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How to cite this publication

Please cite the final published version:

Hayne, H., Jaeger, K., Sonne, T., & Gross, J. (2016). Visual attention to meaningful stimuli by 1- to 3-year olds: implications for the measurement of memory. *Developmental Psychobiology*, 58, 808–816.

doi:[10.1002/dev.21455](https://doi.org/10.1002/dev.21455)

Publication metadata

Title:	Visual attention to meaningful stimuli by 1- to 3-year olds: implications for the measurement of memory
Author(s):	Hayne, H., Jaeger, K., Sonne, T., & Gross, J.
Journal:	Developmental Psychobiology
DOI/Link:	10.1002/dev.21455
Document version:	Accepted manuscript (post-print)

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Visual Attention to Meaningful Stimuli by 1- to 3-Year-Olds: Implications for the Measurement of Memory

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The research was funded by Marsden grants (09-UOO-074, 15-UOO-061) from the Royal Society of New Zealand to HH and JG. TS was supported by a grant from the Danish National Research Foundation (DNRF93).

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Abstract

The visual recognition memory (VRM) paradigm has been widely used to measure memory during infancy and early childhood; it has also been used to study memory in human and nonhuman adults. Typically, participants are familiarized with stimuli that have no special significance to them. Under these conditions, greater attention to the novel stimulus during the test (i.e., novelty preference) is used as the primary index of memory. Here, we took a novel approach to the VRM paradigm and tested 1-, 2-, and 3-year-olds using photos of meaningful stimuli that were drawn from the participants' own environment (e.g., photos of their mother, father, siblings, house). We also compared their performance to that of participants of the same age who were tested in an explicit pointing version of the VRM task. Two- and 3-year-olds exhibited a strong familiarity preference for some, but not all, of the meaningful stimuli; 1-year-olds did not. At no age did participants exhibit the kind of novelty preference that is commonly used to define memory in the VRM task. Furthermore, when compared to pointing, looking measures provided a rough approximation of recognition memory, but in some instances, the looking measure underestimated retention. The use of meaningful stimuli raise important questions about the way in which visual attention is interpreted in the VRM paradigm, and may provide new opportunities to measure memory during infancy and early childhood.

The common challenge faced by many developmental psychobiologists is to establish experimental methods that allow us to infer complex psychological processes on the basis of nonverbal behavior. For all of her professional career, Carolyn Rovee-Collier boldly faced this challenge; she established a range of new and innovative methods that have helped to document the development of learning and memory during human infancy (for reviews, see Rovee-Collier, 1999; Rovee-Collier & Cuevas, 2009; Rovee-Collier & Gerhardstein, 1997). Her work using the mobile conjugate reinforcement and operant train paradigms pushed the boundaries of what was known about infant learning and memory, and many of her conclusions flew in the face of our extant understanding of early development.

When Carolyn first began publishing her work using operant measures of learning (Rovee & Rovee, 1969) and memory (Rovee & Fagen, 1976), the Visual Recognition Memory (VRM) paradigm dominated the field. In the VRM task, infants are familiarized with a visual stimulus (or stimuli) for a defined period or until their looking time to that stimulus decreases to a predetermined level. The familiarization stimulus is then paired with a novel stimulus and the distribution of looking to both stimuli is measured during the test, which typically occurs immediately or shortly after the end of the familiarization period (e.g., Fantz, 1964; Olson, 1976; Olson & Sherman, 1983; Rose, 1981; Werner & Perlmuter, 1979).

The VRM paradigm that is used with infants capitalizes on the orienting response, an automatic reaction to novel stimuli that was originally described by Pavlov (1927). He referred to the orienting response as the “what-is-it” reaction. For Pavlov, the orienting response was often a behavioral nuisance. When visiting academics would visit to see what he was up to in his laboratory, his dogs were often distracted by the novelty of the visitors in the room, turning their attention to them and failing to exhibit the appropriate conditioned response (see Bradley, 2009).

Traditionally, infants' performance in the VRM paradigm has been interpreted in the context of Sokolov's (1963) comparator theory of the orienting response. According to Sokolov, the presentation of a novel stimulus elicits an orienting response, which consists of a range of physiological and behavioral reactions, including directed, visual attention (for review, see Campbell, Hayne, & Richardson, 1992). When this occurs, the brain begins to create an internal model (i.e., a representation) of the stimulus. If the brain receives the same input multiple times, the internal model becomes stronger and more complete. As this happens, the orienting response to that particular stimulus declines, and the organism's attentional resources are diverted elsewhere. Sokolov's comparator model was not unique to humans; in fact, it was originally established with multiple species in mind.

