Published in final edited form as:
Dev Rev. 2010 June 1; 30(2): 128–154. doi:10.1016/j.dr.2010.03.001.

Transfer of learning between 2D and 3D sources during infancy: Informing theory and practice

Rachel Barr
Georgetown University

Abstract

The ability to transfer learning across contexts is an adaptive skill that develops rapidly during early childhood. Learning from television is a specific instance of transfer of learning between a 2-Dimensional (2D) representation and a 3-Dimensional (3D) object. Understanding the conditions under which young children might accomplish this particular kind of transfer is important because by 2 years of age 90% of US children are viewing television on a daily basis. Recent research shows that children can imitate actions presented on television using the corresponding real-world objects, but this same research also shows that children learn less from television than they do from live demonstrations until they are at least 3 years old; termed the *video deficit effect*. At present, there is no coherent theory to account for the video deficit effect; how learning is disrupted by this change in context is poorly understood. The aims of the present review are (1) to review the conditions under which children transfer learning between 2D images and 3D objects during early childhood, and (2) to integrate developmental theories of memory processing into the transfer of learning from media literature using Hayne's (2004) developmental representational flexibility account. The review will conclude that studies on the transfer of learning between 2D and 3D sources have important theoretical implications for general developmental theories of cognitive development, and in particular the development of a flexible representational system, as well as policy implications for early education regarding the potential use and limitations of media as effective teaching tools during early childhood.

The notion of transfer of learning across contexts has been central to memory theorists since the time of Thorndike (1932) and many recent memory theories have been developed that have transfer of learning at their core. Theorists generally assume that a memory is a hypothetical collection of attributes that represent what the subject noticed at the time of original encoding (Estes, 1973, 1976; Roediger, 2000; Spear, 1978; Tulving, 1983; Underwood, 1969). The encoding specificity hypothesis states that a memory will be retrieved only if an individual encounters a cue with attributes that match those represented in the memory at the time of original encoding (Tulving, 1983). The ability to retrieve memories despite changes in proximal or distal cues, allowing learning to be generalized to novel situations has been referred to as 'representational flexibility' (Eichenbaum, 1997).

Historically, researchers have suggested that representational systems emerge relatively late in infancy (e.g., Baldwin 1894/1915; Piaget, 1962). More recently, Hayne (2004) has argued

Corresponding author, Rachel Barr, PhD, Associate Professor, Department of Psychology, Georgetown University, Washington DC 20057, rfb5@georgetown.edu, Phone: 202-687-8064.

that there are marked developmental changes in representational flexibility that occur even into early childhood. That is, early in development, successful memory performance is dependent on the perception of a close match between the cues at the time of encoding and the cues at retrieval; even minor mismatch at testing can disrupt performance. However, memory performance becomes more flexible across development. Older participants show an increased ability to tolerate differences between conditions at encoding and retrieval and can use novel cues to retrieve a target memory. Developmental studies of transfer of learning across physical contexts and objects have shown age-related changes in generalization using operant conditioning procedures (Hartshorn et al., 1998; Hayne & Findlay, 1995) and with toddlers using the imitation paradigm (Barnat, Klein, & Meltzoff, 1996; Hanna & Meltzoff, 1993; Hayne, Boniface, & Barr, 2000; Hayne, MacDonald, & Barr, 1997; Hayne, Herbert, & Barr, 2003a; Herbert & Hayne, 2000; Klein & Meltzoff, 1999). Hayne argues that the gradual developmental change occurs because over time infants need to encode information in a variety of contexts and take advantage of a wide range of retrieval cues. The representational flexibility account posits the existence of an active developmental process whereby performance is dependent upon age, task, and experience.

The representational flexibility account highlights an additional cognitive difficulty presented by the need to equate between 2D sources, including television, books, touch screens and computers, and 3D objects. According to this account, the infant must cognitively match a 2D symbol present at encoding to the corresponding 3D referent present at testing. Successful transfer of learning in an imitation task for example, involves the formation of both an object and an action representation that can be retained over a delay. That is, infants must form an internal mental representation of the target actions at the time of demonstration, as well as, encode specific perceptual features of the objects, context, and model used during the demonstration (Bandura, 1986; Estes, 1973, 1976; Meltzoff, 1988c, Tulving, 1983). At the time of the test, infants must match perceptual attributes of the 3D test object that is presented to stored attributes of the memory representation of the original 2D video display. Ultimately success on 2D–3D transfer tasks would depend on the operation of a flexible capacity to recognize and act on the stimulus regardless of its dimension at the time of encoding. Based on Hayne's hypothesis, learning from 2D sources would be more challenging than learning from face-to-face interactions because there are fewer retrieval cues at the time of the test that specifically match the original encoding conditions.

Transfer of learning across content and context is at the core of educational policy; it enables the development of abstract thinking, and in particular the development of a flexible representational system (Barnett & Ceci, 2002; Hayne, 2004). Learning from books, television, touch screens and computers can be considered a specific form of transfer of learning from a 2D representation to a corresponding 3D response. Studies that examine 2D to 3D transfer of learning provide us with important practical, educational information about learning across these different media platforms. At the same time, these findings will also provide us with new theoretical information, garnered from highly controlled manipulations, about the developmental course of transfer of learning (Durkin & Blades, 2009). Taking Barnett and Ceci's framework into consideration, studies of transfer of learning from 2D sources allows for specific manipulation of modality (from 2D to 3D and vice versa), physical context (different experimenter, different room), temporal context (immediate v. delay), tasks difficulty (simple v. complex tasks), memory demands (practice, repetition, delay), and perceptual and linguistic cues. Analogue studies of transfer of learning from 2D sources, necessarily need to use ecological valid methodologies that are appropriate and that take into consideration the typical context of learning during early childhood (Barnett & Ceci, 2002).

The present review will therefore describe the ecological context of early media exposure, and the methodological approaches that have been taken to examine the transfer of learning from

2D sources during infancy with a specific focus on imitation paradigms. These findings will illustrate how a number of different retrieval cues both disrupt and enhance learning from 2D. Together these findings reveal that learning from television during toddlerhood presents a unique cognitive challenge and taxes the emerging memory system.

What is the ecological context of transfer of learning from television?

> "…it does not make sense to detach study of young people and the media from study of young people per se. The bolder point is that the reverse holds, too: it does not make sense to detach the study of young people from their interactions with the world in which they live."
>
> p. 6 Durkin & Blades (2009)

Given the potential impact on learning that 2D sources of information may have on development, the effect of these activities on cognition are of interest to parents, psychologists, educators, and policy makers. Over the past 15 years, the media landscape for infants has changed dramatically. Since the 1990's, a growing number of infant-directed television programs and DVDs, educational videogames, and interactive books have been developed and targeted specifically at young infants (e.g., Baby Einstein, Brainy Baby) (Garrison & Christakis, 2005). The sales of Baby Einstein videos alone were estimated at $200 million in 2005 (Bronson & Merryman, 2006). Early screen media exposure has come to the forefront of public health debate as parents increasingly adopted media displayed on television, computers and touch screens, as teaching tools with infants in the first year of life (Rideout & Hamel, 2006; Zimmerman, Christakis, & Meltzoff, 2007a, b; Zimmerman, Glew, Christakis, & Katon, 2005).

Rideout and Hamel (2006) conducted a nationally representative US phone survey of over 1000 parents of children aged 6 months to 6 years to understand how infants, toddlers, preschoolers, and their parents were using media in their homes. The authors reported that almost all homes have at least one television (99%), most have two or more televisions (84%) and access to cable or satellite television (80%), as well as access to computer (78%) and the internet (70%) and 19% of children under 2 have a television in their bedroom (Rideout & Hamel, 2006). By 3 months of age about 40% of children are exposed to television or videos and by age 2 this has risen to 90% of children (Zimmerman et al., 2007a). In fact the majority of 6- to 23-month-olds (61%) are exposed to some sort of screen media, with 14% exposed to more than 2 hours in a typical day, and nearly one-third of children under 6 years old live in homes where the television is on all or most of the time (Rideout & Hamel, 2006). These surveys also indicated that 80% of toddlers engage in daily picture-book reading interactions for around half an hour per day. Television, video, and books are the most popular forms of media for very young children, with very few children under two using computers (2–11%) (Rideout & Hamel, 2006). The fact that infants and toddlers spend so much time with media begs the question of whether they transfer learning from 2D media to the real world.

Parents clearly believe that their children do transfer learning from television and computers from a very early age (Calvert, Rideout, Woolard, Barr, & Strouse, 2005)—29% of parents report that the "most-important reason" for their child watching television was the belief that "television is educational or good for the child's brain" (p. 476). Specifically, parents list vocabulary expansion (particularly in a foreign language), exposure to a variety of different experiences, and exposure to diversity as positive benefits of television exposure (Rideout & Hamel, 2006). Commercially available infant-directed programming tends to be highly thematic and educational domains are most closely associated with their content-matched presentation strategies; that is, social-emotional content is usually matched with more and higher quality onscreen interactions, language content with language development strategies, and cognitive development with executive functioning strategies (Fenstermacher et al., 2009). The impact of the structure of these forms of infant-directed media still remains largely untested.

The long-term effects of early television exposure are similarly not well understood. On the one hand, there are beneficial effects of screen media specifically designed for children as young as age two years. For example, exposure to high-quality children's educational programs such as *Sesame Street* and *Mister Rogers' Neighborhood* during the preschool years is associated with enhanced cognitive development, language development, and prosocial skills, and has a long-lasting positive impact on school readiness and academic performance (e.g., Anderson et al., 2000; Anderson, Huston, Schmitt, Linebarger, & Wright, 2001; Rice, Huston, Truglio, & Wright, 1990; Wright et al., 2001). Wright and his colleagues (2001), for example, found that 2-year-olds who were exposed more to child-directed educational programming, such as *Sesame Street*, had higher levels of school readiness than those who were primarily exposed to adult-directed television programs. These findings suggest that potential for transfer of learning from television during the preschool years is high. On the other hand, heavy exposure to television during infancy has also been associated with poorer school performance, increased bullying, poor attention and sleep problems (Christakis, Zimmerman, DiGiuseppe, & McCarty, 2004; Paik & Comstock, 1994; Thompson & Christakis, 2005; Zimmerman & Christakis, 2005; Zimmerman et al., 2005; Zimmerman, et al., 2007b). For example, Christakis and colleagues (2004) found that heavier television viewing at ages 1 and 3 was associated with parent-reported attentional problems at age 7 (but see Foster & Watkins, in press for a reanalysis of the dataset). Other researchers found no association between early television exposure and later developmental outcomes (Gentzkow & Shapiro, 2008; Mistry, Minkovitz, Strobino, & Borzekowski, 2007; Obel et al., 2004; Schmidt, Rich, Rifas-Shiman, Oken, & Taveras, 2009; Stevens & Mulsow, 2006).

As predicted by Barnett and Ceci's transfer of learning model, these discrepancies in the literature may be due to differences in content of programming. Television exposure to child-directed programs that are created specifically for infants and young children are differentiated from adult-directed programs that are created for an adult audience (see Anderson & Pempek, 2005). For example, looking time to child-directed programs is high, averaging approximately 70% for 12- to 18-month-olds (Barr, Zack, Garcia, & Muentener, 2008). Children's programs often have very dense concentrations of perceptually salient formal features, such as sound effects (Huston et al., 1981; Goodrich, Pempek & Calvert, 2009). For preschool and elementary school children, these perceptually salient audio features can elicit attention at key points in television programs, thereby improving comprehension of the contiguously presented content (Calvert, Huston, Watkins, & Wright, 1982).

Attention to adult-directed programs is far lower than it is for child-directed programs. One- to 3-year-olds attend to adult-directed television for only 5% of the time, probably because they do not understand the content (Anderson & Pempek, 2005). Despite the lower levels of attention, exposure to adult-directed content tends to be associated with more negative outcomes for children. Specifically, adult-directed television reduces the quantity of parent-child interactions, with parents responding passively rather than actively to their 1- to 3-year-olds' requests when an adult-directed television program was being played when compared to no television program being played (Kirkorian & Anderson, 2008; Kirkorian, Pempek, Murphy, Schmidt, & Anderson, 2009). Furthermore, infants' quality and quantity of play with toys was significantly worse when adult-directed television was on as compared to a time period in which the television was off (Schmidt, Pempek, Kirkorian, Lund, & Anderson, 2008). Presumably adult-directed television disrupts play because perceptually salient audio characteristics elicit an attentional orienting reflex to the television screen, thus distracting infants from sustained play episodes. Because the content is incomprehensible to a young viewer, attention to the television screen is not sustained. Repeated disruptions to children's play may interfere with the development of attention (see Anderson, this volume).

Early childhood exposure to higher levels of violent television programs, which contain high levels of perceptually salient formal features, are also associated with parental reports of attention problems in 7-year-olds (Zimmerman & Christakis, 2007). Similarly, Barr, Lauricella, Zack and Calvert (2010) reported that for a low-risk sample, higher exposure to adult-directed television during the second year of life was associated with poorer executive functioning in preschool, but early exposure to child-directed content was not. There are at least three possible explanations for these content-related findings. Early exposure to adult-directed television content may disrupt 1) attention regulation and/or 2) parent-child interaction or, alternatively, 3) children who are exposed to more television may have a predisposition to executive functioning and school readiness problems. These explanations are not mutually exclusive.

Although, findings have been mixed, the American Academy of Pediatrics (AAP) (1999) argues that exposure to screen media may actually be harmful to infant cognitive and emotional development. The AAP argues that television can impede early learning in two ways. First, screen media can pull a parent's attention away from an infant and reduce the quantity of the interactions. Second, it alters the style that a parent uses when interacting with an infant, which can reduce the quality of the interactions. Based on concerns that television exposure may disrupt parent-child interaction, the AAP currently recommends that children under the age of 2 avoid exposure to screen media altogether and that the viewing time of children over two be limited to no more than 2 hours a day (American Academy of Pediatrics, 1999). The AAP (1999) also recommends that pediatricians advise parents to co-view programming with their children, and not to use electronic media as a babysitter. As described above, a substantial number of parents are not following the AAP (1999) recommendation for their infants.

