When and How Do Interactive Digital Media Help Children Connect What They See On and Off the Screen?

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ABSTRACT—***Understanding screen media—even television—can be a challenging task that requires substantial cognitive effort, especially for young children with relatively limited cognitive resources. Toddlers are less likely to transfer information across contexts (e.g., from video images to actual objects) than within the same context. Interactivity, such as that afforded by video chat and touchscreen mobile applications, may promote this transfer. However, some types of interactivity may be more beneficial than others, and the optimal conditions for learning differ across children. In this article, I describe what we know and what we need to understand more fully about children's transfer in the context of interactive digital media. I emphasize the extent to which cognitive constraints and the complexity of tasks likely moderate the effects of digital media on early learning and development.***

KEYWORDS—*transfer; video deficit; digital media; learning; working memory*

Imagine a 2-year-old watching a television program. The program differs substantially from the child's experience in the world, presenting many unique challenges for comprehension and transfer learning (1). For instance, can the child understand the symbolic relation between on-screen images of objects and the real objects they represent, even when the objects look different? The empirical literature suggests this is difficult during the first years of life: Toddlers are less likely to generalize information across different contexts (e.g., from video to real objects) than within the same context (e.g., using only real objects; 2, 3).

Now imagine another child viewing the same information by tapping through a mobile application or digital game rather than observing a video. Does this interactivity increase or decrease the likelihood that the child connects what she sees on and off the screen? Research on learning from interactive digital media is only beginning to emerge, but interactivity appears to promote transfer, at least in some cases. Nonetheless, some types of interactivity are more beneficial than others, and the optimal conditions for learning may vary considerably across individuals.

In this article, I describe research on how toddlers learn from digital media and consider questions from the perspective of a psychologist who studies cognitive development. My purpose is not to create evidence-based principles for designing educational media, which has been done elsewhere (4). Rather, I seek to build on the literature on young children's transfer and synthesize early research on toddlers' learning from interactive digital media. Consistent with hypotheses about digital media and early learning (5), I focus on the task demands and developmental considerations that may promote transfer during infancy and early childhood.

WHY IS TRANSFER FROM NONINTERACTIVE VIDEO SO DIFFICULT FOR YOUNG CHILDREN?

Decades of research have demonstrated that children are engaged cognitively when watching television, and that they can learn about a range of domains from well-designed educational television programs (6). However, in laboratory studies with

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experimental stimuli, learning from video is not the same as learning from direct experience. In research on transfer, toddlers appear to have particular difficulty learning from observational (i.e., noninteractive) media during the first 2 or 3 years of life (2, 7). Studies have also demonstrated poor transfer in older preschoolers who were tested on more difficult tasks (8, 9). Thus, difficulties in transfer seem to occur when children are just beginning to master a particular skill, that is, when tasks are challenging but surmountable. Furthermore, the difficulties are apparently domain general, seen in children using wide-ranging skills such as imitation (10, 11), object retrieval (12, 13), and word learning (14, 15).

Scholars have proposed that problems with transfer result from several cognitive demands that are not mutually exclusive. Some explanations have to do with the nature of video itself. For instance, compared to three-dimensional objects and spaces, two-dimensional video images contain less information (12). Thus, children may require additional time to process two-dimensional images. Indeed, electroencephalography (16) and eye-tracking data (17) suggest that toddlers process two-dimensional images more slowly than three-dimensional objects. This may explain why the likelihood of transfer increases when video stimuli are repeated (18–20), providing more opportunities for toddlers to process the perceptually impoverished two-dimensional images.

Video is also impoverished socially because it lacks many cues that support learning during social interactions, such as eye gaze, pointing, contingent responses to children's behavior, and personally relevant information (e.g., using a child's name; 21, 22). When these social cues are incorporated into screen media using video chat with a person, transfer is enhanced (23–26). Toddlers learn more from contingently responsive video chat partners who provide personally relevant information than they do from prerecorded people on video. However, this learning benefit does not happen when toddlers watch prerecorded videos in which on-screen partners do not respond contingently to children's behavior and provide incorrect information (e.g., using the name of a different child; 23, 24, 26).

Other explanations for difficulties in transfer relate to transfer more generally, not just transfer from video to real situations. For instance, to generalize from screens to actual situations, children must recognize the symbolic nature of video, that is, they must mentally hold and update many mental representations: the video screen as an object in itself and the video screen as a symbol representing actual objects and spaces. Such symbolic reasoning applies to a range of media, including photographs and three-dimensional models, and apparently develops during toddlerhood (27).