When Sokolov's model is applied to infants' behavior in the VRM paradigm, memory is inferred when the infant exhibits greater attention to the novel stimulus relative to the familiar one during the test. Based on Sokolov's theory, because the internal representation of the familiarization stimulus is presumably still intact, its presentation no longer elicits an orienting response, and the infant's attention is deployed to the novel stimulus that the familiarization stimulus is paired with it. It is assumed that as long as the infant maintains an adequate representation of the familiar stimulus, he or she will pay more attention to the novel member of the stimulus pair. As forgetting

occurs, exposure to the previously familiar stimulus will once again elicit an orienting response, resulting in equivalent looking to the familiar and novel stimuli (i.e., null preference; Cornell, 1979; Fagan, 1973, 1974; Pancrantz & Cohen, 1970). Although the VRM paradigm was originally developed for use with human infants, it has subsequently been adapted for use with toddlers and young children (Imuta, Scarf, & Hayne, 2013; Morgan & Hayne, 2006a, 2006b, 2007, 2011), as well as with human (McKee & Squire, 1993; Pascalis & Bachevalier, 1998; Richmond, Colombo, & Hayne, 2007) and animal adults (Pascalis & Bachevalier, 1998, 1999).

The VRM paradigm and the conclusions it offered always puzzled Carolyn Rovee-Collier (Rovee-Collier & Cuevas, 2009; Rovee-Collier & Gerhardstein, 1997; Rovee-Collier & Hayne 1987). The estimates of the duration of infant retention that were based on novelty detection paled in comparison to estimates that were based on her operant conditioning procedures. With few exceptions (Fagan, 1973; Pascalis, De Haan, Nelson, & de Schonen, 1998), researchers using the VRM task found that retention by infants less than 6 months of age persisted for seconds or minutes at best (Diamond, 1995; Fagan, 1973; Olson, 1976; Pancrantz & Cohen, 1970; Slater, Morrison, & Rose, 1983; Strauss, 1981), while infants of the same age exhibited retention for days or weeks when tested in the mobile conjugate reinforcement and train paradigms (for review, see Hartshorn, Rovee-Collier, et al., 1998).

One potential reason that the VRM and operant conditioning paradigms yield such different estimates of infant memory is that in the VRM paradigm, infants are commonly tested with meaningless stimuli that hold no significance for them (e.g., a photograph of a stranger or a chair). In the mobile conjugate reinforcement and train paradigms, on the other hand, infants learn to produce a response that yields a significant outcome. Over the course of the training sessions, the mobile or the train acquires meaning in the context of the task, undoubtedly prolonging the infants' memory for these stimuli. In contrast, the very nature of the VRM task teaches infants that the initially novel familiarization stimulus is irrelevant, while the operant tasks teach infants that the training stimulus is important. Considered in this way, testing infants with novel stimuli is likely to engage defensive motivational systems, while testing infants with meaningful stimuli is likely to engage appetitive motivational systems (cf. Bradley, 2009). Given this fundamental difference, it is hardly surprising that one set of tasks yields substantially longer estimates of retention than the other.

But what would happen in the VRM paradigm if infants were tested with stimuli that were meaningful in some way—stimuli that infants might remember and be motivated to attend to? In most studies, the familiarization stimuli are novel to the infant prior to the experimental procedure and the familiarization phase is used to establish a memory representation. In a handful of studies, however, researchers have used the VRM paradigm to measure infants' attention to stimuli that they have encountered in the course of their daily interaction with the world; in these studies, infants' memory for meaningful stimuli is assessed on the basis of representations that they bring to the experimental setting. For example, in a series of studies conducted with newborns and very young infants, researchers have assessed infants' looking time to their mother's face relative to their looking time to another infant's mother's face (Bushnell, 2001; Bushnell, Sai, & Mullin, 1989; Field, Cohen, Garcia, & Greenberg, 1984; Pascalis, de Schonen,

Morton, Deruelle, & Fabre-Grenet, 1995). In all of these studies, newborns exhibited a strong *familiarity* preference for their mother's face--a stimulus that is highly meaningful to their survival. The direction of the infants' visual preference (i.e., a familiarity preference) is contrary to the traditional Soklovian account of the orienting response, but is exactly what we would predict from the perspective of memory retrieval if infants were sampling cues during the test that were part of a previously established representation (Estes, 1973; Spear, 1978; Tulving, 1983).