More than merely sources of entertainment, television and books may also serve as tools through which toddlers learn about the world around them. A common, but poorly explored assumption, held by parents, teachers, and researchers is that very young children can directly and easily transfer information from books and television to their corresponding real-world objects: For example, recognizing a real koala at the zoo after seeing one on a television, on a computer screen or in a picture book (Rose, 1977; Yoon Winawer, Witthoft, & Markman, 2007). However, toddlers' ability to do so, has received relatively little empirical attention (see Anderson & Pempek, 2005; Barr, 2008; Courage & Setliff, 2009; Kirkorian & Anderson, 2008).

How to study transfer of learning during early childhood? Methodology

The ecological context of early media exposure, as illustrated above, is complex. Although both positive and negative effects have been associated with early exposure to television, it is difficult to assess the transfer of learning from television to the real world from such studies. One explanation for the dearth of research in this area is that it is difficult to parse out some of the critical factors essential for transfer of learning in such a complex environment. Furthermore, it is difficult to assess learning in pre- and early-verbal children. Thus, behavioral measures must be devised to determine if and what children have learned. In recent decades, a number of procedures have been utilized to investigate the transfer of learning from media including habituation, imitation, object search and forced choice paradigms (see also Linebarger, this volume; Troseth this volume). Imitation procedures will be the focus of this review.

Perceptual factors: Habituation measures: Early evidence of transfer

Mapping a memory encoded from a 2D image on to a 3D object presented at a later time relies on a representation of the object that can enable translation between dimensions. The need for a translation between 2D images and 3D objects presents significant perceptual challenges: in most laboratory tests, they are smaller in size than the real objects, the resolution of the image is degraded relative to real objects, and many aspects of the object (depth cues from self-induced motion, shadow, and gradients, for example) are at best absent, and at worst substantially different, across the 2D–3D change. Even color values are likely to change to some degree when a TV image replaces a 3D object.

Object representation is a complex process that develops across childhood, with difficult aspects not maturing until late in the pre-adolescent period (Mondloch, Dobson, Parsons, & Maurer, 2004). Adult object perception appears to use multiple representations, one of which is based on form and is viewpoint invariant, size invariant, and not dependent upon surface features such as color (for reviews see, Hummel & Stankiewicz, 1996; Palmeri & Gauthier, 2004). For example, adults can look at an object from one view and form a complete representation (Biederman & Gerhardstein, 1993; Stankiewicz, 2002), whereas infants need experience with multiple viewpoints to form that same representation (Kellman, 1984; Kraebel & Gerhardstein, 2006). Using 3D multi-part novel objects, 3- to 4-month-olds have been shown to discriminate between a familiar and a novel shape, following familiarization during which 30–35 degrees of rotation experience (but not a smaller range) was provided (Kraebel & Gerhardstein, 2006). However, for 2D presentations, infants may require a full 360° rotation during familiarization to discriminate novel from familiar shapes depicted in 2D videos (Kellman, 1984), suggesting that infants below 9 months have a functioning, but relatively immature ability to represent the 3D structure of an object.

Infants under 9 months do transfer learning across visual presentations. Using a habituation-dishabituation procedure, DeLoache, Strauss and Maynard (1979) habituated 5-month-olds to a 2D photograph, and then tested them with either the 3D object depicted in the photograph, or a novel object. Infants looked longer at the novel 3D object suggesting that they can recognize some aspect of a 3D object from a 2D photograph. Rose (1977) was the first to demonstrate both transfer and discrimination between dimensions by 6-month-olds in a single experiment. She used 2D black and white patterns (e.g., 4 diamonds) and 3D black and white raised shapes on a flat white board. She showed 6 month-old infants 2D images of different objects during the familiarization phase of a task. During the test phase, the familiar stimulus was paired with a stimulus that differed in dimension (2D or 3D), pattern, or both dimension and pattern. Interestingly, infants looked significantly longer at (i.e., discriminated and transferred to) the novel stimulus in all groups (both directions of dimensional change, 2D–3D and 3D-2D). That is, infants can detect differences in 3D and 2D presentations (Rose, 1977). By 9 months infants can transfer between line drawings and 3D objects (Jowkar-Baniani & Schmuckler, 2009). Although this research provides some evidence that very young infants can detect differences in dimensions and can even visually transfer knowledge across dimensions, these findings are based on the infants' visual attention to the object, not a task in which the child is required to transfer a behavior learned in one dimension to another.

Focus on the imitation paradigm: Imitation from television

Historically, researchers chose imitation to investigate the potential impact of television exposure. At the time policy makers were concerned about the impact of media content on children's behavior outside of the media context. As such imitation provided a direct and ecologically valid measure of information transfer from the media context to the real world (Bandura, 1965; Bandura, Ross & Ross, 1963; Huston-Stein & Wright, 1979; Lemish, 1987;

Lorch, Anderson & Levin, 1979; Sprafkin, Gadow, & Abelman, 1992). That is, imitation from television is a direct measure of transfer of learning from the 2D to the 3D context. The initial focus of imitation research was on the imitation of aggressive actions (for review see, Paik & Comstock, 1994). In Bandura's seminal studies 3- to 5-year-old children watched as an adult modeled a number of novel, aggressive acts toward an inflatable Bobo doll (Bandura, 1965; Bandura et al., 1963). Children who were exposed to the televised adult model exhibited high levels of aggressive behavior toward the doll when they were allowed to play with it immediately after the demonstration (Bandura et al., 1963). Furthermore, children were as likely to imitate aggressive acts modeled on television as when they were modeled live. Subsequently, studies demonstrated that preschoolers were able to imitate pro-social behaviors as well (for review see, Calvert, 2006; Mares, 1996). These findings demonstrate that transfer of learning from video was high for preschoolers.

Similar concerns about the potential negative impact of media apply to toddlers. The fact that imitation paradigms are nonverbal allows researchers to directly examine transfer of learning from media by infants and toddlers (e.g., Barr & Hayne, 1999; Hayne, Herbert & Simcock, 2003b; Hudson & Sheffield, 1999; McCall, Parke, & Kavanaugh, 1977; Meltzoff, 1988a).

The imitation paradigm essentially employs a "monkey see monkey do" procedure. Based on Piaget's (1962) theoretical conceptualization, Meltzoff (1985, 1988 a, b, c, 1990, 1995) experimentally derived a standard deferred imitation paradigm. Infants observe an experimenter demonstrating a novel action sequence, usually several times in succession. The infants are given the objects either immediately or after a specified delay and they are allowed to reproduce the action sequence. The participant is prevented from interacting with the objects prior to the test, which precludes motor learning and the duration of the response phase is controlled and matched to the control groups. Performance is compared to that of age-matched controls. To determine the rate of spontaneous production of the target actions controls never see a demonstration of the target actions—reducing the likelihood that the participant is guessing the target actions based on the appearance of the objects. Group performance significantly above baseline is operationally defined as imitation.

Researchers argue that deferred imitation is a nonverbal measure of declarative memory (McKee & Squire, 1993; Meltzoff, 1985; 1995). This is supported by research showing that human amnesiacs, lacking declarative memory, fail tests of deferred imitation (McDonough, Mandler, McKee & Squire, 1995). Moreover, recent perspectives on imitation suggest that early copying behavior is driven by the imitators social awareness and motivation to be like the model (Nielsen, 2006; Nielsen, Simcock & Jenkins, 2008; Meltzoff, 2007), as well as their understanding of the models goals and intentions (Carpenter, Call, & Tomasello, 2002; 2005). Further evidence showing that imitation requires social insight comes from studies showing an imitation deficit in toddlers with autism, who lack social awareness and theory of mind skills (Rogers, Hepburn, Stackhouse, & Whener, 2003; Nadel, 2004).

Imitation paradigms allow for the manipulation of a number of important media variables. First, people do not typically encounter television presenters or visit television studios. In imitation studies this can be simulated by having one experimenter demonstrate the target actions on television and another experimenter interact with the child in the home. Second, infants would only infrequently have immediate access to materials presented on television. To more closely simulate these real-world conditions, infants are frequently tested after a delay. The change in context (experimenter and location), the memory delay, and modality change (from 2D to 3D) all increase the task difficulty according to Barnett and Ceci's transfer of learning model.

Meltzoff (1988a) adapted his deferred imitation procedure to televised stimuli. He exposed infants to a televised model demonstrating a novel target action. He found that infants as young as 14 months of age reproduced a one-step action viewed on television above rates produced by age-matched controls who never viewed the target action. The study documented both immediate and deferred imitation following a 24-hour delay. Subsequent studies have found that 6- to 30-month-olds can imitate complex novel 3-step action sequences from television—even when they are tested after a delay of 24-hours and when no narration accompanied the demonstration of the target actions (Barr & Hayne, 1999; Barr, Garcia, & Muentener, 2007a; Barr, Muentener, Garcia, Chavez, & Fujimoto, 2007b; Hayne, et al, 2003b; Huang & Charman, 2005; McCall et al.,1977) and from books as early as 18-months (Simcock & DeLoache, 2006; Simcock & Dooley, 2007; Simcock , Garrity, & Barr, 2009). That is, infants and toddlers show some capacity to transfer learning from television and pictures to the real world.

Video Deficit Effect

The video deficit effect refers to the fact that infants' ability to transfer learning from television and still 2D images to real-life situations is poor relative to their ability to transfer learning from face-to-face interactions (for review see, Anderson & Pempek, 2005). The video deficit effect is non-apparent at 6 months of age, peaks around 15 months of age, and persists until at least 36 months of age depending on the task complexity (Barr & Hayne, 1999; Barr et al., 2007a; Barr et al., 2007b; DeLoache & Burns, 1994; Deocampo & Hudson, 2005; Flynn & Whiten, 2008; Hayne, et al., 2003b; Hudson & Sheffield, 1999; Kuhl, Tsao, & Liu, 2003; McCall, et al., 1977; Meltzoff, 1988b; Nielsen, et al., 2008; Schmitt & Anderson, 2002; Sell, Ray, & Lovelace, 1995; Sheffield & Hudson, 2006; Simcock & DeLoache, 2006; Simcock & Dooley, 2007; Troseth & DeLoache, 1998).

Infants exhibit a video deficit in transfer of learning of multi-step tasks from television (Barr & Hayne, 1999; Barr et al., 2007a, b; Hayne et al., 2003b; Hudson & Sheffield, 1999; McCall et al., 1977; Simcock & DeLoache, 2006; Strouse & Troseth 2008). In a seminal study, McCall and colleagues (1977) showed that 18-, 24-, and 36-month-olds could imitate from a small black-and-white television but their performance was inferior to that of groups that had been shown the target actions by a live demonstrator. The video group performance only approached that of the live group at 36-months. There were, however, large task demands. At the time of test, children had to pick the target objects from a set of distractors and then imitate the target actions. Even when the selection phase was removed and children were tested in their homes using color television sets, Hayne and colleagues (2003b) replicated these findings with 24- and 30-month-olds. Infants were randomly assigned to the live model, video model, or baseline control groups. After a 24-hour delay, both the live and video model groups performed significantly above baseline, but the performance of the video group was inferior to that of the live group. This pattern replicates with different imitation tasks between 12 and 30 months (Barr & Hayne, 1999; Hayne et al., 2003b; Strouse & Troseth, 2008).

More recently, more complex multi-step imitation tasks that include omissions, irrelevant actions, and distracters have been investigated and have shifted the study of the video deficit to older ages once again: Three-year-olds continue to show a profound video deficit but 5-year-olds do not (Flynn & Whiten, 2008; Gerhardstein, Dickerson, Zack, & Barr, 2009; McGuigan, Whiten, Flynn, & Horner, 2007). These studies examine not only whether or not children correctly reproduce the goal of the sequence but also how they reproduce the target actions. Three-year-olds also show video deficits in reproducing the actions, whereas 5-year-olds imitate the gestures from video precisely even when more efficient strategies exist (McGuigan et al., 2007). These findings are consistent with the representational flexibility account. As task complexity increases, the transfer task difficulty also increases due to an increase in the mismatch between encoding and retrieval cues.

Retention

Surprisingly, very few studies have examined retention after video demonstrations. A videotaped demonstration is an effective reminder for 18-month-olds for events they learned from a live model 10 weeks earlier (Hudson & Sheffield, 1999). In this study, 18- to 30-month-old toddlers learned 6 or 8 novel event sequences in a laboratory playroom and a 10-week delay was imposed. On the day of the test, toddlers were presented with a brief videotaped reminder demonstration of the activities that they had learned before. They performed significantly more target actions than controls who did not see the video reminder (Hudson & Sheffield, 1999). Photograph reminders, however, were only effective for 30-month-olds (Deocampo & Hudson, 2003). There were, however, limitations on infants' performance. If infants were shown the reminder video and then tested two weeks later, the reminder was no longer effective (Hudson & Sheffield, 1999).Thus, by the middle of their second year, infants show some capacity to relate television to objects in the real world; moreover, learning and memory is affected by the nature and timing of the televised demonstration.

The *video deficit* is not platform specific.

Picture books

Recent studies have explored toddlers' ability to imitate from an even more impoverished 2D source, a picture book. In one study, 18-, 24-, and 30-month-olds were exposed to books with illustrations that varied in iconicity and were accompanied with narration describing the target actions (e.g., "put the ball into the jar" and "put the stick on the jar") (Simcock & DeLoache, 2006). This research showed that the 18-month-olds only imitated from the book illustrated with color photos; the 24-month-olds imitated from books with colored photos and colored pictures; and the 30-month-olds imitated from all versions of the book. Imitation from books becomes increasingly more generalized across development (Simcock & Dooley, 2007). In this study, 18-month-olds failed to generalize from the book to the novel test stimuli: infants only imitated if they were tested in the same room with the same rattle as during the reading session. In contrast, the 24-month-olds could generalize: they imitated from the book even when both the room and rattle were altered simultaneously. Finally, videos are imitated significantly better than books because there are fewer retrieval cues (including motion) in common with real objects in the book condition than the video condition (Simcock et al., 2009).

