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Long-term transfer of learning from books and video during toddlerhood

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ABSTRACT

Television viewing and picture book reading are prevalent activities during toddlerhood, and research has shown that toddlers can imitate from both books and videos after short delays. This is the first study to directly compare toddlers' long-term retention rates for target actions learned from a video or book. Toddlers ($N = 158$) at 18- and 24-months of age saw an experimenter demonstrating how to make a novel three-step toy rattle via a prerecorded video or a picture book. The toddlers' imitation of the target actions was tested after a specific delay (e.g., 2, 4 weeks), and their performance was compared with that of age-matched controls who did not see a demonstration. The 18-month-olds retained the target actions for 2 weeks, exhibiting forgetting at 4 weeks, whereas the 24-month-olds retained the information for up to 4 weeks, exhibiting forgetting at 8 weeks. Retention rates for books and videos did not differ at either age. These findings demonstrate very impressive retention from a brief two-dimensional media demonstration, and they contribute to our overall understanding of long-term memory processes during infancy.

Introduction

Every day toddlers are faced with the mnemonic challenge of learning about their world from a variety of sources, and they must subsequently apply what they learned to diverse problems in different contexts, and sometimes they must do so after long delays have elapsed—referred to as transfer of learning. The notion of transfer of learning across contexts has been central to memory theorists since

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the time of Thorndike (1932), and many subsequent memory theories have transfer of learning at their core. Transfer of learning across context enables the development of abstract thinking, in particular the development of a flexible representational system (Barnett & Ceci, 2002; Hayne, 2006; Klahr & Chen, 2011). 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). This is based on Tulving's (1983) encoding specificity hypothesis in which 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.

Based on Tulving's specificity hypothesis, Hayne's (2006) developmental representational flexibility theory states that early in development successful memory performance is contingent on an exact match between the cues at the time of encoding and the cues available at retrieval. A mismatch at learning and test can decrease memory performance, but with age toddlers can increasingly tolerate differences between conditions at encoding and those at retrieval. Support for this theory comes from imitation studies in which younger participants exhibit recall only when the test objects are identical to the demonstration objects (e.g., Hanna & Meltzoff, 1993; Hayne, Barr, & Herbert, 2003; Hayne, Boniface, & Barr, 2000; Hayne, MacDonald, & Barr, 1997). In contrast, older participants imitate successfully even when the test objects differ perceptually (e.g., size, color) from the demonstration objects (e.g., Barnat, Klein, & Meltzoff, 1996; Hayne et al., 1997, 2000). To date, however, imitation studies have focused exclusively on transfer of learning after relatively short delays (e.g., immediately, 24 h), and no imitation studies have explored the effects of longer delays on representational flexibility even though toddlers exhibit representational flexibility daily when transferring learning from television and picture books to the real world. In these cases, toddlers must encode information presented in a two-dimensional (2D) format and later retrieve it when presented with the real three-dimensional (3D) objects—a challenging transfer task for toddlers because there is a mismatch between the cues available at encoding and those available at retrieval. Particular perceptual characteristics of 2D images may be difficult for toddlers to understand: the images are smaller than the corresponding real objects, the resolution of the images is degraded relative to real objects, and the images lack features such as depth cues typical of real objects (Barr & Hayne, 1999; Schmitt & Anderson, 2002; Suddendorf, Simcock, & Nielsen, 2007).

Despite the apparent difficulty, recent research using various experimental paradigms has found that young children can learn from videos and picture books. However, toddlers typically learn less from media presentations than from direct experience—a phenomenon termed the "media deficit" effect (Anderson & Pempek, 2005; Barr & Hayne, 1999; DeLoache & Burns, 1994; Hudson & Sheffield, 1999; Kuhl, Tsao, & Liu, 2003; McCall, Parke, & Kavanaugh, 1977). In one study, for example, Barr and Hayne (1999) found that although 15- and 18-month-olds imitated from video, they imitated more from the live demonstration than the video demonstration after a 24-h delay. Similarly, 18- and 24-month-olds imitated a novel three-step event from a picture book, but at rates significantly lower than when imitating from a live model (Simcock & DeLoache, 2006). Ganea, Bloom-Pickard, and DeLoache (2008) examined transfer of learning from picture books to real objects by 15- and 18-month-olds and found that infants were able to transfer learning of a novel label from a book to the 3D object and vice versa, but the infants were better able to transfer information when realistic photographs of objects were used rather than cartoon depictions. Performance also decreased when infants were asked to generalize performance to a novel exemplar that differed in color, and these results are consistent with the representational flexibility hypothesis where transfer of information is facilitated by the degree of overlap in features across context.

