Can Infants Use Video to Update Mental Representations of Absent Objects?

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Abstract

Before their second birthday, infants can update their knowledge based on what someone tells them, but can they do so based on what a video shows them? The current study explored whether infants can update their representation of an absent object's properties after seeing a video of something happening to it, following seminal work showing that they can update their representation after being told about something happening to it (Ganea et al., 2007). It thus adapted an existing paradigm for testing infants' understanding of references to absent objects (using language) to investigate a different symbolic medium (video). Twenty-two-month-olds first played with a toy and later saw on video that the toy underwent a change in state while they were out of the room. Infants in the current study did not subsequently identify the toy based on this new information, whereas those in previous research did. Infants this age thus appear less likely to update their representation of an absent object's properties using video than using language. This result is consistent with the possibility that infants may understand the representational function of symbolic objects later in development than they understand the representational function of language. It also aligns with evidence of the video deficit in which infants learn less effectively from video than from firsthand experience.

Keywords: Mental representation, absent objects, updating, video deficit

1. Can Infants Use Video to Update Mental Representations of Absent Objects?

Unlike other animals, humans acquire considerable knowledge about the world indirectly from others, not just from their own direct experience. Much of what people learn occurs from indirect experience, mediated by what others tell them and by what they see and hear in symbolic media such as books, television, videos, and the internet (e.g., DeLoache & Ganea, 2009). In particular, screen-mediated experience is becoming more common during early childhood with the rise of remote learning (Szente, 2020). Learning information indirectly rather than directly can be more challenging earlier in infancy. For example, 2-year-olds show more robust understanding of speech about objects and people that are no longer directly present than 1-year-olds do (for review, see Ganea & Saylor, 2013). Screen-mediated learning is particularly challenging during infancy. Infants can learn new information from screen media under some circumstances, but are also susceptible to a *video deficit* in which they learn less from screen media than from equivalent real-life experience (Anderson & Pempek, 2005). During the first 3 years of life, infants gradually develop the understanding that a video can symbolize an event that they have not directly perceived (Troseth, 2010). Research on what helps and hinders infants' learning from screens is becoming increasingly important as they gain experience with screens at ever earlier ages and as new forms of screen media emerge (e.g., Rideout & Robb, 2020). The current study's aim was to explore whether infants can update their representation of an absent object's properties after seeing a video of an event that happened to the object. It thus tests a different symbolic medium (video) using an existing paradigm which has shown that infants can update their representation after being told about an event that happened to the object (Ganea et al., 2007). A review is first presented on what is known about infants' ability to update their representations of absent objects via language and via video.

1.1. Updating Mental Representations of Objects via Language

During the second year of life, infants begin to understand that a word can be used as a symbol to stand for something that is not present but can be called to mind by naming it (for review, see Ganea & Saylor, 2013). The ability to understand communication about an absent object or person allows infants to learn new information about absent things without experiencing it directly (Ganea et al., 2007). Updating one's knowledge about an absent entity on the basis of language involves several cognitive processes. Acquiring new information from displaced speech requires activating a mental representation of the absent thing upon hearing its name, processing new linguistic information about it, and incorporating the new information into the existing representation (DeLoache & Ganea, 2009; Ganea & Harris, 2013). Infants' developing capacity for these processes is apparent by their second birthday, as demonstrated in tasks when they are told about the current location of an absent object and asked to act on this new information.

1.1.1. Language-mediated Location Updating. Infants' use of symbolic information, including language, to update their knowledge about an absent object has been tested most often with object retrieval tasks (DeLoache, 2004). When 24- and 30-month-olds old hear that someone has moved a toy from an old hiding location experienced firsthand to a new hiding location after they left the room (i.e., from A to B), they subsequently search the correct location more often than expected by chance (DeLoache & Burns, 1994; Ganea & Harris, 2010, 2013; Schmidt et al., 2007; Troseth et al., 2006). By contrast, when younger infants of 23 months hear of this change, they tend to search perseveratively at the old location (Ganea & Harris, 2010, 2013). This A-not-B error is not due simply to poor working memory, because 23- and even 19-month-olds search accurately if they witness the object's displacement instead of hearing about it

(Ganea & Harris, 2010, 2013). When infants hear about this change, however, the new verbal information contradicts their previous firsthand knowledge that encoded the object as being in a specific location, and updating the representation requires overwriting the old information with the new, which appears challenging before 24 months (Ganea & Harris, 2010).

However, when the new information does not contradict the old but simply adds to the representation, infants younger than 24 months old update successfully. When 19- and 23-month-olds old hear that someone has simply hidden a toy at location A, they search the correct location more often than expected by chance (Ganea & Harris, 2010, 2013). In this case, the new verbal information does not contradict the old because the infants' representation contained no information about its specific location. These studies show that before 24 months, infants can use language to update their representation of an absent object by adding new information about its location, and from 24 months on, they can update an absent object's location even when it requires overwriting old information. Infants can thus activate a mental representation of an absent object upon hearing its name, understand verbal information about the object's current location, incorporate the new information into their existing representation, and act on the object using the updated representation (DeLoache & Ganea, 2009; Ganea & Harris, 2013; Ganea & Saylor, 2013).