Touch screens

Touch screens have recently been used to investigate learning in 11-month-olds (Ayoun, 1998), attention in 1- to 3-year-olds (Gerhardstein & Rovee-Collier, 2002), spatial search in 2- to 4 year-olds (Sutton, 2006), and imitation in rhesus monkeys (Subiaul, Cantlon, Holloway, & Terrace, 2004) and preschool children (Subiaul, Cantlon, Romansky, Klein & Terrace, 2007). Prior imitation studies have only compared performance with a 3D test object following a 2D (television) demonstration. One innovation of a more recent study (Zack, Barr, Gerhardstein, Dickerson, & Meltzoff, 2009) was the combination of touch screen technology with the imitation approach in order to test transfer from 2D to 2D and 3D to 2D (as well as testing from 2D to 3D and 3D to 3D as before). Independent groups of 15-month-old infants were randomly assigned to non-transfer (2D/2D, 3D/3D) and transfer (3D/2D, 2D/3D) conditions. For the non-transfer conditions, an experimenter demonstrated an action by pushing a virtual button on a 2D screen or a button on a 3D object to produce a sound; infants were given the opportunity to imitate that action using the same touch screen image or object. For the 3D/2D condition, an experimenter demonstrated the action on the 3D object and infants were given the opportunity to reproduce the action on a 2D touch screen image of the object and vice versa for the 2D/3D condition. Infants in baseline control conditions did not view a demonstration before being shown the 3D test object or 2D touch screen image.

This study demonstrated that infants can imitate target actions on the 2D touch screen and with the 3D object. Both non-transfer groups (2D/2D and 3D/3D) performed significantly above baseline, but did not differ. Infants can also imitate across dimensions. Both the transfer groups (2D/3D and 3D/2D) performed above baseline, but did not differ. However, the transfer groups (2D/3D, 3D/2D) produced significantly fewer target actions than the non-transfer (3D/3D, 2D/2D) groups. That is, the transfer groups exhibited the typical video deficit effect, or transfer deficit, even though the 2D medium was a touch screen and the demonstration occurred with either 2D images or 3D objects. Transfer across dimension was impaired in *both* directions.

The *video deficit effect* is not task specific.

Emotion processing tasks—The video deficit effect is also seen during emotion processing tasks. Mumme and Fernald (2003) found that 12 months old were capable of responding to emotional cues shown on television but 10-month-olds were not. Infants were given unfamiliar objects (e.g., plastic valve) to explore. Next, they watched a videotape in which an actor responded in either a positive or negative manner to each of these objects. If an adult on television reacted negatively toward a novel object, 12-month-olds avoided that object when given a second opportunity to play with it. In contrast, if an adult on television reacted positively toward the novel object, 12-month-olds showed increased levels of exploration when given a second opportunity to play with it.

Object search tasks—The video deficit is also exhibited in object search tasks (Deocampo & Hudson, 2005; DeLoache & Burns, 1994; Schmitt & Anderson, 2002; Schmidt, Crawley-Davis, & Anderson, 2007; Suddendorf, 2003; Troseth, 2003; Troseth & DeLoache, 1998; Troseth, Pierroutsakos, & DeLoache, 2004; Troseth, Saylor, & Archer, 2006; Zelazo, Sommerville & Nichols, 1999). It is not until approximately 2.5 years of age that toddlers begin to use information from television and pictures to locate a toy hidden in a room. Using a standardized paradigm, children are given an extensive orientation to the correspondence between the video of a room and the room. During the hiding task, the experimenter goes into the test room and hides a toy. The child views the hiding game on a television monitor in an adjacent room. Immediately after the toy is hidden, the child goes into the test room and is asked to retrieve the hidden toy. Two-year-olds are unable to find the hidden toy, but 2.5 year-olds are successful (Troseth & DeLoache, 1998). Two-year-olds performed significantly better on the object-retrieval task when they were told that that were viewing the hiding of a toy through a window, when in fact they were viewing a television monitor that looked like a window into the room (Troseth & DeLoache, 1998, Experiment 3).

The sheer magnitude of change in size between the television monitor and the room where the object was being hidden as well as the change in dimension from 2D screen to 3D real world might have disrupted performance. To test this hypothesis, Schmidt and colleagues (2007) built a felt-board that was the same size as the television screen. Two-year-olds assigned to the live group watched the sticker being hidden behind a felt-object on the felt-board. Two-year-olds in the video group viewed the same hiding event on a television screen. The live group succeeded in finding the sticker, but the video group did not. They also showed that the child does not retrieve the object if the adult simply verbally told them the location.

It is also possible to alter the difficulty of the object search task and to change performance. Zelazo and colleagues (1999, Exp. 3) increased the difficulty of the task by hiding an object with the child in the room. Then they told the child that the experimenter had decided to change the hiding location and that the experimenter would show the child where the new location was via videotape. In this instance 3-year-olds failed the task, but 4-year-olds succeeded. Rather than looking in the location where they had viewed the experimenter hide it on the television, the 3-year-olds searched the location where they themselves had hidden the object. That is, they perseverated. Zelazo and colleagues concluded that the additional conflicting information of having previously participated in the hiding location placed an additional load on the memory system. Similarly, when Suddendorf (2003) made the search task less difficult by changing the search room on each trial, 2 year-olds succeeded on a televised object search task.

Self-recognition tasks—Children first show self-recognition via a mirror between 18- and 24-months, then via an immediate video at 3 years, and finally via delayed video at 4 years (Povinelli, Landau, & Perilloux, 1996; Skouteris, Spataro, & Lazaridis, 2006; Suddendorf, 1999; Suddendorf, Simcock, & Nielsen, 2007). In the typical mirror self-recognition task, an experimenter surreptitiously places a mark on the child's head and then the child is allowed to look in a mirror. If the child attempts to remove the mark from his/her own head, he/she is said to have self-recognition. If however, the child points to or reaches for the mirror image he/she does not. Although it has been debated whether this task measures self-recognition, this task is a complex representational task. To succeed the child has to connect the mirror image of the self with proprioceptive feedback from his/her body.

For example, Suddendorf and colleagues (2007) compared immediate video displays with typical mirror self-recognition tasks in 24-, 30- and 36-month-olds. In the immediate video condition, an image of the child was displayed on a large projection screen, the same size as a mirror and like the mirror the video image was "an enantiomorph, where the left and right are reversed while the other canonical dimensions (up–down and front–back) are maintained" (Suddendorf et al., 2007, p. 187). Surprisingly, even though the enantiomorph was used and the size of image was the same as a mirror, children in the immediate video condition passed the mark test one year later than they passed the mark mirror self-recognition test.

The authors tested two further possible explanations for the poor immediate video self-recognition. First, they tested the possibility that children failed because of expectations that television images would not provide meaningful information. To test this hypothesis, they placed a mirror inside a television frame. Two-year-olds easily passed this self-recognition test, suggesting that the expectation about the utility of televised images was not impairing performance on the immediate video task. Second, they test the possibility that children failed because of the lack of eye contact in the video condition. To test this hypothesis, they tested recognition of the legs rather than the face. In a novel test, the child sat in a high chair such that the trousers were hidden from the child's view, and the mark was placed on the child's trousers. The only way that they could derive information was via the immediate video feed or a mirror depicting the child's trousers. Two-year-olds were highly successful on the mirror version of the novel mark test but only 1/3 of 2-year-olds passed the immediate video version of the novel mark test. The authors concluded that relative levels of experience with mirrors vs. immediate video representations were the cause of the poor performance. Infants literally spent hours of their lives with mirrors and much less time with immediate video displays.

Language transfer of learning tasks—Most recently, the video deficit has been exhibited in word learning tasks (e.g., Ganea, Bloom & DeLoache, 2008; Kcrmar, Grela & Lin, 2007; see also Linebarger, this volume). Findings have been mixed, with some studies indicating that transfer of learning is possible (Krcmar et al., 2007, Linebarger & Walker, 2005; Vandewater, Park, Lee & Barr, in press), and others indicating that it is not (DeLoache et al., 2008; Robb, Richert & Wartella, 2009). For example, Krcmar, Grela, and Lin (2007) examined whether 15- to 24 month-old infants could fast map novel words presented on television and match the words to real 3D objects. They contrasted learning from a commercially available video with an experimentally produced video. In a repeated measures design they examined word learning under five experimental conditions; 1) adult video—a video clip with an adult speaker labeling one of 5 novel objects, such as a whisk 2) children's television video—a voiceover on the children's program "Teletubbies" labeling one of the 5 objects; 3) adult live joint reference–an adult labeled one of 5 objects when the toddler was attending, 4) adult live discrepant reference—an adult labeled one of 5 objects when the toddler was not attending, and 5) no word control condition to assess whether infants could match a still 2D image with the corresponding 3D image. During the labeling phase the object was labeled 5 times using a novel word like "mope" in the presence of 4 other distracter objects. At test, infants were asked to give the experimenter the "mope".

There were a number of important findings. First, the control condition data revealed that infants were able to match a 2D image to the 3D object as early as 15 months. Second, learning in the adult video condition was similar to children's performance in the adult live joint reference condition. Third, learning from the children's television program was significantly worse than the adult live joint reference condition and similar to the adult live discrepant reference condition. This finding was qualified by an age by condition interaction that indicated that children younger than 22 months did not learn words from the children's television program but were able to learn a novel word in the adult live joint reference condition. The authors concluded that learning was maximized by face-to-face interaction in a joint reference context. Although they were able to match 2D depictions and 3D objects, infants continued to exhibit a video deficit effect at least when the novel words were embedded in a commercially available television program (Krcmar et al., 2007).

Krcmar and colleagues (2007) argued that learning may have been impaired because the children's television program contained too much information. Infants under 22 months were not able to attend to the relevant information in order to parse out the novel word in a fast 'mapping task. Learning from an adult on video may have been easier because there were fewer distracting stimuli. In this way, the adult video condition more closely mimicked the live face-to-face interaction. When the stimulus characteristics are fitted to the viewer's current cognitive capacity and are also directed at the viewer in a pseudo-face-to-face context, it appears that infants and toddlers could learn at levels similar to the actual face-to-face context. In contrast, learning from commercial programming, may be more difficult than learning from experimentally produced stimuli because commercial programming contains more complex formal features, including cuts, sound effects, music tracks, and processing of formal features that requires working memory (Kcrmar et al., 2007; see formal features).

In summary, the video deficit effect is exhibited across multiple different experimental paradigms by infants ranging from 1 year to at least 3 years of age. Given that the severity of the performance deficit can be directly manipulated by increasing the level of difficulty of the task, these findings are consistent with a representational flexibility account (Hayne, 2004). Why might we expect toddlers to have difficulty transferring learning from these media?

Theoretical Considerations

> *Encoding, representing, retrieving, mapping, and extending knowledge are general processes that inhere in a very broad range of cognitive performances, not just in transfer tasks. Thus, the application of general cognitive skills may be involved in transfer, but their successful application may be moderated by myriad contextual factors*.
>
> (Barnett & Ceci, 2002, p. 632)

Perceptual processing and memory demands, as well as social contingency and symbolic processing limitations, contribute to reduced ability to learn from television during early childhood. Cues that are likely to influence transfer of learning include perceptual, social, and linguistic cues. Development in the integration and processing of these retrieval cues is also likely to influence transfer of learning. Due to this "myriad of contextual factors" a number of independent theories have developed to account for difficulty in transfer of learning from 2D to 3D. What these accounts have in common is that the very nature of the media makes it difficult for toddlers to understand and relate to the real-world objects; that is, by definition representational flexibility is required to solve the transfer of learning problem. Below, other accounts are described and related to the pattern of results. However, ultimately any theory that accounts for the video deficit effect must be subsumed within a theory that accounts for transfer of learning and the developmental of representational flexibility; that is how cues, including visual, auditory, social and linguistic cues that must be encoded and transferred, affect retrieval.

Poor perceptual cues: Perceptual impoverishment account

The perceptual impoverishment hypothesis accounts for the video deficit by suggesting that because the 2D perceptual input is impoverished relative to a 3D presentation, encoding and transfer of learning is impaired (Barr & Hayne, 1999; Schmitt & Anderson, 2002; Suddendorf, 2003; Suddendorf et al., 2007). This theory is consistent with Johnson's more general theory of perception, termed the threshold model (Johnson & Aslin, 1996; Johnson, 1997, 2005). Johnson has proposed that the perceptual system requires a minimum amount of information for perception regardless of its source (e.g., 2-D or 3-D stimuli). Studies using 2D stimuli have demonstrated that younger infants require information from more sources to form an object percept than older infants do (Johnson, 1997; 2000, 2005). By this account, a 2D presentation may not match its 3D counterpart until a sufficient number of individual sources of information are available to match from 2D to 3D (see Smith, 2000, for a similar argument regarding language acquisition).

The suggestion that infants process 2D and 3D information differently is supported by two recent studies. First, researchers using event-related potentials (ERPs) have demonstrated that 18-month-olds process 2D images more slowly than 3D objects, recognizing a familiar 3D object very early in the attention process (shown by the early sensory exogenous N2 component) and recognizing a familiar object presented in a 2D digital photo significantly later (during the middle latency Nc component) (Carver, Meltzoff, & Dawson, 2006). Second, researchers using NIRS (near infra-red spectroscopy) have demonstrated that 6-month-olds actively process live demonstrations of action in the sensorimotor cortex more than when the same information is presented on television (Shimada & Hiraki, 2006). Either the slower processing of 2D information or the cognitive load associated with transfer from 2D to 3D could account for the video deficit effect. Additional studies are needed to investigate brain correlates of 2D to 3D transfer (Courage & Setliff, 2009).

Taken together, however, the bulk of the research suggests that infants can perceive of the perceptual similarities at least by the end of the first year of life. It is the the mismatch between the perceptual cues available when encoding the 2D images and the real 3D objects present at testing that presents a difficult transfer of learning task for toddlers who have a fragile representational memory system.