Although the research to date shows that toddlers exhibit recall from video and books after relatively short delays (e.g., 10 min, 24 h), there has been little attempt to assess retention over longer durations (e.g., weeks, months) (but see Hudson & Sheffield, 1999). In contrast, a large body of research has examined toddlers' long-term retention from a live model, and this research consistently shows that older toddlers remember for longer intervals than do younger toddlers (Bauer, 2004; Bauer, Wenner, Dropik, & Wewerka, 2000; Hayne et al., 2000; Herbert & Hayne, 2000a). In one imitation study, for example, although equivalent levels of performance were exhibited by 18- and 24-month-olds immediately after the demonstration, 24-month-olds exhibited retention for at least 3 months, whereas 18-month-olds exhibited retention for only 2 weeks (Herbert & Hayne, 2000a). This age-related increase in retention is theorized to be due to age-related increases in representational flexibility (Hayne & Herbert, 2004; see also Carver & Bauer, 2001). The question asked here is whether the same types of changes in long-term memory occur for information presented via a 2D media format.

The primary purpose of the current research was to systematically document the duration of toddlers' recall for a novel action sequence from a book or video presentation. Studies that examine 2D to 3D transfer of learning over long retention intervals will provide us with important practical and educational information about learning across these different media platforms during toddlerhood. At the same time, these findings provide us with new theoretical information, garnered from highly controlled manipulations, about the developmental course of transfer of learning (DeLoache, Simcock, & Marzolf, 2004; Durkin & Blades, 2009; Keates, Graham, & Ganea, 2011) and the development of representational flexibility (Hayne, 2006). Taking Barnett and Ceci's (2002) taxonomy of transfer framework into consideration, the current study of transfer of learning from 2D sources allows specific manipulation of modality (from 2D to 3D), social context (media model vs. experimenter), and temporal context (immediate vs. delay). Moreover, understanding the development of representational flexibility will provide a potential explanation for the media deficit effect that is currently under investigation in the developmental literature (Anderson & Hanson, 2010; Barr, 2010; Troseth, 2010).

Analogue studies of transfer of learning from 2D sources require ecologically valid methodologies that are age appropriate and take into consideration the typical context of learning during early childhood (Barnett & Ceci, 2002). The methods used here are based on the study of Simcock, Garrity, and Barr (2011), who compared 18- and 24-month-olds' imitation from books and videos using the "make a rattle" task (Barr & Hayne, 1999; Bauer, Hertsgaard, & Wewerka, 1995; Bauer & Shore, 1987; Herbert & Hayne, 2000a). The quality of the image and the duration of the demonstration were controlled for by using professionally produced books and videos that were equated for color, contrast, clarity, overall length, narration, and number of demonstrations. The narrative cues in the book and video were identical and described the target actions required to make the rattle. These full narrative cues mimicked how toddlers encounter books and videos in the real world, thereby increasing the ecological validity of the research. The experimenter read the book to toddlers while the same narrative cues were dubbed directly onto the video as a voiceover; prior research has shown that toddlers can learn from voiceovers (Barr & Wyss, 2008; Krcmar, Grela, & Lin, 2007; Rice & Woodsmall, 1988; Scofield, Williams, & Behrend, 2007). Simcock and colleagues (2011) found that after a 10-min delay, toddlers imitated from both media types when either descriptive narrative cues or meaningless narrative cues accompanied the demonstration, and toddlers imitated more from the video than from the book.

Identical to Simcock and colleagues (2011), the video and book conditions in the current research served as analogues for television viewing and picture book interactions; however, we varied the length of time between demonstration and test for different toddler groups of 18-month-olds (Experiment 1) and 24-month-olds (Experiment 2) for each media type. Based on Hayne's (2006) representational flexibility theory, and the finding that toddlers imitate more from a video than from a book after a 10-min delay (Simcock et al., 2011), we predicted that retention would be shorter for the book condition than for the video condition because there are fewer retrieval cues in common with real objects in the book condition (e.g., motion, sound).

Experiment 1: 18-month-olds

Method

Participants

The sample consisted of 60 typically developing, full-term 18-month-olds ($M = 18.42$ months, $SD = 0.27$, 31 girls and 29 boys). Parents were contacted from a participant database and were invited to participate in the study for a small gift. Participants were African American ($n = 4$), Asian ($n = 1$), Caucasian ($n = 39$), Latino ($n = 1$), or mixed race ($n = 7$) (eight parents did not identify their race or ethnicity). Parents' mean educational attainment was 16.52 years ($SD = 1.74$, with 85% reporting), and the mean rank of socioeconomic index (SEI) (Nakao & Treas, 1992) was 78.60 ($SD = 13.71$, with 87% reporting). SEI ranks occupations from the US census on a scale from 1 to 100, with higher status occupations (e.g., physicians) assigned higher ranks, and these ranks are based on three major components of socioeconomic status: educational attainment, occupational status, and annual income (Nakao & Treas, 1992).