1.1.2. Language-mediated Property Updating. Infants' successes in updating their representation of an absent object's properties (e.g., getting wet, changing color) rather than its location support arguments that they can use language to make simple updates before their second birthday. When 22-month-olds hear that someone spilled water on a toy after they left the room, they subsequently identify the wet toy rather than a dry exemplar more often than expected by chance (Ganea et al., 2007). After the current study began, additional studies similarly showed that infants aged 21 months and older update their knowledge after hearing that an absent object was painted a different color (Galazka & Ganea, 2014; Özdemir & Ganea, 2020). These are straightforward updates, given that infants' attention was not specifically drawn to the initial property (being dry, being a particular color) when they first interacted with the object. Infants thus did not need to resolve a conflict between a property that was specifically encoded beforehand with a new property that contradicts it, such as the object was dry but now it is wet (Ganea & Harris, 2010, 2013). Infants younger than 21 months, however, do not make these simple updates as easily. Nineteen-month-olds fail to update their representation after hearing about a new property unless their representation of the object is relatively strong or they receive a visual reminder of the object during its absence (Galazka & Ganea, 2014; Ganea et al., 2007). Developmental improvements in the strength of infants' representations of absent objects likely contribute to their ability to update object representations based on language.

Moreover, when infants aged 21 to 35 months hear about both a property change and a location change in a within-participants design, they update the property change more accurately than the location change (Özdemir & Ganea, 2020). This finding is consistent with arguments that language-mediated updates that require overwriting information in the representation are more challenging at this age than those that simply require adding information (Ganea & Harris, 2010, 2013). Developmental improvements in infants' ability to reconcile conflicting information thus contribute to their ability to update object representations based on language. Collectively, this set of studies shows that infants both begin to understand the symbolic function of words before their second birthday, and continue to improve in their ability to use language to carry out more challenging updates to their representations of absent objects in the months that follow.

1.2. Updating Mental Representations of Objects via Video

When do infants begin to understand the symbolic function of video? They can learn some things from video in the first 2 years of life. For example, 6- to 24-month-olds imitate novel actions with unfamiliar objects after watching an adult model them in a video (Barr et al., 2007; McCall et al., 1977; Meltzoff, 1988; Schmitt & Anderson, 2002; Strouse & Troseth, 2008). In addition, 8- to 24-month-olds learn new words for unfamiliar objects from video, including videos adapted from commercially produced programs such as Teletubbies and Baby Einstein (Krcmar et al., 2007; Vandewater, 2011; Vandewater et al., 2010). However, learning a novel action or word from video is simpler than updating a representation of an absent object using video. Although it shows that infants can process information about an unfamiliar object depicted in a video and act on that information when they encounter the real object, it involves creating a new representation where none existed before, rather than updating an existing representation of an object while it is absent. A recent meta-analysis confirmed that young children's learning from video is better in the learning domains of action imitation and word learning than in the learning domain of object search, which requires memory updating (Strouse & Samson, 2021).

Using video to update a representation depends upon some of the same cognitive processes as using language to do so. It requires activating a mental representation of the absent object upon seeing it on the screen, processing new visual information about it, and incorporating the new information into the existing representation (DeLoache & Ganea, 2009; Ganea & Harris, 2013). However, updating a representation from video has an important additional cognitive demand. Unlike a word, a video is a symbolic object that has a dual nature. It is both a visible thing itself and a symbol of something else (DeLoache, 1987), in this case a real event. Achieving a dual representation of a symbolic object is difficult early in development

(DeLoache, 1987, 2004). To update their knowledge about an absent object using information from video, infants need to see past the video's concrete nature and mentally represent the symbolic relation between the event they see in the video and the real event (Troseth & DeLoache, 1998). They also need to understand to direct their actions not to the object on the screen, but to the real object (Troseth, 2010). Infants' capacity for these processes is apparent by their second birthday under some circumstances, as demonstrated in object retrieval tasks.

1.2.1. Video-mediated Location Updating. When 24- and 30-month-olds see on video that an adult in the next room has moved a toy from an old hiding location to a new one, they subsequently search the correct location more often than expected by chance (Troseth, 2003a, 2003b; Troseth & DeLoache, 1998). However, when they receive several repeated trials of the adult on video hiding the toy in a different location each time, 24-month-olds' search accuracy subsequently deteriorates relative to that of 30- and 36-month-olds (Schmitt & Anderson, 2002; Suddendorf, 2003). Twenty-four-month-olds tend to search accurately on the first trial (location A), but perseveratively on subsequent trials (locations B, C, and D; Schmitt & Anderson, 2002; Suddendorf, 2003). Video-mediated updating, like language-mediated updating, appears more challenging earlier in development when it requires overwriting the representation because new information conflicts with old (e.g., the toy was hidden at A but now is hidden at B; Ganea & Harris, 2010). However, when the video-mediated updating allows a simple, straightforward addition to the representation (i.e., the toy has been hidden at A), 24-month-olds update successfully.