Poor symbolic understanding: Dual representation account

Another theoretical explanation for children's difficulty relating 2D depictions, whether moving or stationary, to the real world is young children's immature *pictorial competence* or understanding of symbolic artefacts, such as pictures and television (e.g. DeLoache & Burns, 1994; DeLoache, Simcock, & Marzolf, 2004). DeLoache (1991) posed the problem of pictorial competence as a dual representation problem. That is, there is "reality" and a symbol x that stands for some aspect or portion of reality and it is how this duality is processed that is the crux of pictorial competence. DeLoache argues that early in development, toddlers do not understand the dual nature of symbols (DeLoache, 1987, 1991, 1995; Pierroutsakos & DeLoache, 2003; Troseth, 2003; Troseth et al., 2004; Troseth this volume). They do not comprehend that a symbol is both an object in itself (e.g., a television set, a picture book, device for entertainment) as well as a representation of another entity (e.g., the depiction on the monitor, or in the book). Thus, toddlers are arrested by the physical characteristics of the symbol and fail to appreciate the representative nature of the artefact. Similar to Hayne (2004) with regard to general representational flexibility, DeLoache (1991) specifically argues that not until toddlers have sufficient experience with a range of symbols do they begin to understand their representational power and thus begin to relate symbols to the real world. One important developmental step in learning from television and computers is appreciating both the similarities and the differences between 2D and 3D stimuli and being able to act accordingly (Flavell, Flavell, Green, & Korfmacher, 1990; Rose, 1977; Troseth et al., 2004).

DeLoache and colleagues have extensively investigated infants' manual responses to 2D images (for review see Troseth et al., 2004). Pierroutsakos and Troseth (2003), for example, found that 9-month-olds treated high resolution video images as if they were real objects, attempting to pick up the toys on video. By 19 months of age the reaching behavior had been replaced by pointing; 15-month-olds were intermediate between the two. Troseth, DeLoache and colleagues (2004) argue that the change between 9- and 19-months is due to experience exploring 2D and 3D objects and recognition that the functional properties of 2D and 3D objects differ. For example, a ball can bounce but a picture of a ball does not. Based on this acquired knowledge, toddlers aged between 1 and 2.5 years fail on tasks presented on 2D media. They learn to disregard the possible informational content of pictures and television. Some time during the third year of life, children master dual representation and can understand that a picture provides meaningful information that can be acted upon in the real world. The video deficit effect dissipates. At this stage, children can represent the image of the picture both as an object and as a symbol for the real object and transfer of information can occur (see also Barr et al., 2007a, showing that 6 month olds do not exhibit a video deficit effect on an imitation task).

It is during the second year of life that infants more sharply differentiate 2D images and 3D objects and learning from television decreases (the video deficit effect). This decrease in learning suggests that the developmental course of this ability does not result from a simple linear increase in perceptual capacity. Thus, the informational value of actions presented in 2D (on television) is substantially diminished because children do not recognize the functional significance of the objects and actions they view on the screen. According to this view, it is not until almost the third year of life that children come to understand that video can provide meaningful information to guide actions in the real world, and the video deficit effect disappears.

Poor cue integration: Common coding theory

According to the common coding theory, there is a similar representation for action perception and action production (Prinz, 1997; see also Aschersleben, 2006). A second major assumption of this theory is that action effects should have large consequences for action production. That is, a salient consequence of an action should be coded and increase the likelihood that the action is reproduced for any given goal-directed sequence. These assumptions have large consequences for transfer of learning across dimensions. If actions are perceived and acted upon using a similar representational coding scheme, then transfer becomes likely (Aschersleben, 2006). Alternatively, if the match between perceived actions and later opportunities to reproduce those actions decreases, then the likelihood of transfer decreases. For example, if perceptual information, such as auditory and visual features, is mismatched, this mismatch will decrease the likelihood that later transfer will occur. Studies analyzing the role of action effects on action control have shown that adding action effects increases imitation scores (e.g., Elsner, Hauf, & Aschersleben, 2007; Klein, Hauf, & Aschersleben, 2006; for review see Aschersleben, 2006). The development of action-effect understanding and observation is, however, gradual across time with action-effect understanding increasing at approximately 12–15 months of age (Elsner & Aschersleben, 2003) and the ability to encode information from demonstrations changing gradually between the first and second year of life (e.g., Elsner et al., 2007). Televised demonstrations provide an avenue to test these assumptions.

Ameliorating the Video Deficit

Recently researchers have investigated whether the video deficit effect can be ameliorated and in so doing have uncovered potential mechanisms to explain the effect.

Repetition

Repetition consistently protracts infant retention following live demonstrations (e.g., Barr, Dowden, & Hayne, 1996; Barr, Rovee-Collier, & Campanella, 2005; Galluccio & Rovee-Collier, 2000; Ohr, Fagen, Rovee-Collier, Hayne, & Vander Linde, 1989) and due to the content of television programming and video technology, infants often see material repeatedly (Mares, 1998; Rideout, Vandewater, & Wartella, 2003). Moreover, repeated presentation of the same television program maintains attention and increases comprehension of television content by preschoolers (Abelman, 1990; Anderson & Levin, 1976; Anderson, Lorch, Field, & Sanders, 1981; Crawley, Anderson, Wilder, Williams, & Santomero, 1999; Sell et al., 1995; Skouteris & Kelly, 2006).

There are several studies suggesting that the video deficit can be ameliorated for 1 to 2 year olds when the demonstration of the target actions was repeated (Barr et al., 2007a; 2007b; Barr & Wyss, 2008; see also Linebarger & Walker, 2005; Vandewater et al., in press). Repetition enhanced deferred imitation by 12- to 21-month-olds (Barr et al., 2007a). In this study, infants exhibited the same level of deferred imitation from both a live and a televised model after the number of demonstrations of the target actions presented on television was doubled. If the number of demonstrations of the target actions presented on video was not doubled, 21-month-olds continued to exhibit a video deficit effect (Barr et al., 2007a). Moreover, repetition increased toddler’s imitative performance from books as well: when children were read a book four times, their imitation scores improved significantly compared to when children were read the book twice (Simcock & DeLoache, 2008). Repetition likely enhances encoding and therefore increases the chances of transfer because processing time during encoding increases, allowing for a better representation of the target actions to be encoded and therefore more retrieval cues to be available at the time of test (see also Carver et al., 2006; Zack et al., 2009).

It may not be repetition of target actions per se but rather the duration of exposure to demonstration that enhances processing. Strouse and Troseth (2008) compared imitation of target actions from live and videotaped demonstrations. When target actions were demonstrated two times at a slowed rate, the video deficit was ameliorated for 2-year-olds: Imitation scores for live and video groups did not differ. When there was only one slow demonstration, a video deficit effect reemerged.

Prior experience

Prior experience with technology and with real world objects enhances transfer of learning from television (Hauf, Aschersleben & Prinz, 2007; Skouteris et al., 2006; Troseth, 2003; Troseth, et al., 2006; Troseth, this volume). Troseth (2003) provided 2-year-old children and their families with video cameras connected to their home television monitors for 2 weeks so that children could experience viewing themselves live on the television screen; their performance on object search tasks improved significantly. Similarly, Skouteris and colleagues (2006) showed that when 3 years olds were trained that video could provide meaningful information, delayed video self-recognition was enhanced. That is, for young children to transfer learning from video to the real world, they may need to have some training about the correspondence between televised and real world information.

Hauf and colleagues (2007) showed that experience with the real objects facilitated transfer of learning. Prior to a visual preference test, they gave 7-, 9- and 11-month-old infants one of two toys (a toy car or ribbons) for 90 seconds. Immediately after, infants were shown two videos playing simultaneously on two different screens for 90 seconds. On one screen experimenters were playing with the toy (sliding the car back and forth or waving the ribbons) that the infant had previously interacted with and on another screen the experimenters played with a novel toy. The 9- and 11-month-old infants preferred to view the video that showed the experimenter interacting with the toy that he/she had previously interacted with but the 7-month-olds showed no preference. The authors concluded that by 9-months, the infants' own motor experiences influenced their subsequent action perception. That is, infant's prior experience with the object, led to a viewing preference for those objects, suggesting that infants may prefer familiar information (see also Barr et al., 2008). The question of how familiar the objects need to be requires empirical attention.

Working memory demands

Limited working memory capacity during infancy and toddlerhood may reduce transfer of learning (Hauf, 2009; Krcmar et al., 2007; Strouse & Troseth, 2008; Suddendorf, 2003; Troseth this volume). During object search tasks, toddlers perform well on trial one but performance deteriorates on subsequent trials (see Suddendorf, 2003). Two-year-olds are rewarded by finding the hidden toy on trial one. They view a second hiding location, but when they return to the room they perseverate to the original hiding location. They perseverate because the memory representation formed from finding a real object competes with that formed when viewing a video-based 2D hiding demonstration on trial two. Suddendorf (2003) tested the memory updating hypothesis. He hypothesized that if the memory demands were reduced such that memory updating was not necessary, then 2-year-olds would be able to find a hidden toy after viewing it hidden on television. Consistent with this hypothesis, performance remained high if toddlers were tested in 4 different rooms rather than being tested repeatedly in the same room (Suddendorf, 2003).

Furthermore, removing working memory demands by testing infants immediately after the video demonstration ameliorates the video deficit in some cases (e.g. Barr & Hayne, Exp. 2, 1999; Huang & Charman, 2005; Lauricella, Barr & Calvert, 2009; Meltzoff, 1988a) but not in others (Flynn & Whiten, 2008; Gerhardstein et al., 2009; Hayne et al., 2003b). It is likely that such discrepancies in findings may arise from the task difficulty. When zero delay and one-step and/or salient enabling sequences are demonstrated, then the video deficit does not occur. In contrast, when task complexity increases due to the addition of target actions and distracters in the sequence (e.g. Flynn & Whiten, 2008; Hayne et al., 2003b; Gerhardstein et al., 2009) performance is disrupted even after no delay.

In typical television learning conditions, the infant/toddler does not interact with the onscreen presenter. Hayne and colleagues found no difference in imitation performance as a function of whether the model on the video was the same or a different experimenter that conducted the test (see also Nielsen et al., 2008). Reducing this particular working memory component by adding a matching retrieval cue at the time of test, in the form of the experimenter, had no effect on performance. It is possible, however, that a decrease in the working memory demand may have been offset by confusion over a person who had been “seen” on television and was now in the same room.

Hauf (2009) also added working memory demands to her task by adding an object selection component and examined whether perception would influence object selection, or action production. In this experiment, 7-, 9- and 11-month-olds first viewed the videos of the experimenters interacting with either the toy car or the ribbons, as before. Immediately afterwards, infants were presented with both toys. Surprisingly, infants did not not choose the object that had been presented on video. Perhaps even more surprisingly, they rarely imitated the 1-step action of sliding the car or waving the ribbons during the 90 second test interval.

Hauf (2009) identified two factors that may have increased working memory demands and reduced imitation performance. First, during the perception phase, two experimenters demonstrated actions to others instead of demonstrating the actions directly to the infant. This type of “overheard learning” has recently been shown to be a difficult method to learn from because social contingency is reduced even further than it is in typical demonstration events (Goldenberg, Troseth, Doherty, Shimpi, Ahktar, & Saylor, 2009; see Troseth this volume for further detail). These studies may have implications for how infants process narrative storylines.

Second, Hauf (2009) noted that infants were required to select the appropriate object and then to imitate the target action. The selection phase increased working memory demands at the time of retrieval (see also McCall et al., 1977). When the selection phase was removed and infants were given only one toy at the time of test, 9- and 11-month-old infants imitated the target action, but 7-month-olds did not. When the experimenter demonstrated the selection phase, 9- and 11-month-olds chose and interacted significantly longer with the toy the experimenter selected (Hauf, 2009).

Other visual features change when demonstrations occur on television. In particular, the start and end state are often shown on video, but the transformation from the end state back to the starting state is often omitted during video demonstrations. During live demonstrations this tranformation is typically (generally for practical reasons) not omitted. Findings related to this transition are inconsistent and likely to be task dependent. For the “dumbbell” task, including the transition does not facilitate performance (Huang & Charman, 2005). For the “rattle” task, excluding the transition does not decrease performance (Lauricella et al., 2009). Actions that have more easily perceived mechanisms are more likely to be imitated from television than those that do not.

In summary, task complexity influences learning from television. Increasing the sequence length and adding distractors (Flynn & Whiten, 2008; Gerhardstein et al., 2009), adding a selection phase (Hauf, 2009; McCall et al., 1977), or requiring memory updating (e.g. Suddendorf, 2003; Troseth & Deloache, 1998) increased working memory demands and disrupted transfer of learning. Transfer of learning deficits can also be exacerbated by task difficulty. Overall, these task-related differences in imitation may provide important insights into what may be most likely to be learned from television.

Formal features

Formal features are the auditory and visual production and editing techniques characterizing television, such as action, sound effects, and pacing (the rate of scene and character changes). Initial studies of imitation from television during infancy and early childhood (Barr et al., 2007a, b; Barr & Hayne, 1999; Hayne et al., 2003b; McCall et al., 1977; Meltzoff, 1988a), failed to incorporate common attention-capturing features into their televised segments.

NIH-PA Author Manuscript

NIH-PA Author Manuscript

According to common coding theory, it is possible that the addition of salient sound effects and music at the time of demonstration and test would increase attention and information processing because there is overlap in the representations for action perception and action production (Prinz, 1997; see also Aschersleben, 2006). Similarly, according to the "sampling model of attention", attention to television is initially directed by perceptually salient formal features that elicit an orienting response. With development and experience, children come to learn that different perceptually salient features serve to mark content for further processing, as well as provide visual and auditory modes that children can use to represent content (Anderson et al., 1981; Calvert et al., 1982; Huston & Wright, 1983). Consistent with this view, placement of attention-orienting salient formal features, such as sound effects or character vocalizations, just before important televised information enhances preschoolers' selective attention and comprehension of the key messages (Calvert et al., 1982; Calvert & Scott, 1989; Huston-Stein & Wright, 1979; Lorch et al., 1979).