Finally, children with relatively less flexible memory are likely to have difficulty reconciling the perceptual mismatch between different contexts, including (but not limited to) video images and actual objects (3, 7). As a result, children with a relatively poor working memory capacity (e.g., relatively younger children) are more likely to have difficulties in transfer. Indeed, 2-year-olds' performance on a working memory task predicted whether they would transfer information from a video to actual objects, even after controlling for the children's age and receptive vocabulary (28). This finding supports the hypothesis that transfer across contexts (e.g., from screen images to actual objects) is demanding cognitively and requires substantial cognitive resources.

DOES INTERACTIVITY SUPPORT OR HINDER LEARNING FROM DIGITAL MEDIA?

Since processing two-dimensional video information and transferring that information to actual problems is apparently cognitively demanding for young children, scholars have speculated about whether interactive digital media help or hinder learning. On the one hand, interactive media may be more demanding cognitively because children must plan and execute appropriate motor responses; when such responses require cognitive effort, interactive digital media may hinder learning (29). On the other hand, interactive media may support learning if they promote a sense of agency, increase engagement through personally relevant or contingent responses, or guide visual attention to relevant information on the screen.

Research demonstrates that some types of interactivity helped some young children transfer information from tasks involving imitation, object retrieval, and word learning. As noted previously, transfer is enhanced with video chat interactions (23–26) compared to noninteractive video. However, toddlers can also learn from interactive media that do not involve video chats with an actual person. Specifically, toddlers also learned more from interactive screen media (versus noninteractive video) when they played a computer game (30) or used a touchscreen application (28, 31, 32).

The impact of interactivity depends in part on the extent to which interactive features direct attention toward relevant information. For instance, younger 2-year olds were less likely to pass a simple word-learning test with actual objects after watching noninteractive videos of an actor opening boxes to reveal the objects than after using an interactive touchscreen application in which they had to touch each box to see the object inside (32). A more general touchscreen application that allowed children to touch anywhere on the screen to see each object did not provide the same benefit. Similar findings were reported using an object-retrieval task (31).

Of course, interactive features may help only to the extent that they guide attention to relevant media content rather than diverting attention to irrelevant content. The most extensive evidence on feature relevance comes from studies with older preschoolers and interactive electronic books. In these studies, interactive features that supported the story (e.g., embedded questions about vocabulary items) apparently increased learning, while features that distracted from the story (e.g., embedded

minigames) hindered learning (33). This finding could generalize to younger children and, by extension, have implications for transfer when toddlers use mobile applications and other interactive media. However, research on electronic books is limited to older preschoolers so its relevance to understanding toddlers' transfer from digital media is unclear.

WHO IS MOST LIKELY TO BENEFIT FROM INTERACTIVITY?

As with most educational interventions, the degree to which interactivity increases learning from screens varies substantially. Even within the same study, the impact of interactivity can vary considerably. For instance, in the word-learning study described previously, younger 2-year-olds were more likely to learn a word from an interactive application than from a noninteractive video (32). However, while younger 2-year-olds apparently benefited from this type of interactivity, older 2-year-olds did not.

The reason for this unusual developmental pattern is unclear. It may have to do with the strategy that children used to learn a new word-object association. While task-relevant interactivity helped younger 2-year-olds pass a simple word-learning test, it did not help them pass a stringent word-leaning test in which they had to determine, by process of elimination, the object that matched a different novel label (32). In other words, interactivity only helped younger 2-year-olds form simple associations between a novel word and object. Thus, researchers must consider different methods of measuring learning to understand fully what children do and do not learn from digital media.

While age-related changes in learning may be explained partly by differences in learning strategies, they may also be due to changes in cognitive constraints (5). If the cognitive load created by interactivity exceeds available resources, interactivity may hinder learning (29). In this case, one might expect only those children with relatively greater cognitive capacity to benefit from interactive digital media. In contrast, interactive features that have been well crafted may support learning by drawing attention to relevant information, supporting integration, and keeping children active and engaged in the learning experience (4). Some evidence supports the hypothesis that the benefits of interactivity outweigh the costs, at least when interactive features align with information to be learned: Two-year-olds were more likely to demonstrate transfer learning in an object-retrieval task when they viewed hidden events on interactive (versus noninteractive) video, regardless of how well they did on a subsequent task designed to measure working memory (34). That is, interactivity apparently improved learning even for toddlers with relatively lower working memory capacity, at least when the toddlers used a structured touchscreen application that taught task-specific information (i.e., where an object would be hidden on a given trial). It remains to be seen whether this finding could be replicated using more open-ended applications that aim to teach more complicated skills.