As is the case with language-mediated updating at 23 months (Ganea & Harris, 2010, 2013), 24-month-olds' difficulty in using video information to update an absent object's location is not simply due to poor working memory, because they search more accurately if they witness the location change directly than if they see it on video (Deocampo & Hudson, 2005; Schmitt & Anderson, 2002; Troseth, 2003a; Troseth & DeLoache, 1998). This difference exemplifies the video deficit (Anderson & Pempek, 2005), in which infants learn better when observing an event firsthand than when observing it on video (for reviews, see Barr, 2010; Troseth, 2010). Twenty-four-month-olds also search more accurately if they believe they are witnessing the object's displacement directly through a window into the next room, even though they are actually looking at a video screen through the window (Troseth & DeLoache, 1998). The need to achieve dual representation with a video (i.e., understanding both its concrete and symbolic nature) thus interferes with infants' processing of the new information, although not enough for their performance to fall to chance levels (Troseth & DeLoache, 1998). However, the video deficit in this task decreases by age 30 months and disappears by 36 months (Schmitt & Anderson, 2002; Troseth & DeLoache, 1998). This pattern suggests that representations updated with video input, like those updated with verbal input, are weaker than those updated with firsthand experience at 24 months but gradually strengthen with age until they are equivalently robust. A recent meta-analysis likewise shows that video-mediated learning improves dramatically for many tasks from age 0 to 36 months and less so after 36 months (Strouse & Samson, 2021). Twenty-four-month-olds also search inaccurately if an adult tells them on video where to find the toy but accurately if the same adult tells them in person (Schmidt et al., 2007; Troseth et al., 2006), suggesting that the double mediation of updating both by language and on video is more cognitively effortful than the single demand of updating by language alone.

1.2.2. Video-mediated Property Updating. Infants' use of video to update a property change has apparently been studied only with the rouge or mark test of self-recognition in which the change occurs surreptitiously on the infant's own body (Povinelli et al., 1996). Unlike 30-

and 36-month-olds, 24-month-olds fail to reach for the mark on their head or foot upon seeing themselves live on video, but succeed in doing so upon seeing themselves in a mirror (Suddendorf et al., 2007). This pattern suggests that infants may struggle to use video to update a representation with a property change by their second birthday. However, updating a representation of the self with a property change that occurred covertly off-screen is likely more cognitively demanding than updating a representation of an absent object with a property change that occurred overtly on-screen. It is unknown whether infants might be capable of the latter by 24 months. The contribution of the current study is therefore to explore whether they can.

1.3. The Current Study

By 24 months, infants can thus use video to update an object's location change (e.g., Troseth & DeLoache, 1998) and by 22 months they can use language to update a property change (Ganea et al., 2007). Can infants as young as 22 months use video to update an object's property change? On the one hand, video-mediated updating appears more demanding than language-mediated updating (DeLoache & Ganea, 2009). On the other hand, property-change updates that require the simple addition of new information may be easier to process than location-change updates that require deleting and replacing information (Ganea & Harris, 2010). The aim of the current study is thus to explore whether 22-month-olds can use video to update their knowledge about an absent object that underwent a property change, following work by Ganea et al. (2007) on infants' use of language to update such knowledge. The current study included 22-month-olds but not 19-month-olds, because Ganea et al. (2007) found that 22-month-olds used language to update their representation whereas 19-month-olds failed to do so, even after the task was simplified.

In the current study, 22-month-olds were introduced to three toys (e.g., two identical pigs and one frog) and taught that one of the identical toys was named Lucy (the *target*). The *distractor* was described by what kind of animal it was (e.g., the froggy), and the *non-target* identical toy (e.g., the other pig) was described as Lucy's friend. Infants then left the toys behind and went into another room to read a storybook with the researcher. During the story, a different adult came into the room with a laptop, announced that something bad had happened to Lucy, and showed infants a video of herself in the other room accidentally spilling coffee on the toys and staining Lucy. Infants were then invited to go see what had happened to Lucy in the first room, where the three toys were displayed. Both the target (Lucy) and distractor were now stained, whereas the non-target was unstained. Infants were asked to point out which toy was Lucy.

If infants updated their representation of Lucy based on what they saw in the video, then they should choose the stained target and ignore the other two toys. If infants did not update their representation but did remember which kind of animal Lucy was, then they should either choose the unstained non-target because it looked most similar to what they had seen before or choose randomly between the unstained non-target and the stained target. Finally, if infants simply found stained toys novel, then they should choose randomly between the stained target and the stained distractor.