Consistent with common coding theory, Klein and colleagues (2006) found that when a sound effect was matched to a target action, 1-year-olds selectively increased their performance of the specific target action relative to an action unaccompanied by a sound effect, but overall imitation performance was not enhanced. These authors did not, however, test the effect of mismatching the action effect and the action during the demonstration. It is possible, that the salience of the action effect simply directed additional attention to the target action.

A stronger test of the theory occurred when Barr, Somanader, and Wyss (2009) assigned 6-, 12-, and 18-month-old infants to one of three conditions: Matched sound effects (salient sound effects timed to each target action), mismatched sound effects (deliberately mismatched to the target actions), or no salient formal features. The 6-month-olds exhibited deferred imitation of the target actions regardless of whether the sound effects were matched or mismatched to the target actions. In contrast, 12- and 18-month-olds imitated target actions from television when the sound effects were matched to the target actions, but performed at baseline when the target actions and sound effects were deliberately mismatched. That is, mismatching sound effects that commonly convey informational content on television interfered with performance by 12- and 18-month-olds, presumably because they expected the sound to match up with an important visual event; such expectations did not seem to exist for the younger 6-month-old infants. The findings are also consistent with the "sampling model of attention" suggesting that initially infants attend to perceptually salient sound effects, but by the end of the first year of life, mismatching sound effects disrupts typical information processing. These findings are also consistent with developmental changes in action perception integration.

In contrast, adding sound effects to a live demonstration interfered with the imitation performance by 6- to 18-month-olds, demonstrating a learning deficit from toys with electronic sound effects. These findings may be related to infants' understanding of actions and their outcomes as a function of experience with electronic sound effects or to the diminished social interaction that occurred when sound effects were added to the live demonstration (Barr et al., 2009).

Adding a background music soundtrack to the video demonstration, disrupted imitation from television by 6-, 12-, and 18-month-olds, regardless of whether the music soundtrack was played during demonstration or was played during both demonstration and test. Adding the same music soundtrack to a live demonstration did not disrupt imitation (Barr, Shuck, Salerno, Atkinson, & Linebarger, in press). When action-matched sound effects and the music soundtrack were added to the video demonstration performance by 6- to 18-month-olds was, once again, significantly above baseline (Barr et al., 2009). This is compelling evidence that music added to a video demonstration, is not passive but very much an active component of attention, learning, and memory retrieval during infancy. The music soundtrack may have disrupted infant processing of the target actions because the music did not contiguously match the target actions being demonstrated. Action-matched sound effects, even in the presence of the interfering music soundtrack, however, potentially enhanced selective attention to the target actions, providing a common perceptually-salient matching auditory and visual representation.

Visual formal features can also be manipulated. Direct comparisons between continuous shots and zooms (Barr & Hayne, 1999) and continuous shots and cuts (Strouse & Troseth, 2008) have revealed no differences in imitation performance. Strouse and Troseth (2008) also attempted to increase the number of matching retrieval cues at the time of test by testing infants in the same location as where the demonstration had been filmed. There was no difference in imitation performance as a function of test location (same or different). Overall, consistent with preschool study findings (Huston & Wright, 1983) manipulations of visual formal features have produced less striking results than manipulations of auditory formal features.

Taken together, the findings from manipulations of formal features suggest that the video deficit may not be due to a perceptual processing problem, but rather, it may reflect the infant’s difficulty with integrating perceptual and action-based information and transferring it to their behavioral repertoire (Barr & Hayne, 1999; Hofer, Hauf, & Aschersleben, 2007; Suddendorf, 2003). Processing of information from 2D may emerge earlier than transfer of information from 2D to 3D contexts (Bahrick & Lickliter, 2004; Carver et al., 2006; Elsner & Aschensleben, 2003; Hofer et al., 2007; Simcock & DeLoache, 2006; Zack, et al., 2009). For example, Hofer and colleagues (2007) showed that 6-month-olds perceived goal-directed actions from video as readily as they perceived them from a live demonstration. Zack and colleagues (2009) found that transfer across dimensions is the rate-limiting step in transfer of learning from 2D or 3D. Finally, Simcock and DeLoache (2006) found that changes in the nature of the stimulus disrupted learning from 2D books, particularly for 2-year-olds who required high levels of iconicity in order to imitate from books. Similarly, the mismatching sound effects and music, and subtle discrepancies in visual cues during video demonstration may be over-taxing infant and toddlers emerging representational systems.

Language cues

Language is an important feature of children’s television programs and picture books; often the purpose of the book or the program is to introduce new vocabulary (DeLoache & DeMendoza, 1987; Ninio, 1983; Rice et al., 1990). Thus, recently researchers have begun to explore whether these factors may impair or ameliorate imitative learning from 2D media sources. The standard infant imitation paradigm excludes verbal cues and narration to prevent differences in imitation performance being attributed to age-related differences in language comprehension. Thus, the demonstration is typically accompanied by ‘empty narration’ (e.g., “look at this”) rather than meaningful language describing the objects or actions (e.g., “this is a rattle”). Moreover, during the test phase the child is asked: “What can you do with these things?” rather than being specifically prompted to produce an outcome (e.g., “Can you show me how to make a rattle?”). However, when infants fail to imitate in the absence of such language prompts, verbal cues have been added to the standard paradigm to measure their facilitative effects. Nonsense words are often substituted for real words to ensure none of the infants have the verbal cues in their receptive or productive vocabulary. One reason for choosing verbal cues is that naming can be an important teaching tool which may increase the salience of object properties and object similarities that an infant might not otherwise notice (Booth & Waxman, 2002; Waxman, 2008). In addition, verbal cues can also serve as an effective memory retrieval tool (Hayne & Herbert, 2004; Herbert & Hayne, 2000).

Research has shown that adult narration during demonstration and test increases the duration of retention (Bauer, Kroupina, Schwade, Dropik, & Wewerka, 1998; Hayne & Herbert, 2004) and facilitates generalization (Barr & Wyss, 2008; Herbert & Hayne, 2000). Barr and

Wyss (2008) demonstrated target actions to 24-month-olds using two sets of stimuli. The experimenter labeled each set of stimuli either “meewa” or “thornby”. The nonsense labels were provided either by a voice-over on the video (voice-over), or by parents during the video demonstration (video parent label). Performance was compared to parents labeling during a live demonstration (live parent label) or to a video with no label group. All video groups saw twice as many demonstrations as the live group. On the test day, the nonsense labels were repeated and infants were presented with a novel version of the toy. The baseline control group was provided with the stimuli and nonsense label only at the time of the test. The live and video demonstration groups all performed significantly above baseline control. However, the video with no label group performed significantly worse than the live parent label group. Both video voice-over and video parent label groups performed as well as the live parent label group. Thus, in a generalization task, 24-month-olds can use a combination of verbal cues and repetition to overcome the video deficit and solve difficult imitation tasks (Barr & Wyss, 2008). Representational flexibility was enhanced by verbal labels at encoding and retrieval.

Similarly, Vandewater and colleagues (in press) experimentally manipulated commercial video content to assess whether toddlers were able to learn a novel word and match it to a shape from a video clip. They tested transfer of learning from video to another 2D symbolic medium, a book. Infants in the experimental condition were significantly more likely to point to the novel crescent shape than infants in the control condition. Groups did not differ, however, on 4 other more common shapes that were presented in both the experimental and control videos. There are two noteworthy findings from this study. First, the specificity and novelty of the content was critical in measuring learning from television during toddlerhood. Second, the learning strategy used in the commercially produced video (a simple visual image matched with a verbal label) may be less taxing on working memory and therefore more appropriate for young children (Krcmar et al., 2007).

Similarly, Ganea and colleagues (2008) examined transfer of learning from picture books to real objects by 15- and 18-month-olds. In their study, they read infants a picture book with 4 familiar pictures (e.g., dog) and 2 novel pictures (e.g., wire egg cup). They labeled the novel object with a nonsense word (e.g. blicket). At test, infants were asked to point to the real “blicket” object. Conversely, the procedure was reversed and the object was labeled and they were tested with the picture book. They found that both 15- and 18-month-olds were able to transfer learning of a novel label from the book to the real object and vice versa. Infants were better able to transfer information when realistic photographs of objects were used than when cartoon depictions were used. Performance decreased when infants were asked to generalize performance to a novel exemplar that differed in color (e.g. a green wire egg cup). Ganea and colleagues argued that transfer of information from the book to the real world and vice versa was facilitated by the degree of overlap in features across context. However, pointing to one of two pictures in a book was difficult for the majority of 15-month-olds. For the 15-month-olds to successfully transfer, researchers had to cut out pictures from the books and asked for infants to pick one of the two cut out pictures at test.

Finally, Simcock and colleagues (2009) found that 18- and 24-month-olds can imitate from books and television regardless of whether or not the demonstration was accompanied by a description of the event (Exp 1). As reported by Hayne and Herbert (2004) following live demonstrations, the language used at retrieval was more important than language at encoding. Infants’ imitative performance was enhanced when specific verbal cues are provided prior to the test (Exp 2). That is, cues at the time of retrieval may be particularly important for transfer of learning across dimensions. Finally, 18- and 24-month-olds imitated significantly above baseline, when pictures of a book were obscured and only verbal cues were provided (Exp. 3).

It is not clear however, when language might first facilitate transfer of learning across dimensions. Zack and colleagues (2008) assigned 15-month-olds to one of three conditions: empty language, nonsense label, and object label and tested them on a touch screen transfer task (2D to 3D or 3D to 2D). Although all groups performed significantly above baseline, the language cues, either providing a novel nonsense label or a well understood label, did not facilitate transfer of learning for 15-month-olds.

Taken, together, the studies that have included language cues suggest that transfer of learning can be facilitated by adding additional verbal retrieval cues. First, although labels are typically very effective at 12- to 15-months in tasks involving live interactions (e.g. Booth & Waxman, 2002; Waxman, 2008), the representational load associated with the transfer of information from 2D to 3D and vice versa may mean that an additional symbolic cue (e.g. label) does not facilitate transfer of learning until approximately 18 months. At 18-months and older, memory representations are beginning to be more flexible and the ability to fastmap labels to objects is rapidly developing (Bloom & Markson, 2001; Hayne, 2004). These findings are consistent with studies showing that vocabulary can be acquired from television by preschoolers (Naigles, & Mayeux, 2001; Rice et al., 1990). It is unlikely, however, that the building blocks of language, such as learning phonemes, can be acquired through video interactions (Kuhl, et al., 2003). Theoretically, changes in working memory during encoding of information from television could account for age-related changes in the effectiveness of language cues on transfer performance. Second, successful transfer has been observed when transfer tasks involve minimal perceptual change (e.g. from a video to a book, or from a highly iconic photo to a real object). These minimal perceptual differences allow for maximal matching of retrieval cues across the video to book context (Barr & Hayne, 1999; Ganea et al., 2008; Suddendorf, 2003). Third, repetition of verbal labels was an important factor (e.g., Linebarger & Walker, 2005; Vandewater et al., in press). In a recent longitudinal study, children who had multiple exposures to the programs high in narrative structure had larger vocabulary gains at 2.5 years (Linebarger & Walker, 2005; see also Linebarger this volume).

Social contingency

Not only do video demonstrations provide a diminished social model, they also exclude the possibility of social interaction with the demonstrator. Research with older toddlers and preschoolers has demonstrated that lack of contingency reduces levels of interactivity and comprehension of televised material (Calvert, Strong, Gallagher, 2005; Crawley et al., 1999; Flynn & Whiten, 2008; Nielsen, et al., 2008; Troseth, 2003; Troseth et al., 2006). Even 5-month-olds prefer to view a close-circuit video that allows eye contact with the model (Papoušek & Papoušek, 1974). Social contingency does increase toddlers' learning from television using a search task (Troseth et al., 2006; Troseth this volume) and an imitation task (Nielsen et al., 2008). Nielsen and colleagues (2008), for example, found that if an experimenter interacted in a social contingent manner via close-circuit television, 2-year-olds were significantly more likely to imitate tool-use than if they had viewed a pre-recorded video session. These findings replicated a prior study (Nielsen, 2006) during which 2-year-olds imitated tool-use significantly more from a socially engaged experimenter than from a live aloof experimenter. Nielsen and colleagues cautioned that adding social/interactive cues into television in the absence of the infant being able to make a contingent response may not facilitate transfer of learning. Particularly because of the increasing use of webcam technology, the use of close-circuit technology could be very useful in furthering our understanding of the role of social contingency on transfer of learning between 2D and 3D.

It has been argued that manipulation of video models is useful for assessing social learning because video models are highly replicable and allow for subtle manipulations of components of social interactions (Huang & Charman, 2005; McGuigan et al., 2007). The video deficit exhibited during a number of studies may have occurred because during the live demonstration the entire model was visible but during the video demonstration, a close-up showing only the hands of the model is shown (e.g., Barr & Hayne, 1999, Exp. 3; Flynn & Whiten, 2008; Huang & Charman, 2005). Huang and Charman (2005) entirely removed the experimenter from the videotaped demonstration and 17-month-olds continued to imitate above baseline but with less fidelity than following a full demonstration. Flynn and Whiten (2008) found that children were less likely to copy how the experimenter had demonstrated the target actions, (i.e. less likely to tap the bolts) when the actions were demonstrated on video than when they were demonstrated by a live model. They concluded that idiosyncratic social behaviors may be less likely to transfer from a video than a live demonstration, thus decreasing overall fidelity (see also Gerhardstein et al., 2009; Huang & Charman, 2005; Nielsen et al., 2008 for similar arguments). It has been argued that exact copying, seen more frequently after live demonstrations than after video demonstrations, may be used by a child to communicate and continue a social interaction (McGuigan et al., 2007; Nielsen et al., 2008; Strouse & Troseth, 2008). That is, the very asocial nature of prerecorded video presentations may reduce infant imitation from television and static images. According to Hayne's (2004) representational flexibility account, the lack of social contingency during video demonstration is a cue mismatch between 2D and 3D contexts (see also Troseth et al., this volume). A more complete theoretical understanding of learning from television will involve consideration of social contingency.

