds and images of their faces – this understanding is often reflected in their ability to look for objects even when these are hidden and they have to find them. However, children of this age do not have fully developed symbolic thinking and memory flexibility, which makes it more difficult for them to make a transfer of knowledge from 2D to 3D objects (see Barr 2013). We therefore recommend that future studies examine children's understanding of object permanence, understanding of commonly used symbols in commercial apps, and the role of 2D pictures in children's understanding of self and others.

12-24 months

Children aged between one and two years of age enjoy simple stories, rhymes, and songs. They often respond to them by imitating the sounds and words. A very popular activity with this age group therefore often is songs and story apps, with which children enjoy pointing to objects and naming them, as well as exploring new textures and shapes. As yet, there is very little known about the impact of repeated, technology-mediated experience of stories, rhymes, and songs on children's language development. Future research is needed to elucidate how children's emerging understanding of mathematical concepts can be influenced by specifically designed apps and electronic toys, independent of parent re-teaching known to be crucial for this age group to learn from digital media.

There are many important milestones to be mastered in this crucial period of child development. As for those which are most relevant to the use of media with this age group, 18-24 month olds start to develop symbolic thinking, understanding of cause, effect, and sequence, and use much more verbal and nonverbal communication with caregivers during toy play. If we consider the many skills and abilities developed at this age (Davies 2010), it is clear that more research is needed regarding how much 18-24 month olds can learn independently from well-designed touchscreen media, how they interact verbally and nonverbally with others around them while using technologies, and whether they are able to generalize this knowledge to their surroundings.

In addition, 12-24 month olds begin the process of individuation from their caregivers, which is accompanied by an increase in negativism, tantrums, and self-directed behaviour (Steinberg, Vandell, and Bornstein 2010). Parents usually experience a higher degree of parenting stress during this time. Only one study (Radesky, Peacock-Chambers, Zuckerman, and Silverstein 2016) has examined how parents use mobile devices to calm difficult infants/toddlers or keep them quiet. In this study, 144 caregivers were surveyed about their toddler's development, parenting practices, and their child's media use practices. Toddlers rated as having social-emotional difficulties were 2.7 more likely to be given a mobile device to calm down when upset, and 3.6 times more likely to be given a device to keep peace and quiet in the house. However, more research is needed to examine whether this alters toddlers' social-emotional trajectory.

Developmental milestones can tell us what infants can achieve at approximate ages; what they cannot tell us is what is actually happening in terms of the mechanism of learning i.e.

how do babies learn and acquire new knowledge? The discussion of potential benefits and limitations of infants' learning with digital media necessitates a theoretical explication of the nature of children's learning. There is a range of theories and possibilities in this area and we spotlight two key learning theories, which have historically dominated the child development literature.

How babies learn? Research and theories

Infants learn by surprise and testing hypotheses

An exciting theory about children's learning is based on the premise that children are born with rich expectations about the world and learn when some of these expectations are violated. They also engage in exploratory behaviours to test and defy their expectations.

In the 1980s and 1990s, this notion was revolutionary: before, the accepted wisdom was that infants do not go beyond the here-and-now sensations in their thinking. In a number of studies, researchers at the John Hopkins University have shown how children's knowledge of the world around them, can ignite and further drive their learning. In a carefully designed experiment, Stahl and Feigenson (2015) examined whether children as young as 11-months would use their surprise at unexpected events as motivation to learn about and explore the events. Examples of unexpected events in such experiments often draw on basic laws of physics, for example researchers show babies small car toys which do not drop on the floor but instead can float in the air or roll through walls. When Stahl and Feigenson (2015) showed 110 infants some examples of such expectancy-defying events, they saw that babies stared at them for longer time. Moreover, the babies were more motivated to explore the objects (touching them, putting them into their mouth, shaking them) and were also better at

retaining new information associated with objects which violated their expectations (and common sense).