In the past, the use of meaningful stimuli in the VRM paradigm has been largely restricted to mothers' faces and to research with very young infants. In an earlier study, we attempted to give stimuli meaning by allowing older infants to interact with those stimuli in the context of the mobile conjugate reinforcement or deferred imitation paradigms (Gross, Hayne, Herbert, & Sowerby, 2002). In two experiments with 6-month-old infants, participants either learned to kick their feet to produce movement in an overhead mobile or they watched as an experimenter modelled a series of actions with a hand puppet. Immediately after one of these learning experiences, infants were tested in a VRM procedure in which their visual attention to their training mobile and a novel one or to the familiar puppet or a novel one was assessed. Following this VRM test, infants were then tested using the procedures associated with the task in which they stimulus was encountered in the first place. Although infants showed excellent retention when they were tested in the mobile conjugate reinforcement or deferred imitation paradigms, they exhibited no retention whatsoever when they were tested in the VRM task with either mobiles or puppets. That is, despite clear evidence of retention in one task, the same infant exhibited a null preference in the VRM task. In a similar series of studies using the mobile conjugate reinforcement paradigm, Wilk, Klein, and Rovee-Collier (2001) found that when the retention interval was increased to 24 hours or longer, 3- and 6-month olds exhibited longer looking to the familiar relative to a novel mobile. Thus, after these delays, infants' memory of the training mobile, a now-meaningful stimulus, was expressed as a familiarity preference.

In the present experiment, we took a slightly different tact to exploring infant visual attention to meaningful stimuli. Here, we tested older infants and young children using stimuli that were drawn from their own environments. To do this, we used the same apparatus that we used in our earlier work on VRM with 1- to 4-year-olds (Imuta et al., 2013; Morgan & Hayne, 2006a, 2006b, 2007, 2011), but rather than using meaningless stimuli, we selected stimuli from the participant's own environment and tested their visual preference for those stimuli relative to similar stimuli from another participant's environment. As in prior research with newborns, we did not include a familiarization phase in our experimental protocol. Instead, we measured participants' visual preference on the basis of the memory representation that they brought to the experimental setting. In addition, we also compared participants' visual attention to these stimuli to the explicit recognition performance of independent groups of participants tested in a pointing task using the same meaningful stimuli.

Participants

The final sample consisted of 120 participants (60 female) recruited from public birth records and by word of mouth. The participants were 1-, 2-, and 3-years old and there

were 20 participants of each age in each experimental condition (looking or pointing). All of the participants were tested within 3 weeks of their birthday. Children received a small, age-appropriate, gift for their participation in the study and parents received \$5 to offset the travel costs of bringing their child to the University. Participants were predominantly of European descent and came from a range of socioeconomic backgrounds. Five additional participants were excluded and replaced from the sample due to inattention during the test period or because of equipment failure (one 1-year-old and 2 each of the 2- and 3-year-olds).

Stimuli

Prior to the test day, we visited each participant's house to take photos of a range of animate and inanimate stimuli that were particular to that child and to his or her home environment. In total, there were nine possible stimuli. The animate stimuli included the child, a family pet, the child's sibling, and his or her mother and father. The inanimate stimuli included the family house and car, the child's security object (e.g., a blanket or soft toy), and the child's favorite toy. With parents' consent, the photos were also used as novel stimuli for other participants in the same experiment.

Apparatus and Procedure

As shown in Figure 1, participants were tested individually in a visual recognition memory apparatus that has been custom built for our laboratory (see Morgan & Hayne 2006a, 2006b, 2007, 2011 for full details). The child was seated on a chair in a three-sided experimental enclosure, with his or her parent standing behind or with the parent seated in the chair, holding the child on their lap. During all phases of the experiment, the child was positioned approximately 1 meter from a peephole located in the back of the enclosure. Parents were asked to remain still and to not direct their child's attention to a particular screen. Video records confirmed that all parents followed our instructions.

Once the child was looking forward, a rotating ball was presented simultaneously on both monitors to orient him or her toward the monitors. The rotating ball was followed immediately by presentation of the first set of test stimuli. During the test phase, a familiar stimulus (i.e., from the child's environment) and a novel stimulus were simultaneously presented, one on each monitor, for a 20-s period. The duration of the test phase was identical to that used in our prior research with participants in this age range.