Conclusions

Overall, this review has documented a small but growing body of data that concludes that processing transfer of learning between 2D to 3D contexts during early childhood is a cognitively complex task, which changes gradually across early childhood. The potential for learning and amelioration of the video deficit effect can be predicted by a number of different representational factors, including repetition of the content (Barr et al., 2007a, 2007b), the structure of the auditory and visual cues unique to media (Barr et al., 2009; Barr et al., in press), linguistic (Barr & Wyss, 2008; Ganea, Bloom & DeLoache, 2008) and social contingency cues (or lack thereof; Huang & Charman, 2005; Nielsen et al., 2008; Troseth et al., 2006), working memory demands (Krcmar, Grela, & Lin, 2007; Suddendorf, 2003), and the perceptual demands (Barr & Hayne, 1999; Schmitt & Anderson, 2002; Suddendorf,et al., 2007) of the particular task used to examine transfer of learning. Increases in cognitive load rapidly exceed the processing capabilities of young children leading to deficits in transfer of learning.

Theoretical implications

Studies of information processing of media during early childhood have important theoretical implications both for understanding the transfer of learning between 2D and 3D contexts, as well as for understanding mechanisms of memory development (see Lorch, 1994 for a similar argument that studies of media and attention contribute to general theories of selective attention). Consistent with the developmental representational flexibility account (Hayne, 2004), transfer of learning between 2D and 3D context develops slowly over early childhood. The bulk of the research suggests that it is the cognitive load imposed at the point of transfer of information between dimensions that is the rate-limiting step. Changes in working memory may be partially responsible for the deficits seen in processing both auditory and visual input and transferring information between 2D and 3D contexts. Working memory may be the bottle neck: As memory flexibility increases, the need to encode and match all attributes decreases and transfer of learning improves. As such, examining transfer of learning from 2D media provides an intriguing window into the emerging representational system (see DeLoache, 1991; Meltzoff, 1988a; Strouse & Troseth, 2008; Zelazo & Lourenco, 2003).

Toddlers may have difficulty integrating simultaneously presented auditory and visual information (Hauf, 2009; Kcrmar et al., 2007; Suddendorf, 2003; Troseth & Deloache, 1998). The fact that the video deficit is counterintuitively, less profound at 6 months of age than at later points in development suggests that detection of 2D to 3D differences, and the integration of auditory and visual streams of information develops gradually across time (Barr et al., 2007a, 2009; Hauf et al., 2007; Hauf 2009). It will be necessary to consider the developing representational system, including both memory and language systems, social, perceptual, and motor systems and the integration of information across these systems in order for a comprehensive theory of transfer of learning during infancy to be developed. Transfer of learning tasks allow for systematic manipulations at different levels of these systems.

Imitation indexes the transfer of information across different contexts and provides important information about the flexibility of the memory system as a function of the organism's history (Barnat et al., 1996; Jones & Herbert, 2006; Hayne et al., 2003a; Hayne et al., 2000; Hayne et al., 1997; Klein & Meltzoff, 1999; Learmonth, Lamberth & Rovee-Collier, 2004). Overall, transfer of learning studies suggest that infant imitation may not necessarily be based on understanding the intentionality of the demonstrator (Huang & Charman, 2005) but that learning may be potentiated in face-to-face interactions relative to video situations due to social contingency prolonging the learning situation. Taken together, transfer of learning studies suggests that examining imitation from television and electronic devices may not only inform us about the potential for learning from television and toys during infancy but may also provide some insight into the processes governing imitation as well (see also Flynn & Whiten, 2008; Huang & Charman, 2005; McGuigan et al., 2007; Nielsen et al., 2008).

Practical implications

Given the prevalence of 2D materials—including books, television, touch screens, and computers—in homes and daycare centers, understanding the basis of the video deficit effect and its amelioration has obvious practical consequences for early education. The current review does suggest that there are multiple ways that commercial producers could enhance learning from television. The judicious use of repetition, formal television features, such as matched sound effects, voice-over on specific key demonstrations may in combination enhance transfer of learning. Commercial programmers need to prioritize developing appropriate evidence-based content that takes rapid infant development into consideration. Unfortunately, many experimental studies have not used commercially available programming and, due to the lack of ecological validity, could equally be over- or under-estimating the ability of transfer of learning from television during early childhood.

Given the results of the effects of social contingency and linguistic cues, programmers should be urged to encourage active parent co-viewing to facilitate transfer of learning across the 2D to 3D context. Parents often perceive television as passive and easy to process. The current literature suggests that processing is neither passive (see Courage this volume) or easy. Joint attention and language development occur rapidly during late infancy, and parental scaffolding may be necessary to reduce the video deficit and maximize the potential for educational enrichment. Although the AAP (1999) recommends that exposure should be minimized or at best eliminated during early childhood, given the current ecological climate of the US home and many other Western countries as well, it seems that increasing parental scaffolding by educating parents about the cognitive complexity of transfer of learning may be a more effective educational/public health strategy. Parents do not question the need for involvement in other 2D contexts such as book reading or even computer tasks, but education is required for the medium of television especially during early childhood.

Parent-child interactions may not be disrupted in the same way as they are during adult-directed television when children are watching child-directed content. When parents coview, which is approximately 50% of the time (Rideout & Hamel, 2006), they are probably watching child-directed content to be with their child, not for their own entertainment. Indeed, research on parent-child interactions during child-directed television programs indicates that some parents interact with their children while viewing and encourage comprehension of the program by labeling content and asking questions (Barr et al., 2008, Fidler, Zack & Barr, in press). If parents actively interact with their children during child-directed programs, but not during adult-directed programs, then one would expect negative associations only between exposure to adult-directed programming and executive functioning skills (Barr et al., 2010). Future studies examining the context of television viewing and subsequent cognitive skills are needed (Christakis, 2009).

Producers also need to examine factors that interfere with learning. Between 6- and 18-months imitation was disrupted by the addition of quite simple sound effects during a live demonstration (Barr et al., 2009) and by a background music soundtrack during a video demonstration (Barr et al., in press). These findings are two examples of significant interference effects that have practical applications. First, learning from electronically enhanced toys may counter-intuitively disrupt learning. If electronic toy makers want to produce toys that enhance learning, they need to examine whether or not additional electronic components enhance or disrupt learning (for review see Hirsh-Pasek & Golinkoff, 2008; Hirsh-Pasek Golinkoff, & Dyer, 2003). Second, producers should pay particular attention to the addition of music to infant-directed videos and action-matched sound effects to ensure that the soundtrack does not add additional cognitive load without meaningfully connecting visual and auditory content.

The long-term effects of early media exposure on social and cognitive development are largely unknown. Although it is recommended that infants and toddlers should have limited exposure to television, the amount of programming targeted to very young children has increased dramatically and television exposure during infancy has increased accordingly. As parents are being told to avoid exposing their infants to screen media, they may also feel pressures to ensure that their children are media literate. The effects of background television exposure on play and the fact that infants learn less from television than from live demonstrations, as documented by the video deficit effect, put limitations on what infants can gain from media exposure. On the other hand, the fact that repeated exposure to televised segments enhances imitation and vocabulary acquisition and evidence of the beneficial effects of television on older children suggests that television has the potential to provide positive and cost-effective benefits during early childhood. Taken together, based on our limited state of knowledge about the costs and potential benefits of early television exposure, the current AAP recommendation of no television for children under 2 remains premature.

Acknowledgments

Authors' note: Support for this chapter was provided by NIH grant # HD056084 to Rachel Barr and Department of Education Ready to Learn Initiative grant (#9300-71000) to Deborah Linebarger.

References

Abelman R. You can't get there from here: Children's understanding of time-leaps on television. Journal of Broadcasting & Electronic Media 1990;34:469–476.

American Academy of Pediatrics, C. O. P. E. Media Education. Pediatrics 1999;104:341–343. [PubMed: 10429023]

Anderson DR, Bryant J, Wilder A, Santomero A, Williams M, Crawley AM. Researching *Blue's Clues*: Viewing behavior and impact. Media Psychology 2000;2:179–194.

Anderson DR, Huston AC, Schmitt KL, Linebarger DL, Wright JC. Early childhood television viewing and adolescent behavior: The recontact study. Monographs of the Society for Research in Child Development 2001:66.

Anderson DR, Levin SR. Young children's attention to "Sesame Street.". Child Development 1976;47:806–811.

Anderson DR, Lorch EP, Field DE, Sanders J. The effects of TV program comprehensibility on preschool children's visual attention to television. Child Development 1981;52:151–157.

Anderson DR, Pempek T. Television and very young children. American Behavioral Scientist 2005;48:505–522.

Aschersleben G. Early development in action control. Psychology Science 2006;48:405–418.

Ayoun C. Maternal responsiveness and search for hidden objects and contingency learning by infants. Early Development and Parenting 1998;7:61–72.

Bahrick L, Lickliter R. Infants' perception of rhythm and tempo in unimodal and multimodal stimulation: A developmental test of the intersensory redundancy hypothesis. Cognitive, Affective, and Behavioral Neuroscience 2004;4:137–147.

Baldwin, JM. Mental development in the child and the race. 3rd edn. New York: MacMillan; 1915. Original work published in 1894

Bandura A. Influence of models' reinforcement contingencies on the acquisition and performance of imitative responses. Journal of Personality and Social Psychology 1965;1:589–595. [PubMed: 14300234]

Bandura A, Ross D, Ross SA. Imitation of film-mediated aggressive models. Journal of Abnormal and Social Psychology 1963;66:3–11. [PubMed: 13966304]

Bandura, A. Social foundations of thought and action : A social cognitive theory. Englewood Cliffs, N.J: Prentice-Hall; 1986.

Barnat SB, Klein PJ, Meltzoff AN. Deferred imitation across changes in context and object: Memory and generalization in 14-month-olds. Infant Behavior & Development 1996;19:241–252.

Barnett SM, Ceci SJ. When and Where do we apply what we learn? A taxonomy for far transfer. Psychological Bulletin 2002;128:612–637. [PubMed: 12081085]

Barr, R. Attention to and learning from media during infancy and early childhood. In: Calvert, SL.; Wilson, BJ., editors. Blackwell Handbook of Child Development and the Media. Malden, MA: Blackwell; 2008. p. 143-165.

Barr R, Dowden A, Hayne H. Developmental changes in deferred imitation by 6- to 24-month-old infants. Infant Behavior and Development 1996;19:159–170.

Barr R, Garcia A, Muentener P. Age-related changes in deferred imitation from television by 6- to 18-month-olds. Developmental Science 2007a;10:910–921. [PubMed: 17973804]

Barr R, Hayne H. Developmental changes in imitation from television during infancy. Child Development 1999;70:1067–1081. [PubMed: 10546335]

Barr R, Lauricella A, Zack E, Calvert SL. The relation between infant exposure to television and executive functioning, cognitive skills, and school readiness at age four. Merrill Palmer Quarterly 2010;56:21–48.

Barr R, Muentener P, Garcia A, Fujimoto M, Chavez V. The effect of repetition on imitation from television during infancy. Developmental Psychobiology 2007b;49:196–207. [PubMed: 17299795]

Barr R, Rovee-Collier CK, Campanella J. Retrieval protracts deferred imitation by 6-month-olds. Infancy 2005;7:263–284.

Barr R, Shuck L, Salerno K, Atkinson E, Linebarger D. Music interferes with learning from television during infancy. Infant and Child Development. (in press).

Barr R, Somanader M, Wyss N. Imitation from television during infancy: The role of sound effects. Journal of Experimental Child Psychology 2009;123:1–16. [PubMed: 19345954]

Barr R, Wyss N. Reenactment of televised content by 2-year-olds: Toddlers use language learned from television to solve a difficult imitation problem. Infant Behavior and Development 2008;31:696–703. [PubMed: 18514319]

Barr R, Zack E, Garcia A, Muentener P. Infants' attention and responsiveness to television increases with prior exposure and parental interaction. Infancy 2008;13:30–56.

Bauer PJ, Kroupina MG, Schwade JA, Dropik PL, Wewerka SS. If memory serves, will language? Later verbal accessibility of early memories. Development and Psychopathology 1998;10:655–679. [PubMed: 9886220]

Biederman I, Gerhardstein P. Recognizing depth-rotated objects: Evidence for 3D viewpoint invariance. Journal of Experimental Psychology: Human Perception and Performance 1993;19:1162–1182. [PubMed: 8294886]

Bloom P, Markson L. Are there principles that apply only to the acquisition of words? A reply to Waxman and Booth. Cognition 2001;78(1):89–90. [PubMed: 11062323]

Booth AE, Waxman SR. Object names and object functions serve as cues to categories for infants. Developmental Psychology 2002;38:948–957. [PubMed: 12428706]

Bronson, P.; Merryman, A. Baby Einstein vs. Barbie [Electronic version]. Time. 2006. Retrieved February 22, 2009, from http://www.time.com/time/nation/article/0,8599,1538507,00.html

Calvert, S. Media and early development. In: McCartney, D.; Phillips, K., editors. Blackwell Handbook of Early Childhood Development. Madden, MA: Blackwell Publishing; 2006. p. 508-530.

Calvert SL, Strong B, Gallagher L. Control as an Engagement Feature for Young Children's Attention to and Learning of Computer Content. American Behavioral Scientist 2005;48:578–589.

Calvert SL, Huston AC, Watkins BA, Wright JC. The relation between selective attention to television forms and children's comprehension of content. Child Development 1982;53:601–610.

Calvert SL, Rideout V, Woolard J, Barr R, Strouse G. Age, ethnicity, and socioeconomic patterns in early computer use: A national survey. American Behavioral Scientist 2005;48:590–607.

Calvert SL, Scott MC. Sound effects for children's temporal integration of fast-paced television content. Journal of Broadcasting and Electronic Media 1989;33:233–246.