Toddlers were randomly assigned to either the *book*, *video*, or *baseline* condition, and those in the experimental (book and video) conditions were tested after a delay (2 or 4 weeks). In total, six 18-month-olds were excluded from the final sample due to equipment failure ($n = 1$), experimenter error ($n = 1$), or toddler fussiness or refusal to touch the test stimuli ($n = 4$).

Using a partial replication approach, a pooled *baseline* group was created by including an additional six age-matched baseline control toddlers that used the same stimuli and experimental procedures as our prior comparison of learning from books and videos (for a similar approach, see Barr, Rovee-Collier, & Campanella, 2005; Barr, Somanader, & Wyss, 2009; Simcock et al., 2011). These new baseline controls were combined with an additional 6 participants from Simcock and colleague's (2011) study who used the same recruitment methods, test stimuli, and procedures. The *baseline* control group was not shown a demonstration of the three target actions and was merely given the three target objects to assess spontaneous production of the three target actions. There was no difference between the baseline scores of the recruited baseline group and the previously collected baseline data for the 18-month-olds, $t(10) = 0.80$, $p = .45$; therefore, these data were collapsed for subsequent analyses.

Materials

Two sets of stimuli were used to assemble a red or green toy rattle in a novel three-step sequence, each of which had the same three target actions: (a) push the ball into the jar, (b) attach the stick to the jar, and (c) shake the stick to make a noise. The red rattle consisted of a red wooden stick (14.5 cm long) with a plug on the end that fitted into a blue plastic ball with a hole in the top (4.5 cm in diameter) and a red wooden ball (2 cm in diameter). The green rattle consisted of a green stick (12.5 cm long) attached to a white plastic lid (9.5 cm in diameter) with Velcro glued to its underside, a green octagonal bead (3 cm in diameter $\times$ 2.5 cm in height), and a clear plastic cup with Velcro around the top (5.5 cm in diameter $\times$ 8 cm in height).

Professionally produced videos and picture books of an experimenter demonstrating how to construct the toy rattles were used for the demonstration. The videos (DVDs) and books were designed simultaneously to maximize similarities of the demonstration from each media type. For example, both were of high resolution, color, and brightness and depicted the same angles and shots of the experimenter. In the video and book, a female adult was shown standing against a gray background at a table covered with black cloth, with the target objects on the table in front of her. The shots alternated from wide angle at the beginning (showing the woman at the table with the target objects on it) and at the end (showing the experimenter holding up the constructed rattle). The middle shots showed close-ups of the stimuli and the experimenter's hands performing the three target actions. Given that toddlers typically do not encounter television presenters or characters in books, the video and book demonstrators never visited the home. The video was shown on a portable DVD player (Element E1023PD) with screen dimensions of 22 $\times$ 13 cm, and the dimensions of the book pictures were 18 $\times$ 14 cm. Although the dimensions of the DVD screen and book differed, the size of the female experimenter and the size of the objects were exactly matched. The portable DVD player was used to eliminate discrepancies between screen sizes of family televisions and to minimize differences between books and video demonstrations.

The narration was identical to that of Simcock and colleagues (2011) and used verbal cues to describe the goal and target actions (e.g., "Linda makes a rattle," "Linda pushes the ball into the jar," "Linda shakes the stick to make a noise—shake, shake"). The set of actions was demonstrated twice, which took approximately 60 s for the video ($M = 59.09$ s, $SD = 2.91$) and picture book ($M = 57.19$ s, $SD = 4.04$); demonstration times did not differ significantly between conditions, $t(46) = 0.21$, $p = .83$.

Procedure

All toddlers were seen in their own homes at a time that the caregivers had identified as a playful period. All toddlers (except those in the baseline condition) participated in two sessions (a demonstration session and a test session) that were separated by a set delay. At the beginning of each visit, the purpose of the study was explained to the caregiver and informed consent was obtained. The caregiver was also asked to refrain from commenting during the study. To build rapport, the experimenter played with the toddler for 5 to 10 min prior to commencing the study. Each session was videotaped for later coding.

Demonstration session. After the 5- to 10-min warm-up, the toddler was seated comfortably for the demonstration. In both conditions, the toddler typically sat on the caregiver's lap ($n = 27$) or beside the caregiver ($n = 27$) and the portable DVD player or book was positioned approximately 30 cm away from the toddler. For the video, the narration was provided by a female voiceover as the target actions were performed. For the book, the female experimenter read the text corresponding to the picture on each page. The demonstration of the target actions was repeated twice for the book and video conditions, and the toddler's behavior was videotaped. If the toddler looked away during the demonstration, the caregiver or the experimenter redirected the toddler's attention back to the video or book by pointing and saying the toddler's name or "look."