2. Method

2.1. Participants

The final sample included 16 typically-developing British infants (M = 22.29 months, SD = .26), with 8 girls and 8 boys. Another 11 infants were excluded. One was excluded because of fussiness, one because of parental interference, two because of experimenter error, two because they did not identify the target during the familiarization phase (described in section 2.2.1), and five because they did not clearly choose one object during the test phase (described in section 2.2.3). Infants were recruited from a database of families in the southeastern United Kingdom who had registered their interest in research participation. Their race was 94% White and 6% more than one race. Most infants came from homes with above-average education. Eighty-two percent had at least one parent with a university degree. Parents gave informed consent for their infant to participate. The study received ethical approval from the Department of Psychology Ethics Committee at Royal Holloway, University of London and conformed to the ethical standards of the Declaration of Helsinki. Data were collected from November 2010 through January 2011.

2.2. Materials and Procedure

The objects included two sets of three stuffed animals: two identical green frogs and one pink pig, or two identical pink pigs and one green frog. Additional materials included a plastic crate to contain the toys, a story book, a cup of coffee, a black shawl worn by the assistant, the video depicting the assistant spilling coffee on the toys, and three aluminum trays to display the three toys after the spillage. The procedure consisted of three phases, following Ganea et al. (2007).

2.2.1. Familiarization. The goal of the familiarization phase was to teach infants the proper name of one of the three toys (Lucy) and provide them with equal exposure to the target toy and the distractor toy. The named toy, Lucy, was always one of the two identical toys. For half of the infants, this was a pig and for the other half it was a frog. The researcher first showed the infant a crate on the table which contained the three toys. She then removed the *target* toy (e.g., one of the two pigs) and said, “This is Lucy.” Next she removed the identical *non-target* toy (e.g., the other pig) and said, “This is Lucy’s friend. Lucy’s friend is going to sit over here and watch us play.” She placed this toy on top of a set of drawers where the infant could see it but not reach it. Finally, the researcher removed the *distractor* toy (e.g., the frog) from the crate and talked about it without naming it (e.g., “Look at the froggy! It’s a nice froggy.”) The researcher engaged the infant in playing with both the target toy and the distractor toy (e.g., playing peekaboo, comparing their body parts), spending equal amounts of time drawing the infant’s attention to each toy. The infant thus was thus equally familiarized with the target (e.g., Lucy the pig) and the distractor (e.g., frog), while the non-target (e.g., pig) remained in sight but out of reach.

The researcher then checked whether the infant had learned which toy was named Lucy by placing the target and distractor side by side in the middle of the table and asking, “Which one is Lucy? Show me Lucy.” If the infant chose correctly, the researcher gave positive feedback (e.g., “Yes, you’re right! This one is Lucy.”) If the infant chose incorrectly, the researcher gave contrastive feedback (e.g., “Nope, not that one. This one is Lucy. That one is the froggy.”) The infant had to identify Lucy correctly twice during this familiarization phase. The researcher thus engaged the infant in playing with the two toys for another minute before asking the infant again which one was Lucy and providing feedback. If the infant succeeded on the first two attempts, then the researcher moved on to the next phase. Otherwise, the researcher alternated between engaging the infant in playing with the two toys for a minute and checking if the infant could identify which one was Lucy. Infants were corrected from 0 to 4 times ($M = 1.33$, $SD = 1.45$). Those who did not meet the familiarization criterion continued to the next phase, but their data were excluded (see section 2.1). Familiarization ended with the researcher putting the three toys back in the crate, saying that they were tired and needed a nap. The researcher then took the infant into the room next door to read a story. The familiarization phase lasted approximately 8 minutes.

2.2.2. Attribution of new information. The goal of this phase was to give infants new information about the target toy. While the researcher was reading a story to the infant, a female assistant wearing a black shawl entered the room, holding a cup of coffee. She announced that she was going to drink her coffee in the room next door (where the toys had been left in the crate). To ensure that the infant noticed the coffee, she invited the infant to smell the coffee inside the cup. She then repeated that she was going to drink her coffee next door, went into the other room, and closed the door. After 2 minutes elapsed, the assistant returned carrying a laptop and exclaimed, "I'm so sorry! I was drinking my coffee next door, and something terrible happened to Lucy! Let me show you what happened." The assistant then played the video on the laptop.

The video depicted the assistant in the black shawl sitting in the next room in a chair to the left of the table where the crate of toys had been positioned. Her right arm was draped over the crate, with the coffee cup in her right hand, while she held a piece of paper in her left hand. After looking at the piece of paper for several seconds, the assistant appeared to sneeze and spill coffee onto the toys in the crate below (Figure 1). Immediately after sneezing, the assistant displayed a look of surprise at this accident, with an open mouth and wide eyes. The video then cut to a still shot of the three toys in the crate. The toy on the left and the toy in the middle of the crate were clearly stained, whereas the toy on right was unstained (Figure 1). The stained toy on the left was the target (i.e., Lucy), the stained toy in the middle was the distractor (e.g., the frog), and the unstained toy on the right was the non-target (e.g., the other pig). The video lasted 19 s.