Carpenter M, Call J, Tomasello M. Understanding ‘prior intentions’ enables 2-year-olds to imitatively learn a complex task. Child Development 2002;73:1431–1441. [PubMed: 12361310]

Carpenter M, Call J, Tomasello M. Twelve- and 18-month-olds copy actions in terms of goals. Developmental Science 2005;8:F13–F20. [PubMed: 15647059]

Carver LJ, Meltzoff AN, Dawson G. Event-related potential (ERP) indices of infants' recognition of familiar and unfamiliar objects in two and three dimensions. Developmental Science 2006;9(1):51–62. [PubMed: 16445396]

Christakis DA. The effects of infant media usage: What do we know and what should we learn? Acta Paediatrica 2009;98:8–16. [PubMed: 18793294]

Christakis DA, Zimmerman FJ, DiGiuseppe DL, McCarty CA. Early television exposure and subsequent attentional problems in children. Pediatrics 2004;113:708–713. [PubMed: 15060216]

Courage. this volume.

Courage M, Setliff A. Debating the impact of television and video material on very young children: Attention, learning, and the developing brain. Child Development Perspectives 2009;3:72–78.

Crawley AM, Anderson DR, Wilder A, Williams M, Santomero A. Effects of repeated exposures to a single episode of the television program Blue's Clues on the viewing behaviors and comprehension of preschool children. Journal of Educational Psychology 1999;91:630–637.

DeLoache JS. Rapid change in the symbolic functioning of very young children. Science 1987;238:1556–1557. [PubMed: 2446392]

DeLoache JS. Symbolic functioning in very young children: Understanding of pictures and models. Child Development 1991;62:83–90.

DeLoache JS. Early understanding and use of symbols: The model model. Current Directions in Psychological Science 1995;4:109–113.

DeLoache JS, Burns NM. Early understanding of the representational function of pictures. Cognition 1994;52(2):83–110. [PubMed: 7924202]

DeLoache JS, DeMendoza OA. Joint picturebook interactions of mothers and 1-year-old children. British Journal of Developmental Psychology 1987;5:111–123.

DeLoache JS, Simcock G, Marzolf DP. Transfer by very young children in the symbolic retrieval task. Child development 2004;75:1708–1718. [PubMed: 15566374]

DeLoache JS, Strauss MS, Maynard J. Picture perception in infancy. Infant Behavior & Development 1979;2:77–89.

Deocampo JA, Hudson JA. Reinstatement of 2-year-olds' event memory using photographs. Memory 2003;11:13–25. [PubMed: 12653486]

Deocampo JA, Hudson JA. When seeing is not believing: Two-year-olds' use of video representations to find a hidden toy. Journal of Cognition and Development 2005;6:229–258.

Durkin K, Blades M. Young people and the media: Special issue. British Journal of Developmental Psychology 2009;27:1–12. [PubMed: 19972659]

Eichenbaum H. Declarative memory: Insights from cognitive neurobiology. Annual Review of Psychology 1997;48:547–572.

Elsner B, Aschersleben G. Do I get what you get? Learning about effects of self-performed and observed actions in infants. Consciousness & Cognition 2003;12:733–752.

Elsner B, Hauf P, Aschersleben G. Imitating step-by-step: A detailed analysis of 9-to 15-month-olds' reproduction of a three-step sequence. Infant Behavior and Development 2007;30:325–335. [PubMed: 17400048]

Estes, WK. Memory and conditioning. In: McGuigan, FJ.; Lumsden, DB., editors. Contemporary approaches to conditioning and learning. New York: John Wiley; 1973. p. 265-286.

Estes, WK. Structural aspects of associative models for memory. In: Cofer, CN., editor. The structure of human memory. San Francisco: W. H. Freeman; 1976. p. 31-53.

Fenstermacher, SK.; Barr, R.; Calvert, S.; Pempek, T.; Brey, E.; Moses, A.; Vaala, S.; Ryan, M.; Garcia, A.; Linebarger, D. Interactional modeling in infant-directed media; Paper presented at the annual meeting of the International Communication Association; Chicago, IL. 2009.

Fidler A, Zack E, Barr R. Television Viewing Patterns in 6- to 18-month-olds: The Role of Caregiver-infant Interactional Quality. Infancy. (in press).

Flavell JH, Flavell ER, Green FL, Korfmacher JE. Do young children think of television images as pictures or real objects? Journal of Broadcasting and Electronic Media 1990;34:399–419.Elsner B, Aschersleben A. Do I get what you get? Learning about the effects of self-performed and observed actions in infancy. Consciousness and Cognition 2003;12:732–751. [PubMed: 14656514]

Flynn E, Whiten A. Imitation of hierarchical structure versus component details of complex actions by 3- and 5-year-olds. Journal of Experimental Child Psychology 2008;101:228–240. [PubMed: 18639887]

Foster EM, Watkins S. The value of reanalysis: TV viewing and attention problems. Child Development. (in press).

Galluccio L, Rovee-Collier C. Reinstatement effects on retention at 3 months of age. Learning and Motivation 2000;30:296–316.

Ganea PA, Bloom M, DeLoache JS. Transfer between picture books and the real world by very young children. Journal of Cognition and Development 2008:46–66.

Garrison, M.; Christakis, DA. A Teacher in the Living Room: Educational Media for Babies, Toddlers, and Preschoolers. Menlo Park, CA: The Henry J. Kaiser Family Foundation; 2005.

Gentzkow MA, Shapiro JM. Preschool television viewing and adolescent test scores: Historical evidence from the Coleman study. Quarterly Journal of Economics 2008;123:279–323.

Gerhardstein P, Rovee-Collier C. The development of visual search in infants and very young children. Journal of Experimental Child Psychology 2002;81:194–215. [PubMed: 11786009]

Gerhardstein, P.; Dickerson, K.; Zack, E.; Barr, R. Learning from screen media in older infants: An extension of the video deficit effect. Chicago, Il: Poster presented at the International Society of Developmental Psychobiology; 2009 Oct.

Goldenberg, E.; Troseth, G.; Doherty, K.; Shimpi, P.; Ahktar, N.; Saylor, M. Does social interaction facilitate learning from video?; Poster presented at the biennial meeting of the Cognitive Development Society; San Antonio, TX. 2009 Oct.

Goodrich S, Pempek T, Calvert SL. Formal production features of infant and toddler DVDs. Archives of Pediatrics and Adolescent Medicine 2009;163:1151–1156. [PubMed: 19996053]

Hanna E, Meltzoff AN. Peer imitation by toddlers in laboratory, home, and daycare contexts: Implications for social learning and memory. Developmental Psychology 1993;29:702–710.

Hartshorn K, Rovee-Collier C, Gerhardstein P, Bhatt RS, Klein PJ, Aaron F, et al. Developmental changes in the specificity of memory over the first year of life. Developmental Psychobiology 1998;33:61–78. [PubMed: 9664172]

Hauf, P. The interchange of self-performed actions and perceived actions in infants. In: Striano, T.; Reid, V., editors. Social cognition: Development, neuroscience and autism. Blackwell: 2009. p. 129-143.

Hauf P, Aschersleben G, Prinz W. Baby Do – Baby See! How action production influences action perception in infants. Cognitive Development 2007;22:16–32.

Hayne H. Infant memory development: Implications for childhood amnesia. Developmental-Review 2004;24:33–73.

Hayne H, Barr R, Herbert J. The effect of prior practice on memory reactivation and generalization. Child Development 2003;74:1615–1627. [PubMed: 14669885]

Hayne H, Boniface J, Barr R. The development of declarative memory in human infants: Age-related changes in deferred imitation. Behavioral Neuroscience 2000;114:77–83. [PubMed: 10718263]

Hayne H, Findlay N. Contextual control of memory retrieval in infancy: Evidence for associative priming. Infant Behavior & Development 1995;18:195–207.

Hayne H, Herbert J. Verbal cues facilitate memory retrieval during infancy. Journal of Experimental Child Psychology 2004;89:127–139. [PubMed: 15388302]

Hayne H, Herbert J, Simcock G. Imitation from television by 24- and 30-month-olds. Developmental Science 2003;6:254–261.

Hayne H, MacDonald S, Barr R. Developmental changes in the specificity of memory over the second year of life. Infant Behavior & Development 1997;20:233–245.

Herbert J, Hayne H. Memory retrieval by 18–30-month-olds: Age-related changes in representational flexibility. Developmental Psychology 2000;36:473–484. [PubMed: 10902699]

Hirsh-Pasek, K.; Golinkoff, RM. Brains in a box: Do new age toys deliver on the promise?. In: Harwood, R., editor. Child development in a changing society. Hoboken, NJ: Wiley Press; 2008.

Hirsh-Pasek, K.; Golinkoff, RM.; Dyer, E. Einstein never used flash cards: How our children really learn and why they need to play more and memorize less. Emmaus, PA: Rodale Press; 2003.

Hofer T, Hauf P, Aschersleben G. Infants' perception of goal-directed actions on video. British Journal of Developmental Psychology 2007;25:485–498.

Huang TC, Charman C. Graduations of emulation learning in infant's imitation of actions on objects. Journal of Experimental Child Psychology 2005;92:276–302. [PubMed: 16081091]

Hudson, JA.; Sheffield, EG. The role of reminders in young children's memory development. In: Tamis-LeMonda, CS.; Balter, L., editors. Child psychology: A handbook of contemporary issues. New York, NY: Psychology Press; 1999. p. 193-214.

Hummel JE, Stankiewicz BJ. Categorical relations in shape perception. Spatial Vision 1996;10:201–236. [PubMed: 9061832]

Huston-Stein AC, Wright JC. Children and television: Effects of the medium, its content, and its form. Journal of Research and Development in Education 1979;13:20–31.

Huston, AC.; Wright, JC. Children's processing of television: The informative functions of formal featues. In: Bryant, J.; Anderson, DR., editors. Children's understanding of television: Research on attention and comprehension. New York: Academic Press; 1983. p. 35-68.

Huston AC, Wright JC, Wartella E, Rice ML, Watkins BA, Campbell T, et al. Communicating More than Content: Formal features of Children's Television Programs. Journal of Communication 1981;31(3): 32–48.

Johnson S, Aslin R. Perception of object unity in young infants: the roles of motion, depth, and orientation. Cognitive Development 1996;11:161–180.

Johnson SP. Young infants' perception of object unity: Implications for development of attentional and cognitive skills. Current Directions in Psychological Science 1997;6:5–11.

Johnson, SP. The development of visual surface perception: Insights into the ontogeny of knowledge. In: Rovee-Collier, C.; Lipsitt, LP.; Hanyne, H., editors. Progress in Infancy Research. Vol. Vol 1. Mahwah, NJ: Lawrence Erlbaum; 2000. p. 113-154.

Johnson, SP. Building knowledge from perception in infancy. In: Gershkoff-Stowe, L.; Rakison, DH., editors. Building Object Categories in Developmental Time. Lawrence Erlbaum: Mahwah, NJ; 2005. p. 33-62.

Jones EJH, Herbert J. Exploring memory in infancy: Deferred imitation and the development of declarative memory. Infant and Child Development 2006;15:195–205.

Jowkar-Baniani, G.; Schmuckler, MA. Picture Perception in Infancy: Generalizing From Two-Dimensional to Three-Dimensional Displays; Biannual conference of the Society for Research in Child Development; Denver, CO. 2009 Mar.

Kellman PJ. Perception of three-dimensional form by human infants. Perception and Psychophysics 1984;36:353–358. [PubMed: 6522232]

Kirkorian, HL.; Anderson, DR. Learning from educational media. In: Calvert, SL.; Wilson, BJ., editors. Blackwell Handbook of Children, Media, and Development. Blackwell: Boston, MA; 2008. p. 319-360.

Kirkorian HL, Pempek TA, Murphy LA, Schmidt ME, Anderson DR. The Impact of Background Television on Parent–Child Interaction. Child Development 2009;80:1350–1359. [PubMed: 19765004]

Klein A, Hauf P, Aschersleben G. A comparison of televised model and live model in infant action control: How crucial are action effects? Infant Behavior and Development 2006;29:535–544. [PubMed: 17138306]

Klein PJ, Meltzoff AN. Long-term memory, forgetting, and deferred imitation in 12-month-old infants. Developmental Science 1999;2:102–113.

Krcmar M, Grela B, Lin K. Can toddlers learn vocabulary from television? An experimental approach. Media Psychology 2007;10:41–63.

Kraebel KS, Gerhardstein P. Three-month-old infants' object recognition across changes in viewpoint using an operant learning procedure. Infant Behavior & Development 2006;29:11–23. [PubMed: 17138257]

Kuhl PK, Tsao F, Liu H. Foreign language experience in infancy: Effects of short term exposure and interaction on phonetic learning. Proceedings of the National Academy of Sciences 2003;100:9096–9101.

Lauricella A, Barr R, Calvert C. Influences of an adult’s eye gaze on infants’ imitation from live and video models. Manuscript submitted for publication. 2009

Learmonth AE, Lamberth R, Rovee-Collier C. Generalization of deferred imitation during the first year of life. Journal of Experimental Child Psychology 2004;88:297–318. [PubMed: 15265678]

Lemish, D. Viewers in diapers: The early development of television viewing. In: Lindlof, TR., editor. Natural Audiences: Qualitative Research of Media Uses and its Effects. Norwood, NJ: Ablex; 1987. p. 33-57.

Linebarger. this volume.

Linebarger DL, Walker D. Infants' and Toddlers' Television Viewing and Language Outcomes. American Behavioral Scientist 2005;48:624–645.

Lorch EP, Anderson DR, Levin SR. The relationship between visual attention and children's comprehension of television. Child Development 1979;50:722–727. [PubMed: 498849]

Mares, ML. Positive effects of television on social behavior: A meta-analysis. Philadelphia: University of Pennsylvania, Annenberg Public Policy Center; 1996.

Mares ML. Children's use of VCR's. Annals of the American Academy of Political and Social Science 1998;557:120–131.