Test session. The deferred imitation test occurred on the second visit and was identical for all conditions (including the no-demonstration baseline group). During the test, the toddler and the experimenter were seated facing each other on the floor and the caregiver was seated directly behind the toddler. The toddler was tested with the target objects presented during demonstration, and the toddler's behavior was videotaped for a 1-min period. During the test, the experimenter placed the three parts of the rattle (ball, jar, and stick) within the toddler's reach and provided the toddler with the test prompt: "You can use these things to make a rattle. Show me how to make a rattle" (Hayne & Herbert, 2004; Simcock et al., 2011).

Language measure. The language ability of the toddlers in the delay groups was assessed using the MacArthur Communicative Development Inventory: Words and Sentences (CDI) (Fenson et al., 1994). This is a parent report inventory that yields a measure of toddlers' general productive vocabulary.

Looking time measure. Each toddler's looking time to the video or book was coded from a video of the demonstration session. The coder timed the duration that the toddler looked to the video or book based on the direction of the toddler's eye gaze during the demonstration. The toddler's looking time was divided by the total length of the demonstration (book reading or video viewing) to give looking time expressed as a proportion. A second coder independently coded 30% of the video clips. An intercoder reliability of intraclass correlation = .97 was obtained.

Imitation scores. The toddler's production of the three target actions was coded from a video of the test session. The three target actions were as follows: (a) put the ball in the jar, (b) put the stick on the jar, and (c) shake the rattle. The coder gave each toddler 1 point for the production of each target action completed within the 60-s test phase, giving a minimum score of 0 and a maximum score of 3. As in prior imitation studies, the actions could be produced in any order. A second coder independently coded 30% of the video clips. An intercoder reliability of kappa = .91 was obtained.

Data analysis plan

The primary goal of the analysis was to establish a forgetting function at each age for each media presentation with performance comparisons with the age-matched baseline controls. To do this, a difference score was calculated for each participant by subtracting the mean of the age-matched baseline condition from each individual score. A two-way analysis of variance (ANOVA) across delay and media conditions could then be conducted at each age while still taking baseline performance into consideration.

Results and discussion

Preliminary analyses

A preliminary ANOVA that included sex of participant, rattle type, media type, and delay group yielded no main effect of gender and no main effect of stimuli type, and neither variable entered into an interaction. The data were collapsed across these variables for future analyses.

Imitation scores

We had two primary research questions regarding toddlers' recall for the media demonstration. First, did imitation scores change as a function of delay? Second, did imitation scores differ from age-matched baseline performance? Forgetting was operationally defined as imitative performance that does not exceed baseline performance. We hypothesized that performance should significantly decrease as a function of delay and that forgetting would occur as the length of the delay increased to a point where there was no difference between the delay group and the baseline performance.

We conducted two sets of analyses to answer the research questions. First, the difference score data depicted in Fig. 1 were subjected to a 2 (Media Type: book or video) × 2 (Delay: 2 or 4 weeks) ANOVA. This analysis yielded a significant main effect of delay, $F(1, 44) = 16.33$, $p < .001$, partial $\eta^2 = .27$. The performance of the 2-week delay group ($M = 0.91$, $SD = 0.85$) significantly exceeded the performance of the 4-week delay group ($M = 0.04$, $SD = 0.62$), showing that forgetting occurred over time. There was no significant main effect of media type, $F(1, 44) = 0.93$, $p = .34$, partial $\eta^2 = .02$, showing that there was no difference in forgetting between the book and video groups. There was also no significant interaction between media type and delay, $F(1, 44) = 0.33$, $p = .57$, partial $\eta^2 = .01$, showing there was no differential rate of forgetting as a function of media type demonstration.

The next analyses were performed to confirm which individual delay groups exceeded baseline performance. We conducted a series of planned t tests comparing the raw imitation scores of the delay groups with the raw imitation scores of the baseline groups. As shown in Fig. 1, toddlers in the book and video 2-week delay groups exceeded baseline, $t(22) = 2.43$, $p = .02$, and $t(22) = 3.26$, $p = .004$, respectively. Toddlers in the book and video 4-week delay groups did not exceed baseline, both $ts(22) < 1$. That is, 18-month-olds remembered the target actions following both the book and video demonstrations after a 2-week delay but exhibited forgetting after a 4-week delay.