Figure 1. Scene from the video of the assistant apparently sneezing and spilling coffee onto the crate of toys (left) followed by a still shot of the stained toys inside the crate (right).

The researcher ensured that the infant attended to the moment that the assistant spilled coffee on the crate of toys by pointing at the video and saying, “Oh no, do you see that? Do you see what happened to Lucy?” The researcher then asked the infant, “Do you want to go see Lucy? Let’s go see Lucy.” The researcher and infant left the room while the assistant remained behind and closed the door.

2.2.3. Test phase. The purpose of this phase was to test whether infants could identify the target toy as the one that had undergone the change they saw in the video. The researcher brought the infant next door where the toys were. The three toys were displayed on three trays on top of the table. The target (Lucy) was now stained brown with coffee. The non-target (e.g., the other pig) was unstained. The distractor (e.g., the frog) was also stained brown with coffee to control for the possibility that infants might select the stained target toy simply because a stained toy looks more interesting than an unstained one. The toys’ locations were counterbalanced. The stained distractor was always in the center. For half of the infants, the stained target was on the left and the unstained non-target was on the right. For the other half, the stained target was on the right and the unstained non-target was on the left. The researcher positioned the child in front of the table and said, “Which one is Lucy? Show me Lucy.”

Figure 2. Infant choosing the stained target toy during the test phase. The stained distractor is in the center and the unstained target is on the left.

2.3. Coding

Videos of the test phase were coded for which toy the infant chose. The infant had to deliberately point to a toy or pick it up and show/give it to the researcher in order to be judged as making an intentional choice (Figure 2). If the infant merely touched or explored a toy without deliberately indicating it to the researcher, then the researcher asked again, "Which one is Lucy? Show me Lucy." If the infant chose two toys, then the researcher asked the infant to indicate which one was Lucy. One person coded all the videos, and another person who was blind to the study hypotheses coded 75% of the videos. Inter-observer agreement was established with a Cohen's kappa value of 1.00, $p < .001$.

3. Results and Discussion

Infants did not select the correct toy more often than expected by chance (33%), χ^2 (2, n = 16) = 2.38, $p = .305$. Eight infants (50%) correctly chose the stained target, five (31%) chose the unstained non-target, and three (19%) chose the stained distractor (Figure 3). Infants in the current study thus showed no evidence of updating their representation of the absent target object on the basis of the event shown in the video, unlike infants in an analogous verbal updating task reported by Ganea et al. (2007). Infants did, however, remember which kind of animal Lucy was (i.e., pig or frog). They chose one of the two identical animals more often than expected by chance (50%). Thirteen infants (81%) chose either the target or identical non-target animal rather than the distractor animal, binomial test $p = .021$. This finding matches that found by Ganea et al. (2007). They reported that 95% of 22-month-olds and 95% of 19-month-olds chose either the target or identical non-target, which shows that both age groups remembered which category of animal Lucy was. Thus, 22-month-olds showed no evidence of updating their representation of an absent object's properties, despite showing an enduring memory for which category the object belonged to, and despite other work showing they succeed in using language to update such representations.

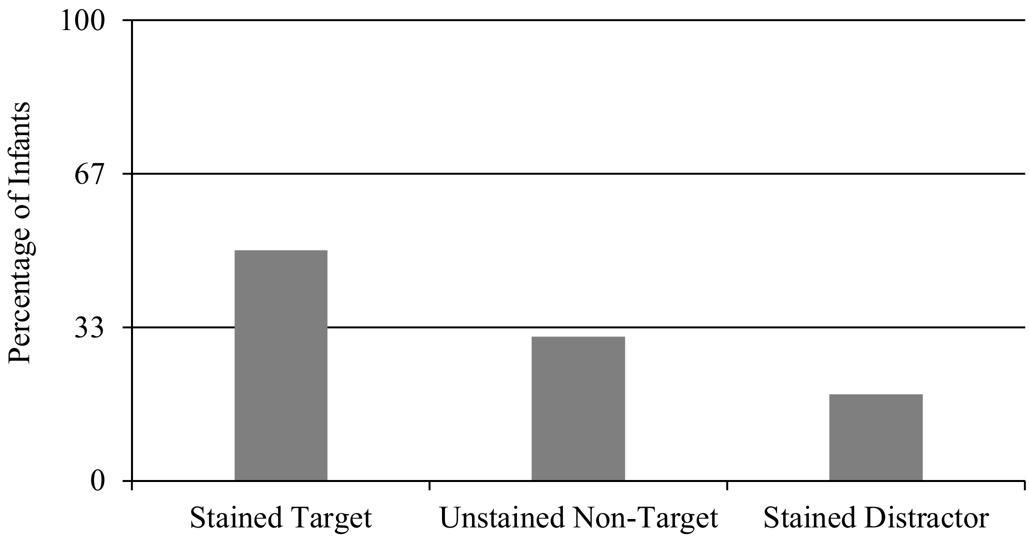

Figure 3. Percentage of infants who chose each of the three objects during the test phase. Responses did not differ significantly from chance (33%).