Each participant could be tested for a maximum of nine trials (range = six to nine trials). The absolute number of trials for each child differed insofar as some participants didn't have pets, siblings, etc. This number of trials we employed in this experiment is well within the range of trials typically administered in studies with much younger infants [e.g., Fagan, 1973, (six trials); Roder, Bushnell, & Sasseville, 2000 (14 trials); Rose, 1981 (four trials); Wetherford & Cohen, 1973 (15 trials)]. The novel stimulus for each category was chosen for each participant by an observer who was unaware of the aim of the study. The observer was instructed to choose a novel stimulus from the same category as the familiar stimulus (e.g., mum or dad) so that each member of the pair was as similar as possible in description and appearance (see Figure 1 for examples).

Within each age group, half of the participants were tested in the standard

looking version of the VRM procedure ($n = 20$ of each age). They were given no verbal instructions and their visual attention to each stimulus was recorded on each trial. The remaining half of the participants at each age were tested in a pointing procedure modeled on that used by Richmond et al. (2007) with adults who were tested in the VRM task. For participants in the pointing condition, following presentation of each set of test stimuli, the experimenter said, "Point to the picture of your dog, mum, brother, ..." and so on, until all of the child's photos had been presented (see Figure 1, bottom panel).

The presentation of the animate and inanimate stimuli was alternated and between each presentation, the display on the screen changed to moving colored balls for 5 seconds to refocus the child. The location of the novel stimulus on the left or right monitor during the test phase was also counterbalanced.

During the test phase, the duration of the participant's visual fixations of the stimuli was video recorded using a low-light camera. One observer coded all of the video records. A second observer scored 25% of the video records. Both observers recorded the amount of time that each participant spent looking at the novel and familiar stimuli during the test. A Pearson product-moment correlation between pairs of observations indicated that inter-observer reliability was $r = .96, p < .01$.

Results

Participants in the looking condition spent almost all of the available time looking at the stimuli during the test trials (overall $M\% = 85.66, SD = 13.47$; range = 71.06 – 100). Although the 1-year-olds looked less ($M\% = 81.54, SD = 15.02$) than did the 2-year-olds ($M\% = 88.36, SD = 11.09$) and 3-year-olds ($M\% = 86.94, SD = 13.19$), $F(2, 385) = 6.20, p < .01, \eta_p^2 = .03$, the absolute difference was very small. There was no significant difference in looking times as a function of stimulus type, $F(8, 385) = 0.86, p > .05, \eta_p^2 = .02$, power = .40, and no interaction, $F(16, 385) = 0.95, p > .05, \eta_p^2 = .04$, power = .65.

Retention in the VRM task is evaluated by comparing the mean novelty preference score for each group against a hypothetical population mean of 50% (null preference). To determine which stimuli yielded a significant directional preference by infants in the looking condition, we used planned t-tests ($p < .05$) to compare the obtained mean novelty preference score for each stimulus type against a hypothetical population mean of 50%.

The data are shown in Table 1 and in the left panel of Figure 2. In no instance, did any age group in the looking condition exhibit a significant novelty preference during the test. When statistically significant visual preferences were observed, they were always in the direction of the familiar stimulus from participants' own environment. In addition, the stimuli for which participants exhibited significant familiarity preferences differed as a function of age. For example, the 1-year-olds in the looking condition exhibited no visual preference whatsoever for any of the test stimuli; none of their scores differed from 50%. In contrast, 2-year-olds in the looking condition exhibited a significant familiarity preference for the Mum, House, Car, Sibling, and Security Object stimuli; they did not exhibit a significant familiarity preference for the Child, Toy, Pet, or Dad stimuli. We note, however, that the number of participants who were tested with the Dad

stimulus was very small ($n = 3$), and all of them looked more at their own dad than they did at the other participant's dad. Finally, the 3-year-olds in the looking condition exhibited a significant familiarity preference for the Child, House, Car, and Security Object stimuli, but they exhibited no directional preference for the Mum, Dad, Sibling, Toy, or Pet stimuli.