Performance checks

We conducted three additional analyses to examine whether toddlers' imitative performance was influenced by factors other than the media demonstration. We assessed the contributions of toddlers'

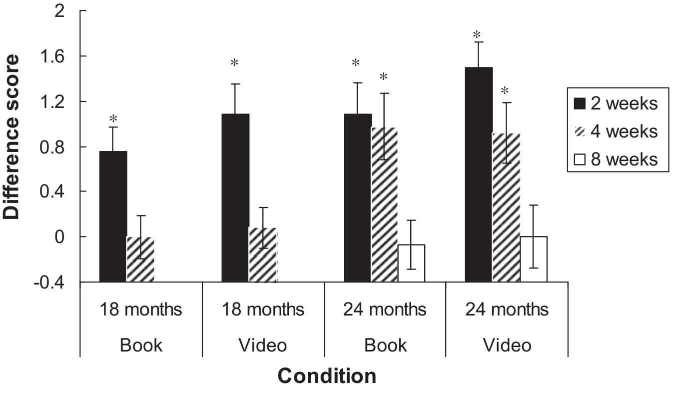

Fig. 1. Difference scores for both 18- and 24-month-olds in book and video conditions as a function of delay. An asterisk (*) indicates significant difference from baseline score.

general language skill, daily exposure to media, and looking time during the demonstration to their imitation performance.

Language measure. Approximately 82% of the CDIs were completed and returned (mean percentile rank = 46th, SD = 31.44). Toddlers' raw CDI vocabulary scores were converted into percentiles and compared across the experimental groups, and the CDI was added as a covariate to the 2 (Media Type) $\times$ 2 (Delay) ANOVA on the difference scores. CDI was not a significant covariate at 18 months, and CDI scores were not considered further.

Daily media exposure. Approximately 94% of the parents reported the average minutes per day that their toddlers were typically exposed to picture books (M = 66.35 min, SE = 6.30) and videos (M = 48.43 min, SE = 7.85). Daily media exposure was added as a covariate to the 2 (Media Type) $\times$ 2 (Delay) ANOVA on the difference scores, and this analysis indicated no significant association between daily television exposure time and imitation from video, $F(1, 20) = 1.47$, $p = .24$, partial $\eta^2 = .07$. Similarly, an analysis of covariance (ANCOVA) exploring the association between daily picture book reading and imitation from books indicated no significance, $F(1, 21) = 0.009$, $p = .92$, partial $\eta^2 = .000$; therefore, daily media exposure times were not considered further.

Looking time measure. A 2 (Media Type) $\times$ 2 (Delay) ANOVA was conducted on toddlers' looking time at the book or video demonstration. There was a significant difference between looking time during the book demonstration (M = 86.40%, SD = 10.30) and looking time during the video demonstration (M = 94.90%, SD = 6.59), $F(1, 43) = 11.18$, $p = .002$, partial $\eta^2 = .21$. However, there was no main effect of delay and no interaction, $F(1, 43) = 0.15$, $p = .70$, partial $\eta^2 = .004$, and $F(1, 43) = 1.16$, $p = .29$, partial $\eta^2 = .03$, respectively.

A one-way ANCOVA to assess whether toddlers' looking time during the demonstration was associated with their imitation scores at the time of test indicated that looking time was not a significant covariate. Looking time during the demonstration accounted for less than 1% of the variance in toddlers' imitation scores, $F(1, 42) = 0.30$, $p = .59$, partial $\eta^2 = .007$. Although looking time differed during the demonstration between books and videos, these looking times were not related to imitation performance; therefore, looking time during demonstration will not be considered further.

In sum, the results of Experiment 1 show impressive retention by 18-month-olds for a novel event they saw via a brief book or video demonstration. In our first research question, we asked whether imitation changed as a function of delay. We indeed found a significant difference in retention across time; toddlers imitated more at the 2-week memory test than at the 4-week memory test. We next compared toddlers' imitation scores with those of the age-matched baseline controls and found that the delay group outperformed baseline at the 2-week test but not at the 4-week test. Thus, 18-month-olds exhibited forgetting by 4 weeks after the demonstration session, and retention was equal across media types. Further analyses indicated that these results were not associated with toddlers' language skills, daily media exposure, or looking toward the media demonstration.

The duration of recall exhibited here from a media demonstration is less than that obtained in research of retention from live models, which is approximately 4 weeks when toddlers are provided with the same types of narrative cues as were presented in the current study (Hayne & Herbert, 2004). We next examined long-term retention by 24-month-olds; based on documented age-related increases in the duration of recall (Herbert & Hayne, 2000a), an 8-week delay group was added to the 2- and 4-week conditions.