It is still a mystery how the mechanisms of learning work through surprise. One theory is that there is greater brain activity following a surprise reaction, which could explain babies' ability to create relationships between concepts (see Baillargeon, Scott, and Bian 2016). Another possibility is that babies learn by testing hypotheses and statistical probability. Alison Gopnik, Laura Schulz, and Rebecca Saxe (see Bedny, Dravid and Saxe 2014; Jara-Ettinger et al. 2015; Meltzoff and Gopnik 2013) have carried out a number of experiments showing that children can figure out cause and effect and use probability calculations to discover new and surprising facts about the world. Their findings show that children spontaneously and naturally engage in cause-and-effect testing in their play and in that way, they test hypotheses, compute several scenarios, falsify and verify information, explore open-ended questions about them – just like scientists do.

In their investigations of children's learning from media, these theories are more likely to foreground the importance of children's own engagement with the technology. The socio-cultural perspective, on the other hand, foregrounds the mediation of technology use with a parent or another child.

Babies learn through guided interaction with others

In 1950, Knowles suggested guided interaction as the ideal adult-child or teacher-student relationship for children's learning. Children do not acquire new information through a simple one-way process of content transmission from the object or environment to their brain. Rather, this learning is always situated and mediated by others who guide their

understanding. Knowles developed guided interaction into a theory of adult learning building on earlier writings of Kapp in 1833. In this century, Lydia Plowman (1992) used the theory in the context of children's learning with digital media (TV, computers, and electronic toys) to conceptualise the various ways in which pre-schoolers learn with technologies at home and in school. Although Plowman's seminal study did not focus on infants and toddlers, the studies provide a relevant conceptual language. Drawing on a series of case studies of pre-schoolers' use of digital media, Plowman & Stephen (2007) argue that guided interaction has two components: proximal and distal guided interaction. Examples of distal (or indirect) interaction include: planning, monitoring, providing resources, ensuring access and help, setting up activities or ensuring access to ICT. On the other hand, proximal (direct interaction) involves demonstrating, enjoying, explaining, instructing, managing, modelling, prompting, providing support and feedback (Plowman and Stephen 2007). For these researchers it is primarily through social interaction that children's learning can occur, and the importance of social mediation does not come second as it perhaps would from the previous perspective, but is given primacy.

Reflecting on these two main theoretical approaches, and their historical importance in advancing the child development research, we recommend that future research on children's development mediated by the use of technology considers, or at least clearly outlines, the adopted theoretical approach. Much contemporary research on children's use of technology is guided by urgency and practical concern, which is problematic. Research which is theory- rather than practice-driven can generate conclusions that are generalizable and applicable across contexts. This is particularly important in a field where practices and tools mediating these are in a state of rapid change and development.

Current guidance in relation to technologies and under 2s

The American Academy of Pediatrics (AAP 2016) has advised parents to avoid media use in children under 18-24 months because it was argued that current research shows children under this age do not benefit from interactions with technology. It was also argued that time allocated to video screens provide no educational benefits and leave less room for activities that do e.g. interacting with other people and playing. The new guidelines, accounting for the abundance of new digital media such as smartphones and tablets, emphasize co-viewing with young children and the importance of high-quality content (e.g. CBeebies in the UK or Sesame Street in the USA).

How can parents reconcile the existing body of evidence linking screen media use to more negative developmental and health outcomes (AAP 2016), with the hope that interactive technologies might be more educational and with the fact that increasingly more children use digital toys, touchscreens and TV on a daily basis? In this chapter, we formulate a conceptual framework of key stages, which could inform parents', educators', and policy-makers' decisions around children's (0-2 year olds) use of technologies. This framework is not intended to replace official guidance; it merely provides some thinking tools facilitating the decision-making around this important topic.

How do infants learn from digital media?

In the remainder of this chapter, we review the available research evidence specifically in relation to four types of screens and technologies to which infants are frequently exposed: videos, TV, touchscreens, and electronic toys. We purposefully separate video studies from TV studies because of the different lines of research in this area. Video studies typically study children's response to pre-recorded materials under laboratory conditions, while TV research,

tends to focus on children's programmes aired on national TV and watched in the home. Under touchscreens we included studies that focus on children's use of touch-manipulable screens such as tablets and smartphones and all activities available for these technologies, apart from TV watching.

