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PAPER

Age-related changes in deferred imitation from television by 6- to 18-month-olds

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Abstract

During the second year of life, infants exhibit a video deficit effect. *That is, they learn significantly less from a televised demonstration than they learn from a live demonstration. We predicted that repeated exposure to televised demonstrations would increase imitation from television, thereby reducing the video deficit effect. Independent groups of 6- to 18-month-olds were exposed to live or videotaped demonstrations of target actions. Imitation of the target actions was measured 24 hours later. The video segment duration was twice that of the live presentation. Doubling exposure ameliorated the video deficit effect for 12-month-olds but not for 15- and 18-month-olds. The 6-month-olds imitated from television but did not demonstrate a video deficit effect at all, learning equally well from a live and video demonstration. Findings are discussed in terms of the perceptual impoverishment theory and the dual representation theory.*

Introduction

There is a small but growing body of evidence examining infant imitation from television both immediately and after a delay. Meltzoff (1988) reported that 14-month-olds imitate from a televised model when tested immediately and also when tested for deferred imitation after a 24-hour delay. More recently, it has been shown that 12-month-olds also exhibit immediate imitation from a televised model (Klein, Hauf & Aschersleben, 2006) and deferred imitation after a 24-hour delay (Barr, Muentener, Garcia, Fujimoto & Chavez, 2007). To successfully imitate from television, participants must form a representation of the object and the target actions during the demonstration of the target actions. Then after a delay, at test, participants must reproduce the actions in the appropriate context. At test, participants match perceptual attributes of the 3D test object to stored attributes of the memory representation of the original 2D video display. Researchers have opted for a deferred rather than immediate test for two reasons. First, deferred imitation is a more complex representational task than immediate imitation because of the cognitive load imposed by the delay interval (e.g. Barr & Hayne, 2000; Meltzoff, 1990). Second, deferred imitation more closely simulates real-world conditions because infants rarely have immediate access to materials presented on television.

Imitation studies also show, however, that an infant's ability to learn multi-step sequences of actions from a televised demonstration is significantly less than his/her ability to learn the same sequence of actions from a live demonstration (Barr & Hayne, 1999; Hayne, Herbert & Simcock, 2003; Hudson & Sheffield, 1999). That is, infants exhibit a *video deficit effect* (Anderson & Pempek, 2005). In Barr and Hayne (1999), for example, on one imitation task, 12-, 15-, and 18-month-olds imitated a live model after a 24-hour delay. In contrast, only 18-month-olds imitated the televised model, and their performance was inferior to that of the live group. Furthermore, Barr and Hayne (1999) found that the video deficit effect occurred even for 12- and 15-month-olds tested immediately after a video demonstration of the task. On a different imitation task, 15-, 18-, 24-, and 30-month-old infants in the video group imitated significantly fewer actions than infants in the live group when tested either immediately or after 24 hours (Barr & Hayne, 1999; Hayne *et al.*, 2003). Imitation tasks reveal evidence of the video deficit until children are 3 years of age (Hayne *et al.*, 2003; Hudson & Sheffield, 1999; McCall, Parke & Kavanaugh, 1977). The video deficit effect is not task specific; it is also exhibited in object search tasks (Deocampo & Hudson,

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2005; Schmitt & Anderson, 2002; Troseth, 2003; Troseth & DeLoache, 1998), emotion processing tasks (Mumme & Fernald, 2003) and language tasks with infants (Kuhl, Tsao & Liu, 2003), and preschoolers (Sell, Ray & Lovelace, 1995).

There are two primary, but not mutually exclusive, theories to account for the video deficit effect. These are the perceptual impoverishment theory and dual representation theory.

Perceptual impoverishment theory

The perceptual impoverishment theory accounts for the video deficit by suggesting that learning is impaired due to an impoverishment of the two-dimensional input relative to a real three-dimensional presentation. In particular, the theory posits that fewer details are encoded from a 2D stimulus. Johnson (e.g. Johnson & Aslin, 1996; Johnson, 1997) has proposed that the perceptual encoding system requires a minimum amount of information for perception regardless of its source (e.g. 2D image or 3D object). Studies using 2D stimuli have demonstrated that in order to form an object representation, younger infants require more information than do older infants (Johnson, 1997, 2000). The ability to use a 2D representation to imitate an action using a 3D object may likewise depend on a summation; a 2D presentation may not match its 3D counterpart until a sufficient number of individual attributes are available to match from 2D to 3D (see also Smith, 2000, for a similar argument regarding language acquisition). If encoding is impoverished, retrieval will also be compromised. It may be compromised as a result of a mismatch of cues at the time of retrieval and/or the lack of specific cues at the time of retrieval (Barr & Hayne, 1999; Hayne, 2004; Schmitt & Anderson, 2002; Suddendorf, 2003).

Recently, researchers using event-related potentials (ERPs; Carver, Meltzoff & Dawson, 2006) have demonstrated that 18-month-olds perceptually process 2D and 3D objects at different rates. Carver and colleagues paired the infants' favorite familiar toy with an unfamiliar toy matched on shape, color, and size. For the 3D condition, toys were placed in a display box. For the 2D condition digital photos of the familiar and unfamiliar toys were taken, and the images were presented on a computer monitor. ERPs showed that 18-month-olds differentiated between familiar and novel toys in both the 2D and 3D conditions. The recognition occurred very early in the attention process for the 3D condition but significantly later for the 2D condition. That is, toddlers are much slower at differentiating between 2D pictures of novel and familiar objects than the real 3D objects.