Experiment 2: 24-month-olds

Method

Participants

The sample consisted of 86 typically developing, full-term 24-month-olds (M = 24.38 months, SD = 0.28, 43 girls and 43 boys). Parents were contacted from a participant database and were invited to participate in the study for a small gift. Participants were African American ($n = 4$), Asian ($n = 3$), Caucasian ($n = 58$), Latino ($n = 5$), or mixed race ($n = 5$) (11 parents did not identify their race or ethnicity). Parents' mean educational attainment was 16.99 years ($SD = 1.57$, with 88% reporting), and the mean rank of SEI (Nakao & Treas, 1992) was 77.24 ($SD = 12.68$, with 86% reporting). In total, seven 24-month-olds were excluded from the final sample due to equipment failure ($n = 1$), experimenter error ($n = 1$), or toddler fussiness or refusal to touch the test stimuli ($n = 5$).

A partial replication approach was again used to create a pooled *baseline* group by including an additional six age-matched baseline control toddlers, and there was no difference between the baseline scores of the recruited baseline groups and the previously collected baseline data for the 24-month-olds, $t(10) = 1.17$, $p = .27$; therefore, these data were collapsed for subsequent analyses.

We also recruited a separate 27-month baseline control condition to ensure that we compared the performance of the 8-week delay experimental group with an age-matched control (cf. Herbert & Hayne, 2000a). In total, 12 typically developing, full-term 27-month-olds ($M = 27.21$ months, $SD = 0.28$) were also included in the sample and were Asian ($n = 3$), Caucasian ($n = 8$), or Latino ($n = 1$). Parents' mean educational attainment was 16.5 years ($SD = 1.93$, with 92% reporting), and the mean rank of SEI (Nakao & Treas, 1992) was 76.15 ($SD = 16.55$, with 92% reporting). A single 27-month-old was excluded from the final sample due to toddler fussiness or refusal to touch the test stimuli ($n = 1$).

Materials and procedure

The materials, study design, procedure, performance checks, and data analysis were identical to those described in Experiment 1 except as noted here. The demonstration took approximately 60 s for the video ($M = 58.86$ s, $SD = 10.19$) and picture book ($M = 55.57$ s, $SD = 1.86$), and these demonstrations did not differ significantly, $t(73) = 1.76$, $p = .83$. During the demonstration session, each toddler typically sat on the caregiver's lap (24-month-olds: $n = 35$; 27-month-olds: $n = 4$) or beside the caregiver (24-month-olds: $n = 43$; 27-month-olds: $n = 8$).

The 24-month-olds were tested after 2-, 4-, and 8-week delays. The difference score for the 24-month-olds in the 8-week delay condition was established by subtracting the mean score of the 27-month baseline from each individual score. For the looking time measure, an intercoder reliability of intraclass correlation = .92 was obtained. For the imitation scores, an intercoder reliability of kappa = .91 was obtained.

Results and discussion

Preliminary analyses

A preliminary ANOVA that included sex of participant, rattle type, media type, and delay group yielded no main effect of gender. However, there was a main effect of rattle type (red vs. green), $F(1, 51) = 18.06$, $p < .001$, partial $\eta^2 = .29$, with performance on the red rattle exceeding performance on the green rattle; rattle type did not enter into any significant interactions. Because rattle type was not a variable of interest, the data were collapsed across both gender and rattle type for further analysis. However, difference score calculations were based on the individual baseline means of the red and green rattles.

Imitation scores

The 24-month-olds' mean difference scores are shown in Fig. 1 as a function of age, media demonstration type, and delay after which each independent group was tested. As with the 18-month-olds, our primary research questions were, first, to examine decreases in imitation performance as a function of time and, second, to examine whether any individual group exceeded baseline performance.

First, to assess recall over time, the toddlers' difference score data depicted in Fig. 1 were subjected to a 2 (Media Type: book or video) $\times$ 3 (Delay: 2, 4, or 8 weeks) ANOVA. This analysis yielded a significant main effect of delay, $F(2, 70) = 13.94$, $p < .001$, partial $\eta^2 = .29$. The Student–Newman–Keuls (SNK, $p < .05$) post hoc analysis indicated that the performance of the 2-week delay group ($M = 1.29$, $SD = 1.02$) and 4-week delay group ($M = 0.95$, $SD = 0.99$) significantly exceeded the performance of the 8-week delay group ($M = -0.03$, $SD = 0.90$). There was no significant main effect of media type, $F(1, 79) = 0.443$, $p = .51$, partial $\eta^2 = 0.01$, showing that there was no difference in forgetting between the book and video groups. There was also no significant interaction between media type and delay, $F(2, 70) = 0.42$, $p = .66$, partial $\eta^2 = .01$, showing that there was no differential rate of forgetting as a function of media type demonstration.