Videos

Early research with videos showed that children younger than 30 months do not learn from screen media as well as they do from in-person interactions, even with child-appropriate educational content (Anderson and Pempek 2005). This so-called video deficit is thought to stem from infants' and toddlers' immature attentional controls, memory flexibility, and symbolic thinking, which prevent them from understanding content (including novel words or visual-spatial reasoning) presented on 2-dimensional screens (Barr 2013). Several studies support this notion, for example Troseth and DeLoache (1998) and Anderson and Pempek (2005). Despite the vast array of videos marketed to infants as 'educational,' such as the now disproven Baby Einstein series, laboratory studies suggest that children under 2 years actually struggle to make sense of screen media, and need help from interactive adults in order to do so. For example, Richert, Robb, and Wartella (2010) and colleagues found that when word-learning videos are co-viewed by infants and parents, 16 month olds could learn new words taught on the videos much better than if they watched the videos alone.

The age of the infant matters significantly when considering learning from video presentations. For example, Deloache and colleagues (2010) compared word learning of 12- to 18-month-old children in a video and non-video condition. The latter was mediated by adults and was shown to be the most effective condition to teach children new words. Despite parents' beliefs that their baby learns from the popular video used in this study, the findings

demonstrated that younger infants did not learn from video exposure without re-teaching from their parents. On the other hand, a study by Krcmar, Grela, and Lin (2007) showed that while children older than 22 months can identify new words when taught through a television program, children under the age of 22 months were not able to identify new words presented on a television screen.

More recent research has shown that, under particular conditions, children between 15 and 24 months of age can learn from repeated viewing of video without adult help. Dayanim and colleagues (2016) showed that 15-month-olds could learn the meaning of sign language symbols after 3 weeks of watching a commercially available video 4 times per week. However, infants in the comparison arm (in which parents taught them signs from a book) retained their knowledge of sign language for longer in this study, suggesting that socially-mediated learning may have different storage in memory than video-mediated learning. Parasocial relationships with video characters may also augment learning: Calvert et al. (2014) showed that after 3 months of playing with a personalized interactive toy, 21-month olds could learn how to stack cups from a video demonstration by this same toy, suggesting that building an emotional bond with an on-screen character improves learning potential.

More recent studies, however, are showing that this 'video deficit' can be overcome with videochatting, which offers contingent interactions with others via a screen medium. Roseberry, Hirsh-Pasek, and Golinkoff (2014) examined how thirty-six 24-30-month-olds learn new words in three conditions: live interaction training, socially contingent video training over video chat, and non-contingent video training. It was only in the socially contingent video training condition that children were able to effectively learn new words. It is important to note that, these children were 2 years and older. More recent work has shown

that infants as young as 16 months can show shared visual attention with others via videochat, and are able to sustain interactions on Skype more readily with parent support (McClure et al. in press – just check whether now published and amend if need be).

The conclusion from the above studies has been that children under the age of two years cannot transfer information presented on a 2D screen to their 3D environments effectively, and that they learn much more readily from real-life interactions. The few studies to show independent learning of new skills from video in children under 2 years necessitated rarefied conditions or repeated viewing, which is not typically reproducible in naturalistic settings. While it might be argued that an educational video is better for child development than a non-interactive parent, or one with low literacy or teaching skills, this has not been borne out in population-based research; Tomopoulos and colleagues (2010) found that low-income toddlers whose mothers did not interact with them during video viewing had poorer language development overall.

TV and educational TV programmes

While many of the above experimental designs involved randomizing children to repeatedly watching videos focusing on specific content, studies of naturalistic TV viewing in children have had less positive findings. In a correlational design, Zimmerman, Christakis, and Meltzoff (2007) administered a survey asking parents of 8- to 24-month-olds about the content and frequency of TV watched at home. They correlated these data with standardized parent-report language measure and found that infants 8-17 months had smaller vocabulary sizes if they watched more TV. There was no apparent association between the amount of TV watching and vocabulary size for children aged 17 months and older. Given that the study was correlational, it cannot be concluded that TV watching was reducing children's

vocabulary as many other factors (including parenting and other factors in the home environment) might be at play. The study does, however, highlight the close association between the amount of time a child spends watching TV and their vocabulary growth.