A complementary explanation for individual differences may lie in children's ability to inhibit behavioral impulses. Specifically, toddlers who have difficulty resisting the impulse to tap the screen indiscriminately may learn more from watching noninteractive video than from using a game or application that requires them to interact with the screen in a prescribed way. Consistent with this hypothesis, toddlers who performed less well on a behavioral inhibition task also tapped more frequently than those with more optimal behavioral inhibition when using a customized word-learning game on a tablet computer (35). Additionally, younger preschoolers and boys were less successful than older preschoolers and girls on the behavioral inhibition task. In a followup experiment, boys learned more words after observing noninteractive videos than after playing an interactive version of the application, whereas the reverse was true for girls. In other words, children who performed less well on a behavioral inhibition task in the first study (i.e., boys) also learned more when they did not have to interact with the screen in the second study, whereas those who generally scored higher on a behavioral inhibition task (i.e., girls) were more likely to learn from the interactive version of the game.

A final complementary explanation for age-related change in transfer has to do with children's prior experience with different types of media. The amount of time toddlers watch television and videos at home does not predict how well they do on video-based learning tasks in a laboratory setting; however, toddlers' naturalistic experience with interactive media such as video chats and digital games does predict performance on video-based learning tasks (36, 37). This correlational finding was replicated in an experimental study in which some 2-year-olds were assigned randomly to several weeks of training with a live video feed (i.e., seeing themselves on their home television set) before coming to the laboratory to complete an object retrieval task (38). This type of actual experience with symbolic media may help children recognize the symbolic nature of video screens (27), enabling them to succeed on learning tasks that use symbolic media such as photographs, videos, and touchscreen applications (36, 37).

WHERE DO WE GO FROM HERE?

While preschool-age children can learn a great deal from educational television, younger toddlers may learn more from interactive digital media than from noninteractive television and videos. However, the specific conditions that lead to learning are unclear: Not all types of interactivity increase learning and not all children learn to the same degree. The extent to which young children learn from screen media depends on (among other things) the intersection between the cognitive demands of a particular learning task and each child's cognitive resources (5). For instance, interactive features that guide attention to important information may be more useful than those that divert attention from that information or provide little guidance.

However, this may be true only if interacting with the screen does not create additional cognitive load; otherwise, children may have difficulty applying information flexibly to new situations or exemplars. When encountering particularly challenging or novel information, children may learn more from observing noninteractive video demonstrations than from using interactive media, at least in the short term (39, 40). This may be especially true for children who have relatively low working memory capacity or difficulty inhibiting the impulse to touch the screen indiscriminately.

Researchers have only begun to examine how children learn from different types of digital media, and the rapid adoption of evolving technology in homes with young children far outpaces the research. Much remains to be learned about transfer in the context of digital media. One critical gap involves types of learning. Most of the findings I have presented address the acquisition of specific knowledge (e.g., the name of a novel object) presented once in a cross-sectional study. Researchers should consider different ways to measure learning across timescales. The conditions that support one-time learning in a single laboratory session may differ from the conditions that support long-term retention of more generalizable skills, and we need longitudinal studies to determine how transfer develops in individual children.

Researchers should also continue examining individual differences in transfer learning. Studies should include measures of online processing during learning tasks (e.g., using eye tracking and other physiological measures), as well as potentially relevant traits that may moderate learning (e.g., working memory, inhibitory control, prior media experience). In so doing, researchers can move beyond questions of whether toddlers can transfer information from digital media to more nuanced questions about how and for whom digital media can support transfer.

Finally, researchers should consider contextual factors that moderate learning. Most of the findings I have described are based on experimental videos and applications designed to test specific hypotheses in a laboratory setting. The degree to which these findings extend to professionally produced digital games and mobile applications that children use when alone and with others outside the laboratory is uncertain. Researchers should observe how parents and other caregivers scaffold toddlers' learning with digital media.

Collaborations among developmental scientists, educators, and media creators may help bridge the gap between laboratory research and actual media content. By identifying the task-specific, individual, and contextual factors that moderate learning, researchers can inform the creation of educational media that are not only scalable and cost-effective (as in the case of television), but also self-paced, individualized, and adaptive.

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