Second, to confirm which individual groups exceeded baseline performance, we conducted a series of planned *t* tests comparing the raw imitation scores of the delay groups with the raw imitation scores of the baseline groups. The performance of the 2- and 4-week delay groups were compared with that of the 24-month baseline group, and the performance of the 8-week delay group was compared with that of the 27-month baseline group. As shown in Fig. 1, toddlers in the book and video 2-week delay groups exceeded baseline, $t(22) = 2.79$, $p = .01$, and $t(22) = 4.53$, $p < .001$, respectively, as did the 4-week delay groups, $t(23) = 3.20$, $p = .004$, and $t(22) = 2.42$, $p = .02$, respectively. Toddlers in the book and video 8-week delay groups did not exceed baseline, $t(24) = 0.03$, $p = .98$, and $t(23) = 0.11$, $p = .91$, respectively. That is, 24-month-olds remembered the target actions following both the book and video demonstrations after a 4-week delay but exhibited forgetting after an 8-week delay.

Performance checks

Language measure. Approximately 83% of the CDIs were completed and returned (mean percentile rank = 59th, $SD = 28.43$). The CDI was added as a covariate to the 2 (Media Type) × 3 (Delay) ANOVA on the difference scores. CDI percentile was not a significant covariate, $F(1, 62) = 0.85$, $p = .36$, partial $\eta^2 = 0.01$; therefore, CDI scores were not considered further.

Daily media exposure. Approximately 96% of the parents reported the average minutes per day that their toddlers were typically exposed to picture books ($M = 67.16$ min, $SE = 9.93$) and videos ($M = 72.24$ min, $SE = 6.89$). One-way ANCOVAs were conducted to assess whether media exposure times were associated with toddlers' imitation scores in the book and/or video conditions. This analysis indicated that neither daily book exposure, $F(1, 35) = 0.49$, $p = .48$, partial $\eta^2 = 0.01$, or daily video exposure, $F(1, 34) = 1.35$, $p = .26$, partial $\eta^2 = .04$, was a significant covariate; therefore, daily media exposure times were not considered further.

Looking time measure. A 2 (Media Type) × 3 (Delay) ANOVA on toddlers' looking time toward the book or video indicated no significant difference between looking time during the book demonstration (94.33%, $SD = 8.52$) and looking time during the video demonstration (95.36%, $SD = 7.61$), $F(1, 67) < 1$, no main effect of delay, $F(2, 67) = 1.51$, $p = .23$, partial $\eta^2 = .04$, and no interaction, $F(2, 66) = 1.41$, $p = .25$, partial $\eta^2 = .04$. A one-way ANCOVA was conducted to assess whether toddlers' looking time during the demonstration was associated with their imitation scores at test. This analysis indicated that looking time during media demonstration was not a significant covariate, accounting for less than 3% of the variance in toddlers' imitation scores, $F(1, 66) = 1.60$, $p = .21$, partial $\eta^2 = .02$. Looking times were not considered further.

In sum, the results of Experiment 2 show impressive retention by 24-month-olds for a novel event they saw via a brief book or video demonstration. Consistent with Experiment 1, we found a significant difference in retention across time; toddlers imitated more at the 2- and 4-week memory tests than at the 8-week memory test and, similarly, the 2- and 4-week delay groups outperformed baseline but the 8-week group did not. Thus, the 24-month-olds exhibited retention for 4 weeks after the demonstration session, which was double the retention that was exhibited by the 18-month-olds. As in Experiment 1, we did not find any differences in retention across media types, and further analyses indicated that these results were not associated with toddlers' language skills, daily media exposure, or looking toward the media demonstration. The duration of recall exhibited here from a media demonstration is once again less than that obtained in research of retention from live models, which is at least 12 weeks even when toddlers are provided with fewer narrative cues than were presented in the current study (Herbert & Hayne, 2000a).

Cross-experiment comparison

In the final set of analyses, we conducted a cross-experiment comparison to assess whether there were age-related performance differences at the 2-week delay between 18- and 24-month-olds. We examined whether the 18-month-olds had forgotten significantly more than the 24-month-olds at the 2-week delay when both age groups were performing significantly above their age-matched control groups. A 2 (Age) $\times$ 2 (Media Type) ANOVA at the 2-week delay point on difference scores indicated no significant main effect of age, $F(1, 44) = 2.24$, $p = .14$, partial $\eta^2 = .05$, or media type, $F(1, 44) = 2.24$, $p = .14$, partial $\eta^2 = .05$, and no interaction between the two factors, $F(1, 44) = 0.03$, $p = .87$, partial $\eta^2 = .001$.

There were no age-related performance differences exhibited at the 2-week delay point, suggesting that both 18- and 24-month-olds exhibited fairly robust retention for the target actions for 2 weeks. Therefore, age-related differences in retention were likely to be due to the 24-month-olds' enhanced representational flexibility in transferring learning across both the modality (2D/3D) and temporal contexts after a longer delay.