Using video to update a representation of an absent object appears more demanding than using language to do so, as 22-month-olds show no evidence of updating in the former case (the current study) but succeed in updating in the latter case (Ganea et al., 2007). This pattern is consistent with the video deficit in which children in the first 3 years of life learn less effectively from symbolic objects such as videos than from equivalent real-life experience (Anderson & Pempek, 2005). Many studies show that infants either fail to learn from video (e.g., DeLoache et al., 2010; Krcmar, 2011) or learn less from video than from equivalent real-life experience (e.g., Barr & Hayne, 1999; Deocampo & Hudson, 2005; Krcmar et al., 2007).

3.1. Dual Representation

One reason that infants apparently succeed in learning from indirect experience via video later than they do via language is that the representational function of symbolic objects is less obvious than the representational function of language (Ganea et al., 2007). A symbolic artifact such as a video has a dual nature. It is a concrete thing itself and a symbol of something else (DeLoache, 1987). Infants struggle to hold two things in mind at once, and it is easier to respond to a symbolic object's concrete nature than to see past it and respond to its symbolic function (for reviews, see DeLoache, 2004, 2011). Language lacks this dual nature. It is solely symbolic. Infants thus appear to detect its representational function earlier in development (Ganea et al., 2007). Infants do not initially appear to regard video as a representation of reality (Troseth, 2010). This is perhaps not surprising if much of their experience with video has been with fictional or animated programs rather than content that reflects real events, let alone ongoing current reality in the next room (Troseth, 2010). Eventually children understand that videos can symbolize real events that they have not directly perceived. Until they acquire this understanding, it would seem difficult for them to use a video as a source of information about a real-world event.

3.2. Representation Strength

Another reason that infants in the current study might not have updated their knowledge is that their representation of the target was too weak for the demands of this task because their degree of exposure to it was relatively low. In several of the studies showing that infants succeed in learning new information from language or from video, infants had repeated exposure to the target object, which likely strengthened their representation of it. For example, 19-month-olds used language to update their knowledge about an absent object having been painted a different color if they were first familiarized with the object 12 times (high-exposure condition) but not 6 times (low-exposure condition), whereas 24-month-olds succeeded in both conditions (Galazka & Ganea, 2014). Eighteen-month-olds in a low-exposure condition succeeded in updating if they were shown a photo reminder of the toy shortly before they were told of the property change

(Galazka & Ganea, 2014). Özdemir and Ganea (2020) later replicated 2-year-olds' success in the low-exposure condition with a sample of infants aged 21 to 35 months, who chose the target more often than expected by chance. Galazka and Ganea (2014) reasoned that 19-month-olds in their low-exposure condition and in the two experiments by Ganea et al. (2007) failed to update their representation of the absent object because their initial representation of the object was too weak for the demands of this task. Younger infants need more experience with an object to construct a representation of the same strength as that of older infants (Munakata et al., 1997). Eighteen- to 19-month-olds needed more exposure to the object to construct a representation as strong as that of older 22- to 24-month-olds, or a brief photo reminder to reactivate their representation, before they successfully used language to update that representation (Galazka & Ganea, 2014).

Action imitation studies similarly show that increasing the number of video repetitions can reduce the video deficit in 6- to 24-month-olds, whereas shortening the video's duration increases this deficit (Barr et al., 2007; Strouse & Troseth, 2008). Similarly, word learning studies show that 17- to 24-month-olds learn new words from a DVD viewed repeatedly at home for 2 weeks (Krcmar, 2014), and 8- to 15-month-olds can do so after 4 weeks (Vandewater, 2011). Repeated viewing may allow better encoding of information. Recent evidence shows that infants' visual attention to the target information in a video improves their ability to update their knowledge (Kirkorian et al., 2016). Infants in the current study might have succeeded if they had more exposure to Lucy beforehand, received a brief visual reminder of Lucy immediately before seeing the video, or saw the video more than once. This might have enhanced their encoding, maintenance, or retrieval of information (Barr, 2010, 2013).