Lisa Guernsey's framework of 3Cs- content, context, and individual child (Guersney 2012) reminds us that in any evaluation of benefits and limitations of technology on children's learning, the content of the video programme matters. Longitudinal studies suggest that high-quality content is protective of child developmental outcomes. For example, Nathanson and colleagues (2013) found that the earlier the age that children began regularly watching TV, the higher their risk of executive functioning problems as pre-schoolers; however, high-quality content (e.g. Sesame Street shows, which have been crafted under the guidance of developmental experts and avoid fast-paced editing) protected against this risk. This study supports earlier work on content: Linebarger and Walker (2005) compared data reported of parents of children aged between 3 and 6 months, in relation to the program, content, intended audience of TV watched with children's vocabulary knowledge and expressive language skills. They found that some programs (Dora the Explorer, Blue's Clues, Arthur, Clifford, or Dragon Tales) were actually supportive of children's language scores, while others (e.g. Teletubbies) were associated with lower expressive language outcomes. As with all other resources, in addition to the actual content of programming, parents' presence during TV watching and their verbal support can determine whether an infant will, or will not, learn from media. With pre-schoolers, parent co-viewing (i.e. watching the TV together with the child) has been advocated by a number of organisations, including Joan Ganz Coney Centre, USA.

Touchscreens

While TV watching on a TV is typically a unidirectional experience – a baby watches a programme without interacting with it – educational programmes and games designed for touchscreens require children's active input. Touchscreens are designed for finger-and touch-manipulation, which does not require teaching as it was the case with a PC mouse. With a range of inbuilt features (such as microphone, camera and touchpad), the possibilities for a child's interaction with moving images and sounds are unprecedented.

Published evidence regarding learning from touchscreens is still sparse, but recent work by Kirkorian and colleagues (2016) has shown that the video deficit can be eliminated in 24 month olds (e.g. to learn a novel word or solve a puzzle) if the app is designed in such a way that it scaffolds the child's choices. It is important to note that apps used in this lab-based experiment were specially designed teaching videos that the child could forward by tapping on certain highlighted areas. Such design is quite different from commercially available 'educational' apps, which have been shown to have low educational potential, target only rote academic skills, are not based on established curricula, and have almost no input from developmental specialists or educators (Guernsey and Levine 2015). The field of children's apps is growing and new programmes are being designed and introduced to the market at a rapid rate. At the time of writing we can say with confidence that the apps which can be useful for infants are those which can be used as prompt for parent-child communication (e.g. browsing pictures), connecting families and building bonds (e.g. Skype with a grandparent or parent not physically available).

Children's electronic toys/objects

In a recent study, Zosh et al. (2015) compared parent-child interaction when sharing electronic versus traditional shape sorters. The researchers transcribed the verbal feedback

provided by the parent and the toy itself when they interacted with the shape sorter and found that there was significantly less rich language (in terms of the spatial vocabulary and mathematics concepts) introduced by parents in the electronic toy condition. Although children in this study were slightly older (3-year-olds), the study highlights what similar studies with children's digital books have found: parent-child interaction and parents' talk are impoverished when they use digitally-enhanced books.

For example, Parish-Morris, Mahajan, Hirsh-Pasek, Golinkoff, and Collins (2013) examined and compared parent-child interaction with 165 children in three conditions: Electronic console (EC) books, CD-rom books, and e-book apps. They found that the more these different kinds of digital books contained enhanced features (e.g. pre-recorded sounds), the less beneficial they were for the parent's use of high-quality language (dialogic reading strategies) and the child's learning (story comprehension). Again, children in this study were three-year olds but it is likely that similar differences in parent-child interaction would occur with electronic toy play with younger children, as another study recently demonstrated (Sosa 2015). Sosa (2015) conducted a controlled experiment with 26 parent-infant dyads. The children (10-16-month-olds) were observed playing with their parents and 3 different toy sets: electronic toys, traditional toys, and books. The analysis focused on the overall numbers of words produced by the parent, by the child, and mutual conversational turns (per minute per each toy/condition). The results showed that with electronic toys, both adults and children produced less words, and there were also less conversation turns, when compared to parent-child play with traditional toys and books. In other words, traditional books and toys can inspire conversations of higher quality than those with enhanced electronic features. There is therefore insufficient evidence to suggest that children under the age of two years playing with an adult should be exposed to digital instead of traditional toys. At the time of writing,

studies which would compare children's solitary play with digital versus traditional toys are not available. However, it has been posited that solitary digital play does not allow the sensorimotor exploration important to parietal lobe development and later visual-spatial abilities, which block play, for example, allows (Verdine et al. 2014).