Consistent with this theory, and the finding that 2D stimuli take a longer amount of time to process, researchers have examined whether repetition ameliorates the video deficit effect. Presumably, repetition would enhance encoding and retrieval of the 2D attributes. Recent findings from studies conducted with infants, toddlers, and preschoolers suggest that repetition does enhance performance following televised presentations (Abelman, 1990; Anderson & Levin, 1976; Anderson, Lorch, Field & Sanders, 1981; Barr *et al*., 2007; Crawley, Anderson, Wilder, Williams & Santomero, 1999; Sell *et al*., 1995). In the study conducted by Barr and colleagues (2007), for example, 12-, 15-, 18- and 21-month-olds were shown two three-step action sequences, making a rattle and making an animal. Infants aged 12 to 21 months exhibited the same level of deferred imitation from both a live and 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, 12- to 21-month-olds continued to exhibit a video deficit effect (Barr & Hayne, 1999; Barr *et al*., 2007). Overall, data collected from immediate and deferred imitation studies are consistent with the perceptual impoverishment theory – the video deficit effect disappears with age and decreases with repetition of target information.

Dual representation theory

A second major theory relevant to the *video deficit effect* is dual representation theory (DeLoache, 1991; Troseth, Pierroutsakos & DeLoache, 2004). DeLoache and colleagues argue that early in development infants and toddlers do not understand the dual nature of symbols, with the consequence that they often confuse symbols and referents. That is, they do not comprehend that a symbolic object is both an object in itself and a representation of something else. Only gradually as a function of experience do they come to relate symbolic and real entities in a mature way.

With respect to television/video, infants do not appreciate the difference between an object on a television screen and the real object it depicts. For example, Pierroutsakos and Troseth (2003) presented 9- to 19-month-olds with videos of appealing toys and recorded the infants' reaction to them. The 9-month-olds manually explored and grabbed at the toys presented on the video screen in a manner similar to how they interact with real toys. The 19-month-olds, however, pointed at the toys on the screen, but did not manually explore them. The 15-month-olds' behaviors were intermediate between the other two age groups.

Based on this and other research, one might propose a three-phase developmental process. During phase 1, infants as young as 5 months can recognize the correspondence between 2D photos and 3D objects (DeLoache, Strauss & Maynard, 1979). Infants manually explore both 2D images and 3D objects. With tactile experience with objects and with pictures and television, infants come to recognize the different functional properties of 2D and 3D objects. That is, for example, a ball can bounce, but a picture of a ball cannot.

Based on this acquired knowledge of the crucial differences between 2D and 3D objects, in phase 2, toddlers between 1 and 2.5 years of age find it difficult to appreciate the relations between them. They fail, for example, to apply information presented on television to real world situations (Troseth, Saylor & Archer, 2006; Troseth & DeLoache, 1998), resulting in a paradoxical increase in the video deficit effect during the second year of life. Thus, during phase 2, the informational value of actions presented in 2D (on video) will be substantially diminished, because children do not recognize the functional significance of the objects and actions they view on the screen.

In the third and final phase, children achieve dual representation with respect to video images. They now understand the representational relation that can exist between video and reality, as well as the differences between them (e.g. Troseth & Deloache, 1998). As a consequence, during the third year of life, children come to understand that video can provide meaningful information to guide actions in the real world. They now readily apply information from video to the real world when appropriate, and the video deficit effect disappears.

The present study

The aims of the current study were threefold. First, we wanted to examine age-related changes in imitation from television in 6- to 18-month-olds using a single imitation task. The two theories, the perceptual impoverishment theory and the dual representation theory, make opposite predictions regarding the video deficit effect. According to the perceptual impoverishment model, the video deficit effect should *decrease* as a function of age. Older infants should require fewer streams of information to encode sufficient details to make the perceptual match and transfer information from a 2D demonstration to a 3D object at the time of retrieval. In contrast, the dual representation theory generates the seemingly counterintuitive hypothesis that the video deficit effect will *increase* between the first and second year of life. This is due to the fact that younger infants have a less developed understanding of television as a symbolic medium.

Second, while doubling the number of demonstrations of the target actions has been shown to ameliorate the video deficit effect by 12- to 21-month-olds (Barr *et al.*, 2007), we wanted to examine the generality of this finding using a different stimulus set and a younger age range. In Barr *et al.* (2007), only rattles and wooden animal toys were used to demonstrate a multi-step sequence. Barr and Hayne (1999), however, found that it was easier for 15-month-olds to imitate making a rattle from television than to imitate removing a mitten from a puppet. Therefore, the present study examined whether repeating the target actions for the video group would increase imitation levels for the puppet imitation task as well.

Third, we wanted to examine whether 6-month-olds would imitate from television at all. If so, would they exhibit a video deficit effect? According to perceptual impoverishment theory, 6-month-olds would be *most* likely to exhibit a video deficit because younger infants require more streams of information to process visual stimuli than older infants. According to dual representation theory, 6-month-olds would be *least* likely to exhibit a video deficit because they are in phase 1 of symbolic understanding and should treat the 2D video demonstration and 3D live demonstration similarly. They should not attempt to form two representations. To answer these questions we examined the effect of repeated exposure on imitation of the puppet task from television by 6- to 18-month-olds using a similar design to that of Barr and Hayne (1999).