3.3. Social Contingency

Finally, infants in the current study may also have struggled to update their knowledge due to the video's lack of social contingency. By 22 months, infants likely have enough experience with video that does not reflect reality to learn that people's behavior on screen lacks contingency with their own behavior (Troseth, 2010). This may hinder them from using video as a source of information when it does reflect reality. Familiarity with the person on the screen may help them relate video to reality. In action imitation studies, 13- to 24-month-olds imitate their mother on screen more than a stranger (Krcmar, 2010), and 21-month-olds imitate a familiar media character more than an unfamiliar one (Lauricella et al., 2011). Even 5 m of interaction with the researcher who later appears on screen is sufficient for 24-month-olds to use video to update an object's location (Troseth et al., 2006). Adding cues to pre-recorded video may also help infants relate video to reality. For example, having the model gaze at the viewer and use interactive language reduced the video deficit for 15- and 18-month-olds in an imitation task (Lauricella et al., 2016). Co-viewers can also scaffold infants' learning from video by enhancing social contingency. For example, word learning studies show that 24- to 30-month-olds learned the name of a novel object shown on video if their parent or another responsive co-viewer modelled appropriate responses to the video model's interactive cues or highlighted the similarity with the real object (Myers et al., 2018; Strouse & Troseth, 2014; Strouse et al., 2018). Infants in the current study may have struggled to relate the video to reality because the task lacked these social contingencies. They might have succeeded if they had received more familiarization beforehand with the assistant who spilled her coffee in the video, if the assistant had used interactive cues in the video, or if they had received scaffolding while viewing the video.

Experience with live video may also help infants detect when people's behavior on screen is socially contingent with their own behavior and thus reflects current reality (Troseth, 2003a). Before video chat became more commonplace, training studies showed that greater experience with live video helped infants successfully update an absent object's location, and that younger infants needed more experience than older infants did. For example, several training trials with live video in the lab helped 30-month-olds but not 24-month-olds use video to update an object's location (Troseth, 2003a). However, 2 weeks of training with live video at home helped 24-month-olds later use video successfully to update an object's location in the lab (Troseth, 2003b). More recent evidence shows that just 3 m of training with live video chat reduced the video deficit for 24- to 30-month-olds in a word learning task (Roseberry et al., 2014). Infants have more video chat experience now, especially since the Covid-19 pandemic, than when the data in the current study were collected (2010-2011). On the one hand, it is thus possible that infants today may succeed more at using video to update representations if they have greater experience with the social contingencies in live video that help them relate video to current reality. On the other hand, infants today are still likely to have less exposure to video that is live and socially contingent than to video that is not (e.g., cartoons), and 22-month-olds are less likely than older infants to understand when video symbolizes current reality and when it does not (Troseth, 2003a). It is thus possible that difficulties in using video to update representations of absent objects may extend into the preschool years (Troseth, 2003b).

3.4. Future Directions

In addition to improving upon the current study by adding manipulations of representation strength and social contingency like those suggested above, another recommendation for future studies is to compare language-mediated vs. video-mediated updating of an absent object's properties within participants, to assess whether one is easier than the other. One study has compared language- vs. video-mediated updating of an absent object's location in older children (3- and 4-year-olds) and found no difference (Zelazo et al., 1999). However, both language- and video-mediated updating improve with age (DeLoache & Burns, 1994; Ganea & Harris, 2010, 2013; Schmitt & Anderson, 2002; Suddendorf, 2003; Troseth & DeLoache, 1998) and children's understanding of the symbolic function of video is argued to lag behind that of the symbolic function of language earlier in development, before age 3 (Schmidt et al., 2007; Troseth et al., 2006). It is thus important to compare the two tasks in younger children. Another study used a within-participants design to compare 2-year-olds' language-mediated updating of an object's location change vs. language-mediated updating of a property change and found that property change appears to be easier to process (Özdemir & Ganea, 2020). Finally, other work shows that the video deficit, in which children's video-mediated learning lags behind their learning by direct observation, is smaller when tested within rather than between participants (Strouse & Samson, 2021). Within-participants designs may thus be more sensitive to the variability of infants' behavior across tasks. A related suggestion is to test video-mediated updating of property changes with age groups beyond 22 months, to trace its development.

Another important line of work for the future is to disentangle the several cognitive processes tapped by video-mediated updating of knowledge. In both the current study and previous video-updating studies (Schmidt et al., 2007; Schmitt & Anderson, 2002; Suddendorf, 2003; Troseth, 2003a, 2003b; Troseth & DeLoache, 1998; Troseth et al., 2006), infants' success at updating is determined by identifying or locating the real object in the final test phase. Choosing accurately shows that infants succeeded at each process: activating the representation of the object upon seeing it on the screen, processing new information about it, relating the information on screen to reality, incorporating the new information into the existing representation, and then acting on the updated representation. However, choosing inaccurately, like 22-month-olds in the current study did and many 24-month-olds in location-change studies have (Deocampo & Hudson, 2005; Schmitt & Anderson, 2002; Suddendorf, 2003; Troseth, 2003a; Troseth & DeLoache, 1998) could be due to failing any one of these processes. Infants might succeed as far as incorporating the new information but then fail to maintain the updated representation well enough to act on it due to poor working memory and fall back on their outdated representation of the object. Improved designs could disentangle the contributions of each of these processes. For example, once infants have seen the new information in the video, asking them to identify the toy on the screen before they identify the real toy would establish whether infants who failed to identify the real toy had in fact updated their representation.