General discussion

This is the first study to demonstrate impressive long-term retention by toddlers for an action sequence learned from a very brief video or picture book demonstration. Consistent with our hypothesis, we found age-related differences in imitation following the book and video demonstrations. Both 18- and 24-month-olds exhibited recall for the media demonstrations after 2 weeks; however, 18-month-olds exhibited forgetting at 4 weeks after the media demonstration, whereas 24-month-olds did not exhibit forgetting until 8 weeks after the media demonstration. Contrary to our predictions, however, toddlers did not exhibit greater retention following a video demonstration than they did following a book demonstration; rather, both media types were recalled at equivalent levels across the delays.

When considered in relation to Barnett and Ceci's (2002) transfer taxonomy, the toddlers here succeeded in transferring the target information across changes to several key domains—physical, social, and temporal. First, the toddlers applied the solution they learned in a 2D media context to a problem they later encountered in the real 3D world. The toddlers did this even though the model in the media demonstration differed from the experimenter who administered the memory test. Finally, the toddlers also exhibited transfer of learning across a considerable temporal delay. The duration of retention shown here is particularly impressive given the challenges that learning from media poses for toddlers. This transfer task is essentially a generalization problem given that successful performance requires decontextualization of the target information that can be achieved only with the development of representational flexibility. As such, these data are the first demonstration of toddlers' very long-term recall for a novel event despite quite dramatic changes to the context between encoding and retrieval.

However, prior research has demonstrated that toddlers show much longer retention using a similar imitation task following a live demonstration. For example, 18-month-olds who observed a live demonstration accompanied by narration exhibited recall for up to 4 weeks (Hayne & Herbert, 2004)—twice as long as the 18-month-olds in the current study. Similarly, 24-month-olds exhibited retention from a live demonstration for 12 weeks even when no language cues were used (Herbert & Hayne, 2000b), whereas in the current study they showed retention from a media demonstration for only 4 weeks. We hypothesize that the general pattern of shorter retention for information learned from media versus live demonstrations stems from the difficulty that toddlers have in generalizing from the 2D images of the media demonstration to the corresponding real-world objects.

Surprisingly, contrary to our predictions, we did not find a difference in retention for books versus videos. Collapsing across age, Simcock and colleagues (2011) found differences between books and videos after a 10-min delay (video: $M = 2.32$, $SE = 0.13$; book: $M = 1.40$, $SE = 0.14$) compared with no difference at the 2-week delay in the current study (video: $M = 2.08$, $SE = 0.18$; book: $M = 1.71$, $SE = 0.19$). We conclude that the extra information given during the video demonstration (e.g., motion, sound effects) may no longer act as an additional cue after a long delay. Prior studies conducted with much younger infants have shown that across time infants tend to remember the gist of a memory rather than the more specific details of the event. Studies using the mobile conjugate reinforcement (Bhatt & Rovee-Collier, 1996; Borovsky & Rovee-Collier, 1990; Hartshorn et al., 1998; Rovee-Collier & Sullivan, 1980) and deferred imitation paradigms (Barr, Dowden, & Hayne, 1996; Barr et al.,

2005) show that 3- to 6-month-olds do not spontaneously generalize to a novel test cue after a 24-h delay. With longer delays, as infants gradually forget the specific details, they increasingly respond to ("recognize") a novel cue until they finally treat the cues equivalently (Barr et al., 2005; Rovee-Collier & Sullivan, 1980). In fact, members of most species exhibit a flattening of generalization gradients over time irrespective of task (Riccio, Ackil, & Burch-Vernon, 1992; Riccio, Rabinowitz, & Axelrod, 1994; Thomas & Burr, 1969). In the current study, after long delays, the toddlers might not recall the source of the demonstration or specific details; therefore, the additional cues provided in the video do not provide any advantage for memory retrieval.

There are a number of practical educational implications to glean from these findings. The current findings suggest that toddlers retain information from 2D symbolic media across significant delays; however, forgetting from these 2D symbolic media sources is likely to be more rapid than forgetting from live interactions. Although the American Academy of Pediatrics (1999) suggests that it is not until 2 years of age when 2D screen media may provide educational benefits, such potential for learning will be heavily influenced by rapid forgetting. Given this change in forgetting functions, parents, educators, publishers, and producers will need to consider presenting information in ways that will facilitate retention of educational material across time. Retention increases exponentially when opportunities for retrieval are presented in the form of repetitions and reminders for both live interactions and 2D presentations (for reviews, see Barr, 2010; Rovee-Collier & Barr, 2010). On a daily basis, toddlers are exposed to a multitude of environmental stimuli; from people and toys to books and televisions, toddlers observe many interactions and acquire a large amount of information about the world around them. How they retain, apply, and integrate this information from multiple sources will play an important role in the developing mnemonic network.

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