Experiment 1: Repetition effects on deferred imitation from television by 12- to 18-month-olds

The current experiment explored the effects of repeated exposure on the video deficit effect using deferred imitation of a puppet task. During the puppet task, an experimenter removes the mitten from the puppet's right hand, shakes the mitten to ring the hidden bell inside, and replaces the mitten on the puppet. We chose the puppet task for two major reasons. First, it has an age invariant baseline from 6 to 24 months (Barr, Dowden & Hayne, 1996). Second, infants attend well to puppets on television making the stimulus an ideal choice to examine learning from television (Anderson & Levin, 1976). Experiment 1 is a replication of research conducted by Barr and Hayne (1999), except that the target actions were doubled for infants in the video group, infants were not tested by the same experimenter who appeared in the video,[1] and two additional brightly colored puppet stimuli were used.

[1] Hayne and colleagues (2003) directly compared performance of a group tested with the same experimenter who appeared on the televised demonstration to a group tested with a different experimenter who did not appear on the televised demonstration and found no effect of experimenter.

Participants

Participants were 108 full-term healthy infants (55 girls, 53 boys) recruited from commercial mailing lists and by word of mouth. The 12-month-olds had a mean age of 380.7 days (SD = 9.0), the 15-month-olds had a mean age of 465.4 days (SD = 10.7) and the 18-month-olds had a mean age of 562.6 days (SD = 7.3). Infants were African-American ($n = 7$), Latino ($n = 14$), Asian ($n = 9$), of mixed ethnic origin ($n = 8$), and Caucasian ($n = 70$). Their parents' mean educational attainment was 16.3 years (SD = 1.5), and their mean rank of socioeconomic status (Nakao & Treas, 1992) was 72.0 (SD = 18.5). Infants of each age were randomly assigned to one of three experimental groups, the *live 3x group*, *video 6x group*, and the *baseline control group* ($n = 12$/group). For each group the number of demonstrations of the target actions are delineated as *3x* or *6x* to refer to the fact that they were shown the target actions three or six times, respectively, in a single session.

Additional infants were excluded from the sample for < 50% looking time during demonstration ($n = 2$), crying during test session ($n = 4$), refusal to sit during the test session ($n = 13$), refusal to touch the puppet ($n = 17$), equipment failure ($n = 3$), experimenter error ($n = 3$), and parental interference ($n = 3$).

Apparatus

Four hand puppets, a pastel pink rabbit, a pale grey mouse, a black-and-white cow, and a yellow duck, were constructed for these experiments and were not commercially available. All puppets were 60 cm in height and were made of soft, acrylic fur. A removable felt mitten (8 cm × 9 cm) was placed over the right hand of each puppet. The mitten was pink, grey, black, or yellow and matched the color of the rabbit, mouse, cow, or duck, respectively. During the demonstration session, a large jingle bell was secured inside the mitten. The puppets (rabbit, mouse, cow, or duck) were counterbalanced within groups. Four professionally produced 60-s video segments, one for each stimulus, were made for the study. In each video segment, the puppet was centered in the middle of the screen and was filmed at close range. Similar to the live demonstration, the adult model's hands and arms were visible throughout the presentation, and the face of the experimenter was only partially visible because the puppet was placed in front of his face.

Procedure

Infants were tested in their own homes at a time when parents said they were most likely to be awake and alert. This time varied across infants but remained relatively constant across sessions of the same infant. All sessions were videotaped for later analysis.

Demonstration session

Infants in *live 3x* and *video 6x* groups participated in this session. For both groups, an experimenter demonstrated three specific actions on the puppet. The *live 3x* group was shown the target actions three times in succession demonstrated by an experimenter in the home. During the live demonstration, the infant sat on the caregiver's lap. The experimenter knelt in front of the infant, placed the puppet on her right hand, and positioned the puppet at the infant's eye level and out of reach, approximately 80 cm from the infant's chest. The experimenter then removed the mitten from the puppet's right hand, shook it three times to ring the bell inside, and replaced it on the puppet's hand. This sequence required approximately 9–10 s and was repeated two more times for a total duration of approximately 30 s for the *live 3x* groups ($M = 27.6$ s, $SE = 4.3$). Allowing for time for the experimenter to say hello and good-bye, the entire demonstration duration was approximately 40 s ($M = 39$ s, SD = 5.4) for the *live 3x* groups. Variations in the live demonstration times were due to occasional interruptions in the household, such as a phone ringing. The face of the experimenter was partially obscured by the puppet throughout the demonstration. The caregiver directed the infant's attention to the experimenter, but did not describe the target actions.

The *video 6x* group was shown the target actions six times in succession on video. The puppet target actions lasted a total of 52 s and the entire video demonstration, once again allowing for the experimenter to say hello and goodbye, lasted 65 s. For infants in the *video 6x* groups, the caregiver and infant were seated approximately 80 cm from the family's own television set such that the screen was at the infant's eye level but out of reach. The video started after the infant and caregiver were correctly positioned. Both the caregiver and the experimenter directed the infant's attention to the television screen using the child's name and the word 'look' but did not describe the target actions. To increase the ecological validity of the study, the video model was not present in the home for infants in the video group because infants do not typically meet television presenters.

Test session

The test session was identical for all groups. During the test session, the bell was removed from the mitten. The experimenter placed the puppet within the infant's reach, and the infant was allowed 90 s from the time he or she first touched the puppet to imitate the target actions. Infants in the experimental groups were tested with the same puppet they had seen the day before either in the live or televised demonstration. The *baseline control* group was used to assess the spontaneous production of the target actions in the absence of the demonstration. Infants in the *baseline control* group did not participate in the demonstration session. Rather, they were shown the test stimuli for the first time during the test session.