While these studies focused on the ways in which children could learn from digital media, there is also evidence of potential risks of technologies on children's development, notably in relation to excessive use.

Limitations of excessive use of digital media for infants

Several potential risks of excessive media use in early childhood have been established. Population-based studies have shown associations of excessive TV viewing in infants with cognitive (e.g. Schmidt, Rich, Rifas-Shiman, Oken, and Taveras 2009; Tomopoulos, Dreyer, Berkule, Fierman, Brockmeyer, and Mendelsohn 2010), language (e.g. Duch et al. 2013; Zimmerman, Christakis, and Meltzoff 2007) and social/emotional delays (Conners-Burrow, McKelvey, and Fussell 2011; Hinkley, Verbestel, and Ahrens 2014; Tomopoulos et al. 2007). Possible mechanisms include effects of adult-oriented content, decreases in parent-child interaction and play when the TV is on (Christakis et al. 2009), and overall higher family chaos in high media use households.

In addition, due to the effects of food advertising and sedentary lifestyle, high levels of media use are associated with obesity and cardiovascular disease later in childhood (Bel-Serrat et al. 2013). For example, a recent study in 2 year olds demonstrated that body mass index was linked to the amount of media exposure (as measured by every hour per week, see Wen, Baur, Rissel, Xu, and Simpson 2014).

In addition, presence of TV or mobile devices in the bedroom is associated with fewer minutes of sleep per night, a finding that it stronger among racial/ethnic minority children (Cespedes, Gillman, Kleinman, Rifas-Shiman, Redline, and Taveras 2014). Mechanisms are thought to include later bedtimes after evening media use (McDonald, Wardle, Llewellyn, van Jaarsveld, and Fisher 2014), arousing effects of violent content (Garrison and Christakis 2012), and suppression of the sleep-inducing hormone, melatonin, by blue light emitted from screens (Higuchi et al. 2003).

In sum, the current literature focuses strongly on learning discrete skills from screen media – often in laboratory-based settings – or on the developmental and health risks associated with children's reported media use in the home. Considering the complex nature of children's development, it is likely that several areas of infant/toddler development are not represented in the literature. We therefore approach the gaps in literature in clinical and theoretical terms of infant/toddler development. To frame the discussion, we use the developmental milestones, which provide an approximate timetable and range of skills children gradually develop as they mature.

Framework to guide practical interpretation of research evidence

The first key decision stage relates to establishing whether children use the technology independently or with an adult/older peer. In our review, we outlined how parents' active presence can mitigate against the video deficit effects in 15-30 month olds, albeit the learning benefits of parent co-viewing of educational media most strongly manifest at pre-school age. Other studies examined the video deficit effects and current evidence is that adult's physical and virtual presence can mitigate against video deficit, but the child's age is important.

Roseberry, Hirsh-Pasek, Parish-Morris, and Golinkoff (2009) examined how 96 30-42-month old children learn verbs from video watching with and without the support of adults (live video interaction). They found that the child's age matter: while younger study participants could only learn new verbs when the videos were accompanied by adult interaction, older study participants could learn the new vocabulary from videos alone. Strouse and Troseth (2014) hypothesise that parents' presence can mitigate against the video deficit, while Dayanim and Namy (2015) stress that this can be even greater if the learning stimuli are not spoken words but signs, such as for example the American Sign Language Signs. Considering the importance of guided interaction for all kinds of learning and the emerging evidence on parents' supporting role with interactive media use (e.g. Hassinger-Das et al. 2016), it is crucial to consider the nature of the interaction: infants will learn considerably more from unidirectional (i.e. videos, TV) or interactive touchscreens/videochat when the activity is scaffolded by a caregiver.

Second, consider the type of technology used by the child: is it an electronic toy specifically developed for children or a parent's smartphone lent to the child? It used to be the case that a screen could be used synonymously with TV as there were not many other screens with which young children would interact. Today, however, the word screen can encompass a wide variety of digital devices, including PCs, Leapsters, Kindles, iPads, smartphones, and others. When talking about the effects of 'screens' on young children's development, we need to be clear about which device we have in mind, as well as which features of this device (e.g. its portability, its possibility to connect to the Internet; possibility to personalise or customise the content). In our review, we considered three different kinds of screens (videos, TV, and touchscreens) and electronic toys. Current evidence suggests that the device or platform is as important as the design of the interactive interface. Although it could be argued

that mobile devices are more likely to be used independently rather than shared (see Wartella 2014), it is also important that the specific app being used scaffolds a child's choice rather than distracts with bells and whistles (Hirsh-Pasek et al. 2015).