Finally, future research might focus on individual differences in infants' ability to update from video. Although infants' responses in the current study did not exceed chance performance (33%) at the group level, 50% of them did correctly choose the target. These individuals may thus have genuinely succeeded in updating their representation. Individual differences that were not measured in the current study might account for the variability in responses. For example, the individuals who chose the target may have had more experience with live video, or less experience with video that is not live, than the individuals who did not choose the target. Other candidates for individual differences include the cognitive processes tapped by updating. Individuals who succeeded may have had greater working memory capacity for encoding, maintaining, or retrieving information about the target object. They may also have had stronger ability to transform the contents of the representation by adding new information. Research on the component processes of working memory updating with adults shows that transformation of memory contents had the biggest effect on updating performance, and may reflect individual differences in information processing speed (Ecker et al., 2010). The significant variability demonstrated in performance of infants in recent related research (Özdemir & Ganea, 2020; Strouse & Samson, 2021) suggests the need to explore individual difference variables in the future, with larger and more representative samples.

3.5. Limitations

In addition to the current study's limitation of collecting the data before video chat became commonplace, it is also restricted in its sampling. First, a sample size of 16 is not large. It is possible that an effect would be detectable with a bigger sample. However, null effects in analogous tasks with infants aged 22 to 36 months have been published with samples of 20 to 60 infants, providing support for the absence of a meaningful effect even when sample sizes are larger and infants are older (Deocampo & Hudson, 2005; Krcmar, 2011; Myers et al., 2018; Özdemir & Ganea, 2020; Schmidt et al., 2007; Strouse & Troseth, 2014; Strouse et al., 2018; Troseth et al., 2018). Conversely, significant effects in analogous tasks with infants aged 6 to 24 months have been published with samples of 8 to 14 infants, suggesting that meaningful effects can be detected with smaller sample sizes even in younger infants (Barr & Hayne, 1999; Barr et al., 2007; Ganea & Harris, 2013; Schmitt & Anderson, 2002; Suddendorf, 2003; Troseth, 2003b; Troseth & DeLoache, 1998; Troseth et al., 2006). A sample of 16 thus appears to have enough power to detect when 22-month-olds' behavior in tasks like these differs from chance. However, given the replication crisis in psychology generally and developmental psychology particularly, studies like the current one should be replicated.

Second, the current study's participants are nearly all white, and like all of the studies cited thus far, from a population that is western, educated, industrialized, rich, and democratic (i.e., WEIRD; Henrich et al., 2010). Most of the studies cited here were conducted in the US (e.g., Barr et al., 2007; Ganea et al., 2007; Krcmar, 2011; Troseth & DeLoache, 1998), with a few in Canada, Australia, and New Zealand (e.g., Barr & Hayne, 1999; Özdemir & Ganea, 2020; Suddendorf, 2003). Although the current study appears to be the first conducted in the UK, its sampling is nonetheless narrow, thus its generalizability may be limited. Infants' previous experience with symbolic media is known to predict their ability to learn from video (Troseth et al., 2007) and the few cross-cultural studies that have been conducted show that infants in less media-rich societies such as rural Peru, India, Ivory Coast, and Tanzania understand the representational function of pictorial symbols later in development (Callaghan et al., 2011; Deloache et al., 1998; Walker et al., 2013). The developmental trajectory of understanding symbolic media is thus one aspect of cognitive development that may not be universal.

3.6. Conclusions

The current study showed that 22-month-olds did not use video to update their mental representation of an absent object, unlike infants of a similar age in comparable studies who succeed in using language to do so (Galazka & Ganea, 2014; Ganea et al., 2007; Özdemir & Ganea, 2020). This pattern suggests that before their second birthday, infants may find it harder to learn from video-mediated experience than from language-mediated experience. It is consistent with arguments that the understanding of the representational function of language develops earlier than that of symbolic artifacts such as video (Ganea et al., 2007). It is also consistent with the video deficit (Anderson & Pempek, 2005) in which children under 3 learn less from video than from equivalent real-life experience, particularly if exposure to the target object and video is not prolonged (e.g., Barr et al., 2007), and the social relevance of the context not emphasized (e.g., Troseth et al., 2006).

In addition to future studies on the replicability and generalizability of findings like these, future work will undoubtedly continue pursuing questions about infants' learning from newer, interactive digital media such as video chat (e.g., Roseberry et al., 2014), which is the only form of screen time sanctioned for infants less than 24 months old (Hill et al., 2016), and touchscreen apps (Kirkorian, 2018). One important question is whether the educational claims of many preschool apps are warranted if children under 3 struggle to relate on-screen lessons to reality. Another question is whether augmented reality and virtual reality affect infants' understanding of actual reality. Screen media form a powerful platform for learning indirectly about the real world and will only become more interactive and more prevalent around the globe in the future.

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