Coding and reliability

Demonstration session

Looking time was coded from videotaped sessions using a computer timer. The coder pressed a key to mark the beginning and end of the demonstration and pressed a key when infants looked at or away from the demonstration. The duration of the looks and overall percent looking were subsequently calculated (e.g. Anderson & Levin, 1976). Data were not recorded for two infants due to technical errors. Based on 35% of the sessions, a Pearson product-moment correlation on percent looking time yielded an interobserver reliability coefficient of .94.

Test session

An observer noted the total number of target actions (remove, shake, replace or attempt to replace the mitten) that each infant imitated during the 90 s from when the infant first touched the puppet (range 0–3). Based on 76% of the test sessions, interobserver reliability was 97.9% (Kappa = .95). When the two raters differed, the primary rater's score was assigned.

Results and discussion

Preliminary analyses

Preliminary analyses revealed that there were no main effects of gender or stimulus on outcome, so data were collapsed across these variables for all subsequent analyses in all three experiments.

Demonstration session

Looking time to the *live 3x* demonstration and the *video 6x* demonstration was high (36.2 s, $SE = 1$ and, 57.5 s $SE = 1.2$, respectively). In order to directly compare the groups on looking time, percent looking time was calculated. Percent looking time to the *live 3x* demonstration and the *video 6x* demonstration was high (94.0%, $SE = 1.1$ and 89.8%, $SE = 2.0$, respectively). A 3 (Age) × 2 (Group; *3x live*, *6x video*) between-subjects ANOVA across percent looking time to the demonstration yielded no main effect of Age, $F(2, 64) < 1$, or Group, $F(1, 64) = 3.47$, *ns*, and no Age × Group interaction, $F(2, 64) = 1.65$, *ns*. Therefore, subsequent differences in imitation cannot be attributed to failures to look during the demonstration since there were no differences in percent looking time as a function of mode of presentation or age. The increased length of the video demonstration did not decrease the overall percent looking time. Looking time during the first half of the demonstration was significantly higher than during the second half of the demonstration for infants in the *video 6x* group, $F(1, 32) = 8.45$, $p < .01$, but did not differ as a function of age.

Test session

The critical question for the present experiment was whether infants would exhibit a video deficit effect when the number of demonstrations of the target actions was doubled for the video presentation. For this reason we conducted a series of one-way ANOVAs to examine two questions. First, did infants of any age in the *video 6x* groups perform significantly above baseline? Imitation was exhibited if any group performed above baseline. Second, was there a difference between the performance of the live and video groups? A video deficit was exhibited if the video group performed significantly worse than the live group.

For 12-month-olds there was a main effect of group, $F(2, 33) = 5.21$, $p < .02$. As shown in Figure 1, post-hoc

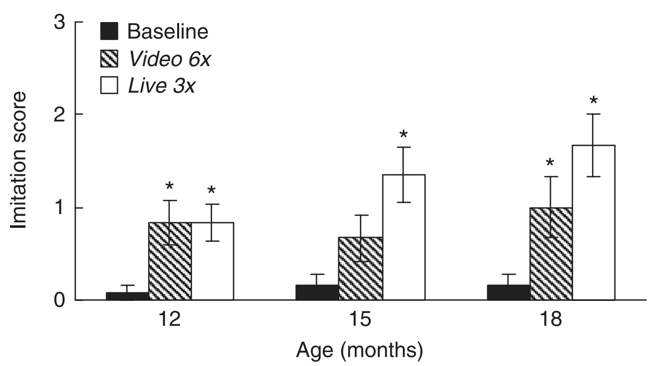

Figure 1 *The mean imitation scores (+1 SE) of 12-, 15-, and 18-month-old infants tested after a 24-hour delay as a function of demonstration group (live 3x or video 6x) in Experiment 1. The mean imitation score (+1 SE) of age-matched infants in the baseline control group is shown by the dark bar. An asterisk indicates that a test group exhibited significant deferred imitation (i.e. its mean imitation score was significantly > the mean test score of the baseline control group).*

Student Newman Kuhls tests (SNK, $p < .05$) showed that 12-month-olds in the *live 3x* and *video 6x* groups performed significantly above baseline and did not differ from one another. That is, when the number of demonstrations of the target actions presented on video was doubled there was no video deficit effect for 12-month-olds. For 15-month-olds, there was a main effect of group, $F(2, 33) = 6.21$, $p < .006$, but the pattern of results was very different. Post-hoc SNK tests ($p < .05$) showed that 15-month-olds in the *live 3x* group performed significantly above baseline but those in the *video 6x* group did not. This finding replicates Barr and Hayne (1999). Finally, the 18-month-olds also showed a main effect of group $F(2, 33) = 8.78$, $p < .001$. Post-hoc SNK tests ($p < .05$) showed that 18-month-olds in the *live 3x* group performed significantly above both the *video 6x* group and the *baseline control* group, and the *video 6x* group performed significantly above baseline. Once again, the 18-month-old findings directly replicated those of Barr and Hayne (1999).

Taken together, the results of Experiment 1 show that although percent looking time was maintained with six repetitions of the target actions, increasing the number of presentations enhanced only 12-month-olds' imitation performance. In contrast to Barr and Hayne (1999) where none of the 12-month-olds imitated following the *video 3x* demonstration, eight 12-month-olds in the *video 6x* group exhibited deferred imitation. Like Barr and Hayne (1999), 15-month-olds in the video group exhibited a video deficit effect and failed to perform above baseline and 18-month-olds performed above baseline but continued to exhibit a video deficit effect.