Third, consider the content of the activity – is it appropriate for your child? Content is one of the 3Cs we had mentioned earlier – content, context, and individual child (Guernsey 2012) – and is crucially important when thinking about the effects a particular technology might have on a child's learning. The quality of the digital content influences what and how much children learn during the interaction. For children's apps available for smartphones and tablets, the UK's literacy charity National Literacy Trust developed an 'app guide', which lists apps recommended by experts to support children's reading for pleasure (http://literacyapps.literacytrust.org.uk/). Other organisations, for instance the Common Sense Media in the USA, regularly review apps for a number of learning benefits, including key language skills relevant for the youngest users (www.commonsensemedia.org).

The content of the activity is closely linked to the skills the child can gain from using the technology. In assessing the 'added value' of a technology for the child's development, it is best if teachers and parents reflect on the ways children learn and the key milestones they need to master as they mature. Again, the type of the technology used and whether its content and design are appropriate for the developmental level of the child will strongly influence the skills and knowledge children can gain.

Finally, it is important for caregivers and adults making media use decisions for infants to think about their own use of technologies and how that might influence your perception of how your child learns and interacts with technology. Currently, many caregivers feel pulled

by two opposing public discourses: one which suggests that technologies can improve if not transform children's play, creativity, and learning; and a contrasting discourse, which suggests that technologies can damage children's development and be detrimental to their relationships with others and holistic growth. The extent to which one or the other discourse dominates a parent's decision-making is a function of personal theories, beliefs, previous experiences, and values of how infants should be raised (as well as the popular media, which often take advantage of this polarised topic). We therefore recommend that caregivers reflect upon their family's culture of technology use as a whole, so that they can make proactive decisions about allowing infant media use only if it supports their parenting values and goals regarding what they want their child to learn.

This leads us to the following cycle of questions and evidence-checking (see Figure 2.1).

<<FIGURE 2.1. HERE>>

Future directions

Some important considerations for future research based on our literature review therefore include these four key points:

When evaluating the benefits and limitations of digital media for infants:

1) Reflect on your own personal theories, beliefs, previous experiences, and values of how infants should be raised and how technology might influence them;

2) Consider whether the technologies are used by the child on their own or with an adult;

3) Think about the content of the activity – what is the specific app/digital game/activity the child is engaging with?;

4) In addition to the content of the activity, think about the type of technology (video, TV, electronic toys, or tablets) the child is using, the particular features of this technology, and context in which it is used.

Conclusion

The aim of this chapter was to ensure that readers are aware of various possibilities of children's learning when evaluating the question of whether technology is, or is not, appropriate to support the earliest stages of children's learning and development. Our review confirms the conclusion drawn by the Academy of Paediatrics in 2016: currently, we do not have sufficient evidence to recommend the independent use of digital media for children under the age of two. Early introduction of screen media is associated with several adverse developmental and health outcomes, but supportive parent interaction around media and high-quality content can reduce some of these risks. Yet, we also know from several survey and observation studies that toddlers and infants regularly interact with tablets, their parents' smartphones, or electronic toys designed for them. The technologies therefore are likely interacting with their developmental trajectory, and we need more research to help us understand how.

All technologies are a moving target; designers and technology developers are refining their products based on the users' feedback and uptake. Our framework provides not only a guide of caregiver decision-making about media use in infants, but also a general approach for understanding, interpreting, and generating new research evidence on this important topic. The framework is not hierarchical – each element matters and is interconnected with the other elements. What is crucial for practitioners, childminders, parents, and policymakers is the

importance of others in mediating children's technology use, which is why we include it as the key first question to ask when thinking about technology impact on infants/toddlers.

In conclusion, with our socio-cultural orientation toward child development, we highlight that for a holistic, optimal, and long-lasting learning to occur, no technology can replace positive human interaction. This is especially true for the development of children's first knowledge of the world and their skills to fully function in it.

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