McCall RB, Parke RD, Kavanaugh RD. Imitation of live and televised models by children one to three years of age. Monographs of the Society for Research in Child Development 1977;42(5)

McDonough L, Mandler JM, McKee RD, Squire LR. The deferred imitation task as a nonverbal measure of declarative memory. Proceedings of the National Academy of Sciences, (USA) 1995;92:7580–7584.

McGuigan N, Whiten A, Flynn E, Horner V. Imitation of causally-opaque versus causally-transparent tool use by 3- and 5-year-old children. Cognitive Development 2007;22:353–364.

McKee RD, Squire LR. On the development of declarative memory. Journal of Experimental Psychology: Learning, Memory, and Cognition 1993;19:397–404.

Meltzoff AN. Immediate and deferred imitation in fourteen- and twenty-four-month-old infants. Child Development 1985;56:62–72.

Meltzoff AN. Imitation of televised models by infants. Child Development 1988a;59:1221–1229. [PubMed: 3168638]

Meltzoff AN. Infant imitation after a 1-week delay: Long-term memory for novel acts and multiple stimuli. Developmental Psychobiology 1988b;24:470–476.

Meltzoff AN. Infant imitation and memory: Nine-month-olds in immediate and deferred tests. Child Development 1988c;59:217–225. [PubMed: 3342714]

Meltzoff AN. What infant memory tells us about infantile amnesia: Long-term recall and deferred imitation. Journal of Experimental Child Psychology 1995;59:497–515. [PubMed: 7622990]

Meltzoff AN. 'Like Me': A foundation for social cognition. Developmental Science 2007;10:126–134. [PubMed: 17181710]

Mistry KB, Minkovitz CS, Strobino DM, Borzekowski D. Children's television exposure and behavioral and social outcomes at 5.5 years: does timing of exposure matter? Pediatrics 2007;120:762–769. [PubMed: 17908763]

Mondloch CJ, Dobson KS, Parsons J, Maurer D. Why 8-year-olds cannot tell the difference between Steve Martin and Paul Newman: Factors contributing to the slow development of sensitivity to the spacing of facial features. Journal of Experimental Child Psychology 2004;89:159–181. [PubMed: 15388304]

Mumme DL, Fernald A. The infant as onlooker: learning from emotional reactions observed in a television scenario. Child Development 2003;74:221–237. [PubMed: 12625447]

Nadel J. Do children with autism understand imitation as an intentional interaction? Journal of Cognitive and Behavioral Psychotherapies 2004;4:165–177.

Naigles, LR.; Mayeux, L. Television as an incidental language teacher. In: Singer, DG.; Singer, JL., editors. Handbook of Children and the Media. Thousand Oaks, CA: Sage Publications; 2001. p. 135-152.

Nielsen M. Copying actions and copying outcomes: Social learning through the second year. Developmental Psychology 2006;42:555–565. [PubMed: 16756445]

Nielsen M, Simcock G, Jenkins L. The effect of social engagement on 24-month-olds' imitation from live and televised models. Developmental Science 2008;11:722–731. [PubMed: 18801128]

Ninio A. Joint book reading as a multiple vocabulary acquisition device. Developmental Psychology 1983;19:445–451.

Obel C, Henriksen TB, Dalsgaard S, Linnet KM, Skajaa E, Thomsen PH, et al. Does children's watching of television cause attention problems? Retesting the hypothesis in a Danish cohort. Pediatrics 2004;114:1372–1373. [PubMed: 15520136]

Ohr P, Fagen J, Rovee-Collier C, Hayne H, Vander Linde E. Amount of training and retention by infants. Developmental Psychobiology 1989;22:69–80. [PubMed: 2912814]

Paik H, Comstock G. The effects of television violence on antisocial behavior: A meta-analysis. Communication Research 1994;21:516–546.

Palmeri TJ, Gauthier I. Visual object understanding. Nature Reviews: Neuroscience 2004;5:291–304.

Papoušek H, Papoušek M. Mirror image and self-recognition in young human infants: I. A new method of experimental analysis. Developmental Psychobiology 1974;7:149–157. [PubMed: 4822847]

Piaget, J. Play, Dreams, and Imitation. New York, NY: Norton; 1962.

Pierroutsakos LL, DeLoache JS. Infants' manual exploration of pictorial objects varying in realism. Infancy 2003;4:141–156.

Pierroutsakos SL, Troseth GL. Video verite: Infants' manual investigation of objects on video. Infant Behavior and Development 2003;26:183–199.

Povinelli DJ, Landau KR, Perilloux HK. Self-recognition in young children using delayed versus live feedback: evidence of a developmental asynchrony. Child Development 1996;67:1540–1554. [PubMed: 8890499]

Prinz W. Perception and action planning. European Journal of Cognitive Psychology 1997;9:129–154.

Rice ML, Huston AC, Truglio R, Wright JC. Words from Sesame Street - learning vocabulary while viewing. Developmental Psychology 1990;26:421–428.

Rideout, V.; Vandewater, E.; Wartella, E. Zero to six: Electronic media in the lives of infants, toddlers, and preschoolers. Menlo Park, CA: Kaiser Family Foundation; 2003.

Rideout, V.; Hamel, E. The media family: Electronic media in the lives of infants, toddlers, preschoolers and their parents. Menlo Park, CA: Kaiser Family Foundation; 2006.

Robb MB, Richert RA, Wartella EA. Just a talking book? Word learning from watching baby videos. British Journal of Developmental Psychology 2009;27:27–45. [PubMed: 19972661]

Roediger, HL. In: Tulving, E., editor. Why retrieval is the key process in understanding human memory; Memory, consciousness, and the brain: The Tallinn Conference; New York: Psychology Press; 2000. p. 52-75.

Rogers SJ, Hepburn SL, Stackhouse T, Wehner E. Imitation performance in individuals with autism and those with other developmental disorders. Journal of Psychology and Psychiatry 2003;44:763–781.

Rose SA. Infants' transfer of response between two-dimensional and three-dimensional stimuli. Child Development 1977;48:1086–1091.

Schmitt K, Anderson DR. Television and reality: Toddlers' use of visual information from video to guide behavior. Media Psychology 2002;4:51–76.

Schmidt ME, Crawley-Davis AM, Anderson DR. Two-year-olds’ object retrieval based on television: Testing a perceptual account. Media Psychology 2007;9:389–410.

Schmidt ME, Pempek TA, Kirkorian HF, Lund AF, Anderson DR. The effects of background television in the toy play behavior of very young children. Child Development 2008;79:1137–1151. [PubMed: 18717911]

Schmidt ME, Rich M, Rifas-Shiman SL, Oken E, Taveras EM. Television viewing in infancy and child cognition at 3 years of age in a US cohort. Pediatrics 2009;123:370–375.

Sell MA, Ray GE, Lovelace L. Preschool children's comprehension of a Sesame Street video tape: The effects of repeated viewing and previewing instructions. Educational Technology Research and Development 1995;43:49–60.

Sheffield EG, Hudson JA. You must remember this: Effects of video and photograph reminders on 18-month-olds' event memory. Journal of Cognition and Development 2006;7:73–93.

Shimada S, Hiraki K. Infant’s brain responses to live and televised action. NeuroImage 2006;32:930–939. [PubMed: 16679032]

Simcock G, DeLoache JS. The effects of iconicity on re-enactment from picture books by 18- to 30-month-old children. Developmental Psychology 2006;42:1352–1357. [PubMed: 17087568]

Simcock G, DeLoache J. The effect of repetition on infants’ imitation from picture books varying in iconicity. Infancy 2008;13:687–697.

Simcock G, Dooley M. Generalization of learning from picture books to novel test conditions by 18 nd 24-month-old children. Developmental Psychology 2007;43:1568–1578. [PubMed: 18020833]

Simcock G, Garrity K, Barr R. The effect of narrative cues on infants’ imitation from television and picture books. Manuscript submitted for publication. 2009

Skouteris H, Kelly L. Repeated-viewing and coviewing of an animated video: An examination of factors that impact on young children’s comprehension of video content. Australian Journal of Early Childhood 2006;31:22–30.

Skouteris H, Spataro J, Lazaridis. Young children’s use of a delayed video representation to solve a retrieval problem pertaining to self. Developmental Science 2006;9(5):505–517. [PubMed: 16911453]

Smith LB. From knowledge to knowing: Real progress in the study of infant categorization. Infancy 2000;1:91–97.

Spear, NE. The processing of memories: Forgetting and retention. Hillsdale, NJ: Lawrence Erlbaum Associates; 1978.

Sprafkin J, Gadow KD, Abelman R. Television and the exceptional child. 1992

Stankiewicz BJ. Empirical evidence for independent dimensions in the visual representation of three-dimensional shape. Journal of Experimental Psychology: Human Perception and Performance. 2002 In press.

Stevens T, Muslow M. There is no meaningful relationship between television exposure and symptoms of attention-deficit/hyperactivity disorder. Pediatrics 2006;117:665–672. [PubMed: 16510645]

Strouse GA, Troseth GL. “Don’t try this at home”: Toddlers’ imitation of new skills from people on video. Journal of Experimental Child Psychology 2008;101:262–280. [PubMed: 18675431]

Subiaul F, Cantlon JF, Holloway RL, Terrace H. Cognitive imitation in rhesus monkeys. Science 2004;305:407–409. [PubMed: 15256673]

Subiaul F, Cantlon J, Romansky K, Klein T, Terrace HS. Cognitive Imitation in 2-Year Old Human Toddlers: A comparison with rhesus monkeys. Animal Cognition. 2007

Suddendorf T. Children's understanding of the relation between delayed video representation and current reality: A test for self-awareness? Journal of Experimental Child Psychology 1999;72:157–176. [PubMed: 10047437]

Suddendorf T. Early representational insight: twenty-four-month-olds can use a photo to find an object in the world. Child Development 2003;74:896–904. [PubMed: 12795396]

Suddendorf T, Simcock G, Nielsen M. Visual self-recognition in mirrors and live videos: Evidence for a developmental asynchrony. Cognitive Development 2007;22:185–196.

Sutton J. The development of landmark and beacon use in young children: evidence from a touchscreen search task. Developmental Science 2006;9:108–123. [PubMed: 16445400]

Thompson DA, Christakis DA. The association between television viewing and irregular sleep schedules among children less than 3 years of age. Pediatrics 2005;116:851–856. [PubMed: 16199693]

Thorndike, E. The Fundamentals of Learning. New York: Teachers College Press; 1932.

Troseth. this volume.

Troseth GL. TV guide: two-year-old children learn to use video as a source of information. Developmental Psychology 2003;39:140–150. [PubMed: 12518815]

Troseth GL, DeLoache JS. The medium can obscure the message: young children's understanding of video. Child Development 1998;69:950–965. [PubMed: 9768480]

Troseth, GL.; Pierroutsakos, SL.; Deloache, JS. From the Innocent to the Intelligent Eye: The Early Development of Pictorial Competence. In: Kail, RV., editor. Advances in child development and behavior. Vol. Vol 32. San Diego, CA: Elsevier Academic Press; 2004. p. 1-35.

Troseth GL, Saylor MM, Archer AH. Young Children's Use of Video as a Source of Socially Relevant Information. Child Development 2006;77:786–799. [PubMed: 16686801]

Tulving, E. Elements of episodic memory. New York: Oxford University Press; 1983.

Ugiris IC. Two functions of imitation during infancy. International Journal of Behavioral Development 1981;4:1–12.

Underwood BJ. Attributes of memory. Psychological Review 1969;76:559–573.

Vandewater E, Park SE, Lee SJ, Barr R. Can infants and toddlers learn a novel shape from video? Journal of Children and Media. (in press).

Waxman, SR. All in good time: How do infants discover distinct types of words and map them to distinct kinds of meaning?. In: Colombo, J.; McCardle, P.; Freund, L., editors. Infant pathways to language: Methods, models, and research directions. Mahwah, NJ: Lawrence Erlbaum Associates; 2008.

Wright JC, Huston AC, Murphy KC, St Peters M, Pinon M, Scantlin R, Kotler J. The relations of early television viewing to school readiness and vocabulary of children from low-income families: The early window project. Child Development 2001;72:1347–1366. [PubMed: 11700636]

Yoon, JMD.; Winawer, J.; Witthoft, N.; Markman, EM. Striking deficiency in top-down perceptual reorganization of two-tone images in preschool children; Poster presented at the annual meeting of the Vision Sciences Society; Sarasota, FL. 2007 May.

Zack E, Barr R, Gerhardstein P, Dickerson K, Meltzoff AN. Infant imitation from television using novel touch-screen technology. British Journal of Developmental Psychology 2009;27:13–26. [PubMed: 19972660]

Zack, E.; Barr, R.; Shuck, L.; Sperle, E.; Dickerson, K.; Gerhardstein, P.; Meltzoff, A. Do language cues facilitate cross-dimension transfer in 15-month-olds. Washington DC: Poster presented at International Society of Developmental Psychobiology; 2008 Nov.

Zelazo PD, Lourenco SF. Imitation and the dialectic of representation. Developmental Review 2003;23:55–78.

Zelazo PD, Sommerville JA, Nichols S. Age- related changes in children's use of external representations. Developmental Psychology 1999;35:1059–1071. [PubMed: 10442874]

Zimmerman FJ, Christakis DA. Children's television viewing and cognitive outcomes: a longitudinal analysis of national data. Archives of Pediatric and Adolescent Medicine 2005;159:619–625.

Zimmerman FJ, Christakis DA. Associations between content types of early media exposure and subsequent attention problems. Pediatrics 2007;120:986–992. [PubMed: 17974735]

Zimmerman FJ, Christakis DA, Meltzoff AN. Associations between media viewing and language development in children under 2 years. Journal of Pediatrics 2007a;151:364–368. [PubMed: 17889070]

Zimmerman FJ, Christakis DA, Meltzoff A. Television and DVD/video viewing by children 2 years and younger. Archives of Pediatric and Adolescent Medicine 2007b;161:473–479.

Zimmerman FJ, Glew GM, Christakis DA, Katon W. Early cognitive stimulation, emotional support, and television watching as predictors of subsequent bullying among grade-school children. Archives of Pediatric Adolescent Medicine 2005;159:384–388.