Experiment 2: Quadrupling the repetitions for 15-month-olds

Information is typically better retained when it is spaced rather than massed (Bjork, 1975; Landauer & Bjork, 1978; Schmidt & Bjork, 1992). Studies with infants and young children have demonstrated that spacing increases both the likelihood of retrieval and the length of retention (e.g. Barr, Rovee-Collier & Campanella, 2005; Hartshorn, 2003; Rea & Modigliani, 1985; but see Barr *et al*., 1996).

Although the 15-month-olds did not perform above baseline, the average imitation score for the *video 6x group* was 0.66 as opposed to 0.16 for the *video 3x* group from Barr and Hayne (1999). Given this result, we decided to examine the effect of quadrupling the number of demonstrations of the target actions on imitation from television by 15-month-olds. Because infants typically view television in short bursts (see Anderson & Levin, 1976), and on repeated occasions (Mares, 1998), we decided to double the number of target action demonstrations both within the session as before (*video 12x massed* group) but also to show them across two sessions separated by 24 hours (*video 2/6x spaced* group). To control for effects of spacing between presentations, spacing was kept constant and all infants were tested 24 hours after the last exposure (see Galluccio & Rovee-Collier, 2000).

A single session *video 12x massed group* was exposed to the demonstration 12 times on day 1 and then tested on day 2. The *video 2/6x spaced group* was exposed to the *video 6x* demonstration on day 1 and again on day 2 and tested on day 3. In order to compare different levels of exposure in one analysis, *the live 3x*, *video 6x* groups from Experiment 1, and the *video 3x* group from Barr and Hayne (1999) were included in the analysis. To insure that power of the analysis would be high enough to detect differences between these groups, the *baseline control* group from Barr and Hayne (1999) was merged with the *baseline control* group from Experiment 1 to create a *pooled baseline control* group (see Barr *et al*., 2005). Given that spacing typically enhances recall, we predicted that only the 15-month-olds in the *video 2/6x spaced group* would perform significantly above baseline.

Participants

Participants were 24 full-term, healthy 15-month-old infants (12 girls, 12 boys) recruited as before with a mean age of 470.9 days (SD = 7.3). Infants were Latino ($n = 2$), Asian ($n = 1$) and Caucasian ($n = 21$). Their parents' mean educational attainment was 16.8 years (SD = 1.0), and their mean rank of socioeconomic status (Nakao & Treas, 1992) was 80.8 (SD = 8.8). Infants were randomly assigned to the *video 12x* group or to the *video 2/6x* group ($n = 12$/group). Additional infants were excluded from the sample for refusal to sit during the test session or to touch the puppet ($n = 4$), or equipment failure ($n = 3$).

Procedure

The *video 12x* group was treated identically to the *video 6x* group except that the video included 12 demonstrations and lasted 130 s rather than 65 s. The *video 2/6x* group was treated identically to the *video 6x* group except that the video was shown on day 1 and then repeated at approximately the same time on day 2, and infants were tested on day 3.

Coding and reliability

The coding methods for Experiments 1 and 2 were the same. Based on 50% of the demonstration sessions, a Pearson product-moment correlation yielded an interobserver reliability coefficient for percent looking time of .96. Looking time was uncodable for one participant on day 2 in the *video 2/6x* group. Based on 54% of the test sessions, the interobserver reliability for imitation score was 100% (Kappa = 1.0).

Results and discussion

Demonstration session

Accrued looking time to the *video 2/6x* demonstration and the *video 12x* demonstration was high (120.2 s, $SE = 2.5$ and 111.7 s, $SE = 3.5$, respectively). The absolute amount of time spent looking during the demonstration session for the *video 2/6x* and the *video 12x* groups did not differ significantly, $t(21) = 1.8$, *ns*. In order to directly compare the groups on looking time, percent looking was calculated. Percent looking time to the *video 12x* (86.9%, $SE = 2.8$) and the *video 2/6x* demonstration was high (90.5%, $SE = 3.5$ on day 1, and 95.4%, $SE = 1.3$ on day 2). A within-subjects *t*-test indicated that there was no significant difference between day 1 ($M = 90.5\%$, $SE = 3.5$) and day 2 ($M = 95.4\%$, $SE = 1.2$) looking for the *video 2/6x* group, $t(10) < 1$. A between-subjects *t*-test also demonstrated that there was no significant difference between percent looking time for the *video 12x* ($M = 86.9\%$, $SE = 2.8$) and *video 2/6x* percent looking time on day 1 ($M = 90.5\%$, $SE = 3.5$), $t(22) < 1$. Just as percent looking time decreased across the 60-s session in Experiment 1, however, it also decreased between the first 60 s ($M = 92.8\%$, $SE = 1.8$) and second 60 s ($M = 79.0\%$, $SE = 4.5$) of the video demonstration for the *video 12x* group, $t(11) = 3.39$, $p < .01$. This finding suggests that the *video 12x* group may have been becoming either slightly fatigued or habituating to the video during the second half of the demonstration. Overall, however, the increased length of the video did not significantly decrease overall percent looking time. Playing the video demonstration on a second day also did not significantly decrease overall percent looking time.

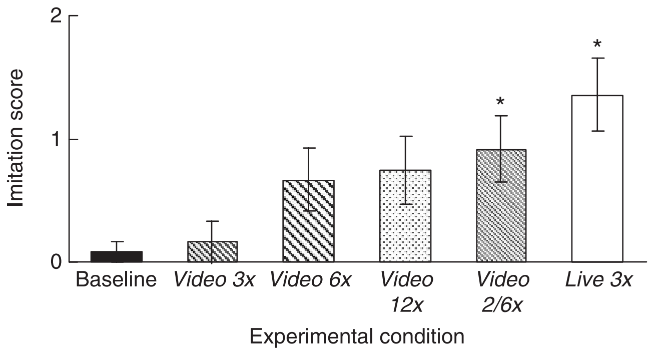

Figure 2 *The mean imitation scores (+1 SE) of 15-month-old infants tested after a 24-hour delay as a function of demonstration group in Experiment 2. The mean imitation score (+1 SE) of infants in the baseline control group is shown by the dark bar. An asterisk indicates that a test group exhibited significant deferred imitation (i.e. its mean imitation score was significantly > the mean test score of the baseline control group). The video 3x group (from Barr & Hayne, 1999), the video 6x and live 3x groups (from Experiment 1) and the pooled baseline group (from Barr & Hayne and Experiment 1) are shown for comparison purposes.*

Test session

The *live 3x*, *video 6x* groups from Experiment 1 and the *video 3x* group from Barr and Hayne (1999) and the *pooled baseline control* group (baseline control Experiment 1 + baseline control Barr & Hayne, 1999) were used for comparison purposes. A 6 (Group; *live 3x*, *video 3x*, *video 6x*, *video 12x*, *video 2/6x*, *pooled baseline*) between-subjects ANOVA was conducted across scores. As shown in Figure 2, there was a main effect of Group, $F(5, 79) = 6.21$, $p < .0001$, and a medium effect size, $d = .46$ (Kirk, 1995). To examine the main effect of Group, post-hoc SNK tests ($p < .05$) showed that the *video 2/6x* and *live 3x* groups performed significantly above baseline but the other groups did not. That is, only the *video 2/6x* group exceeded baseline threshold and exhibited deferred imitation from television. Furthermore, the group's score was not significantly lower than the *live 3x* group, indicating that the video deficit effect was ameliorated. The fact that the *video 12x* group did not exceed baseline performance suggests that spacing is critical (see also Galluccio & Rovee-Collier, 2000). The analysis also showed, however, that the *video 3x*, *video 6x*, *video 12x*, and *video 2/6x* groups did not significantly differ from one another. That is, the performance of *video 2/6x* group was not better than the other video groups; rather, there was a gradual increase in performance which was influenced by both repetition and spacing.

These findings suggest that mechanisms other than encoding play a critical role in learning from 2D presentations. Consistent with our hypothesis, infants in the spaced group performed above baseline and did not exhibit a video deficit effect but infants in the massed group did not perform above baseline. Although the encoding time, as indexed by presentation duration and looking time, did not differ significantly across the *video 12x* and *video 2/6x* groups, the *video 2/6x* group had additional chance to retrieve the memory for the target actions during the second presentation. We conclude that the second presentation may have served as a non-verbal rehearsal opportunity for the *video 2/6x* group (Barr *et al.*, 2005; Bjork, 1975; Wagner, 1976). From a theoretical standpoint, the memory representation is modified by the process of effortful retrieval (Bjork, 1975). Given that encoding and retrieval from 2D presentations are effortful during infancy, such repeated presentations may enhance both encoding and retrieval. Taken together, the findings from Experiments 1 and 2 are consistent with the perceptual impoverishment theory. According to this account, repetition ameliorated the video deficit effect by enhancing the representation of the target actions.

Experiment 3: Imitation from television by 6-month-olds

In the final experiment we examined three interrelated questions: (1) would 6-month-olds imitate from television? (2) If so, would they exhibit the video deficit effect? (3) If they exhibited the video deficit effect, would repetition ameliorate the effect? Perceptual impoverishment theorists would predict that the video deficit would be present and that repetition would serve to ameliorate this effect. In contrast, dual representation theorists would predict that the video deficit effect would not be present. This is due to the fact that younger infants have a less developed understanding of property differences between 2D and 3D objects.

The fact that deferred imitation from television has not previously been demonstrated prior to 12 months of age may be due to lack of an appropriate task to model on television (see Abravenal & DeYong, 1997, who found no evidence of gestural imitation from an animated televised model in a study of 3- and 5-month-olds). As discussed earlier, the puppet task is appropriate for 6- to 24-month-old infants (Barr *et al.*, 1996). There are two important parameter differences that change with this task at different ages. First, due to immature motor planning skills (infants only begin reaching at 5 months), 6-month-olds require additional time at test to reproduce the target actions. Specifically, infants are given 120 s rather than 90 s at test to reproduce the target actions. Second, older infants learn the puppet task more rapidly than younger infants. After three live demonstrations of the target actions, 12- to 24-month-olds imitate the target action after a 24-hour delay. In contrast, 6-month-olds do not show deferred imitation unless the target actions are demonstrated six times (Barr *et al.*, 1996). In the present experiment, therefore, we assigned 6-month-olds to a *live 6x* rather than a *live 3x* group. We also examined whether 6-month-olds would imitate from television and whether the video deficit effect existed. To answer this question, infants were assigned to either a *video 6x* or a *video 12x* group.

Participants

Participants were 48 full-term, healthy infants (23 girls, 25 boys) recruited as before. They had a mean age of 200.7 days (SD = 9.5). Infants were African-American ($n = 2$), Latino ($n = 4$), Asian ($n = 6$), other or mixed ethnicity ($n = 5$), Caucasian ($n = 30$) and one unreported. Their parents' mean educational attainment was 17.2 years (SD = 1.6), and their mean rank of socioeconomic status (Nakao & Treas, 1992) was 80.4 (SD = 13.3). Infants were randomly assigned to four groups, *live 6x*, *video 6x*, *video 12x*, and a *baseline control* ($n = 12$/group). Additional infants were excluded from the sample due to crying for 2 min ($n = 1$), refusal to touch the puppet ($n = 3$), parental interference ($n = 2$), attention < 50% to the demonstration ($n = 4$), and equipment failure ($n = 3$).

Apparatus and procedure

The same apparatus and procedure were used in Experiment 3 as in Experiment 1, except that infants in the live group were exposed to the target actions 6x and infants in the video groups were exposed to the demonstration either 6x or 12x. Allowing for the experimenter to say hello and goodbye, the live demonstration lasted approximately 80 s ($M = 79.7$, SD = 7.7). The duration of six demonstrations of the target actions for the *live 6x* group was 60 s ($M = 60.92$, SD = 5.5). The *video 6x* group saw an equal number of demonstrations as infants in the *live 6x* group except that they were shown the target actions on videotape which lasted approximately 65 s. The *video 12x* group was shown double the number of demonstrations of the target actions as infants in the *live 6x* group, and the actions were presented on videotape and lasted 130 s. The three experimental groups (*live 6x*, *video 6x*, *video 12x*) were tested after a 24-hour delay. As before, an age-matched baseline control group was used to assess the spontaneous rate of production of the target behaviors and did not participate in the demonstration session. Following Barr *et al.* (1996), during the test session 6-month-olds were given 120 s from the time they touched the puppet to reproduce the target actions.

Coding and reliability

Data were coded in the same manner as in Experiment 1 and Experiment 2, except that during the test session infant behavior was coded for 120 s rather than 90 s. Based on 54% of the demonstration sessions, interobserver reliability for percent looking time was high ($r = .95$). Looking time data were not recorded for two infants. Based on 81.5% of the test sessions, the interobserver reliability for imitation score was 97.4% (kappa = 0.94).

Results and discussion

Demonstration session

Looking time to the *live 6x* demonstration, *video 6x* demonstration and *video 12x* demonstration was high (74.6 s, $SE = 2.2$, 54.9 s $SE = 2.4$, and 113.1, $SE = 2.6$, respectively). In order to directly compare the groups on looking time, percent looking time was calculated. Percent looking time to the *live 6x* demonstration, the *video 6x* demonstration and the *video 12x* demonstration was high (94.2%, $SE = 1.5$, 88.3%, $SE = 3.2$, and 89.3%, $SE = 1.5$, respectively). A one-way ANOVA across the experimental groups indicated that there was no main effect of group on percent looking time during the demonstration, $F(2, 33) = 1.23$, *ns*. For the 6-month-olds in the *video 12x* group there was no significant decrease in percent looking time between the first six demonstrations of the target actions and the second six demonstrations of the target actions, $t(9) < 1$. Therefore, subsequent differences in imitation cannot be attributed to failures to look during the demonstration since there were no differences in percent looking time as a function of mode of presentation.

Test session

A one-way ANOVA across groups indicated that there was a significant main effect of group on imitation score, $F(3, 44) = 4.01$, $p < .03$, and a large effect size, $d = .78$ (Kirk, 1995; see Figure 3). Post-hoc SNK tests ($p < .05$) indicated that, although the experimental groups all differed from the baseline control, there were no differences between experimental groups. These findings demonstrate that 6-month-olds can imitate from television. That is, 6-month-olds imitated the target actions regardless of whether they were presented live or on the television, and regardless of whether the target actions were repeated 6x or 12x. These results are compelling. Despite the fact that 6-month-olds need double the amount of exposure to the target actions on the puppet to exhibit deferred imitation from a live model than older infants, they require the same amount of exposure to imitate a video model as they do to imitate a live model.

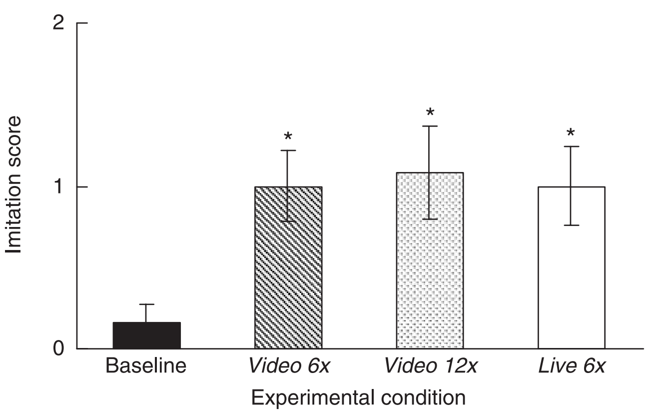

Figure 3 *The mean imitation scores (+1 SE) of 6-month-old infants tested after a 24-hour delay as a function of demonstration group in Experiment 3. The mean imitation score (+1 SE) of infants in the baseline control group is shown by the dark bar. An asterisk indicates that a test group exhibited significant deferred imitation (i.e. its mean imitation score was significantly > the mean test score of the baseline control group).*

Overall, the results of Experiment 3 support the dual representation theory. These results extend those of Pierroustakos and Troseth (2003) who found that younger 9-month-olds would reach for objects moving on the screen but older toddlers (15- to 18-month-olds) would not. Using imitation as an index of performance, the 6-month-olds in the present study did not demonstrate a video deficit effect while the older infants did.

General discussion

The present series of experiments examined age-related changes in imitation from television by 6- to 18-month-olds. We compared and contrasted two prominent theories, the perceptual impoverishment theory and the dual representation theory. We found some support for both theories but neither theory could account for all of the findings. Consistent with perceptual impoverishment theory, repetition ameliorated the video deficit effect for both 12- and 15-month-olds. These findings are consistent with the notion that infants require more streams of information to encode and retrieve information from a 2D source than from a 3D source. These findings are also consistent with those of Barr and colleagues (2007), albeit that the degree of amelioration of the video deficit effect was less in the present study using the puppet stimuli.

These task-dependent differences could arise because some tasks may be easier to perceive on television, affording easier transfer from 2D to 3D than others. For example, perceptual degradation of the target action of replacing the mitten on the puppet may have differentially impacted imitation from television by older infants, leading to a video deficit for older 15- and 18-month-olds relative to the 12-month-olds. Typically, following a live demonstration, 6- and 12-month-olds do not replace the mitten on the puppet whereas older 18-month-olds do (Barr *et al.*, 1996). It is possible that the action of replacing the mitten may be less perceptibly available when demonstrated on television, decreasing the mean imitation score of the video groups tested at 15 and 18 months to a greater extent than the video groups tested at 6 and 12 months.[2] This explanation does not, however, account for the result that in the absence of repetition of the target actions, 6-month-olds did not exhibit a video deficit effect and 12-month-olds did. Parameter differences between 6- and 12-month-olds in the live condition, however, mean that further validation of imitation from television by 6-month-olds on another task is warranted. The fact that the 6-month-olds were able to imitate from television was surprising given the complex representational nature of the task. To our knowledge, this was the first study to demonstrate deferred imitation from television by infants during the first year of life.

The data are also consistent with dual representation theory when age-related differences in task performance on the puppet task are taken into consideration. Dual representation theory posits that during infancy and early toddlerhood, children learn the properties of symbols and how they differ from other objects, thus leading to paradoxical deficits in learning from symbols, including the video deficit effect. Though the video deficit effect was ameliorated by repetition for older infants, it did not even occur at 6 months. That older infants needed more repetitions to succeed on the video task suggests that the task was more cognitively demanding for older than for the youngest infants. In terms of dual representation theory, these findings suggest that during the first year of life infants form one representation of a televised object or event, interacting with 2D objects in a similar manner to 3D objects. Not understanding the crucial difference between them, infants automatically transfer information from the televised to the real object in an imitation task. No video deficit occurs.

During the second year of life, however, infants begin to cognitively appreciate the fundamental differences between 2D and 3D objects and come to realize that they are interacted with in fundamentally different ways. As a consequence, imitation from video becomes representationally more complex than imitation from live displays: Knowing that 2D and 3D objects are crucially different, infants have to mentally represent the relation between the 2D images and the 3D objects they represent. A video deficit is a consequence of this increased representational complexity. The present findings suggest, however, that the repetition of the target information ameliorates this cognitive challenge. Additional exposure to the video information apparently facilitates the achievement of dual representation. The present study is consistent with other recent studies that have shown an amelioration of the video deficit effect as a function of specific experiences (e.g. Barr *et al*., 2007; Suddendorf, 2003; Troseth, 2003; Troseth *et al*., 2006).

The present findings raise a number of questions. Additional research is required to disentangle perceptual and representational/cognitive load explanations for the data. Imitation studies involve presentation of a 2D source and reproduction of the target actions on a 3D object. Such an experimental design does not allow us to disentangle whether the video deficit effect arises from an impoverished 2D input or the cognitive load due to transferring information from a 2D demonstration to a 3D object, or whether there are contributions of both of these factors. The present findings highlight an additional complicating factor. Perceptual and social processing skills increase across time, allowing older infants to make finer discriminations between 2D and 3D object representations. For example, perceptual cues such as size and texture and social contingency cues provide information to distinguish between 2D and 3D object representations. These age-related changes in discrimination of properties contribute to the emergence of the video deficit effect. We are currently using touchscreen technology to manipulate size and texture cues to examine age-related effects on subsequent transfer of information. Specifically, we are able to both demonstrate actions and test imitation in 2D using touchscreen technology, as well as using more conventional 3D objects. We can therefore examine transfer from a 3D demonstration to 2D test and within the 2D/2D domain.

Overall, the present study demonstrates that imitation from television can occur in infants as young as 6 months of age. The findings also suggest that imitation from television continues to be challenging throughout the second year of life, but that repetitions may ameliorate some of the processing difficulties associated with encoding from a 2D presentation and transferring information to a 3D object. The findings do not unequivocally support either the perceptual impoverishment theory or the dual representation theory. Rather they suggest that there is an interesting interplay between perceptual factors, representational factors, task and age. A singular explanation that the deficit arises because of perceptual differences between 2D images and 3D objects, or because of encoding or retrieval deficits, or because of age-related difference in how 2D images are processed across time will not suffice. Learning from television is a complex representational task that develops slowly. In order to create a comprehensive theory, aspects from both the perceptual impoverishment theory and dual representation theory will have to be embraced.

[2] It is important to note, however, that chi-square analyses indicated that the frequency of each of the target actions did not statistically differ either across age or experimental condition.

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