To help us interpret the looking data, we examined the performance of the participants in the pointing condition. These data are shown in Table 2 and the right-hand panel of Figure 2. For the 1-year-olds, the pointing data were highly consistent with the looking data; in both the looking and the pointing conditions, participants' performance was not different from chance. For the 2-year-olds, the pointing data were also highly consistent with the looking data; with the exception of the Sibling stimulus, participants in the pointing condition exhibited above chance performance when tested with stimuli for which participants in the looking condition exhibited a significant familiarity preference (i.e., Mum, House, Car, and Security Object stimuli). Furthermore, the 2-year-olds failed to perform above chance in the pointing condition when they were tested with stimuli for which 2-year-olds in the looking condition exhibited a null preference (e.g., Child, Toy, Pet). As shown by the hatched bars, although we did not analyze participants' performance on the Dad stimulus for either condition due to the low participant numbers, all of the 2-year-olds in the pointing condition pointed to their own dad during the test. Finally, the relation between looking and pointing was much less direct for the 3-year-old participants. Like the 2-year-olds, the 3-year-olds in the pointing condition exhibited above chance performance when tested with stimuli for which participants of the same age in the looking condition exhibited a significant familiarity preference (i.e., Child, House, Car, Security Object), but they also accurately identified stimuli for which participants in the looking condition exhibited a null preference (i.e., Mum, Dad, Sibling, Toy, Pet).

DISCUSSION

Taken together, the results of this experiment yielded four findings. First, 2- and 3-year-olds exhibited a strong familiarity preference for some, but not all, of the photographs of stimuli that were drawn from their own home environment; when tested with the same stimulus categories, 1-year-olds did not. Second, at no age did participants exhibit the kind of novelty preference that is commonly used to define memory in the VRM task. Third, when compared to pointing, participants' visual preference provided a rough approximation of recognition memory. That is, in almost all instances in which participants in the looking group exhibited a significant familiarity preference, participants in the pointing condition exhibited above chance recognition of the familiar stimulus. Finally, for the 3-year-olds, looking measures underestimated recognition memory. That is, for some stimuli, participants in the pointing condition exhibited above chance performance, while participants of the same age in the looking condition did not.

On the one hand, the present data illustrate some remarkable memory skills by young children. Despite the fact that memory retrieval by infants is easily disrupted by changes in context between encoding and testing (for review, see Hayne, 2004; Rovee-Collier, 1997), the 2- and 3-year-olds in the present experiment recognized 2-dimensional representations of some stimuli from their environment when they were encountered

out-of-context in the laboratory. Furthermore, they achieved this feat even when the novel stimulus with which it was paired was remarkably similar to the target. It is perhaps not surprising that parents (and sometimes siblings) were among some of the stimuli that they recognized most often--these are stimuli that they encounter constantly during the course of their daily lives and that have important physical and emotional value to them. These are also stimuli that are encountered in multiple contexts—an experience that has been shown to facilitate memory retrieval in novel contexts, even by much younger participants (for review, see Rovee-Collier & Cuevas, 2006). What is possibly more remarkable is that they also recognized inanimate objects from their environment (e.g., house, car) on the basis of photographs alone that were encountered in an unfamiliar context. At least one of these stimuli (e.g., their house) is only ever encountered in one context. Taken together, these data not only highlight young children's memory skill, but also their emerging understanding of the representational nature of photographs (Ganea, Allen, Butler, Carey, & DeLoache, 2009; Simcock & DeLoache, 2006).

In contrast to the recognition memory exhibited by 2- and 3-year-olds, the 1-year-olds exhibited no recognition whatsoever on either version of the task. Whether their poor performance relative to their older peers was due to a lack of memory per se, or to a lack of representational flexibility, or other task specific factors is impossible to determine. Negative findings are always difficult to interpret, but given that even newborns look longer at their mother's actual face than at the face of another woman (e.g., Bushnell, 2001; Bushnell, Sai, & Mullin, 1989; Pascalis et al., 1995), we suspect that the use of photographs made our recognition task particularly difficult for the youngest participants. This difficulty was compounded in the pointing task by the requirement to follow verbal instructions (e.g., "Where's Dad?") and to exhibit a directed motor response. In fact, in the pointing version of the task, 1-year-olds only pointed on 30% of the trials.

From an historical perspective, the present data re-ignite some longstanding concerns about the weight placed on visual attention tasks in early debates about the nature of infant memory development (e.g., Schacter & Moscovitch, 1984). Carolyn Rovee-Collier frequently argued that the VRM paradigm created an impossible situation from the perspective of memory. "What was the point of encoding and storing information about an event that will not be attended to again until it is forgotten?" (Rovee-Collier & Hayne, 1987, p. 187). In her view, the VRM paradigm provided a measure of novelty detection, distraction, vigilance, information processing, or short-term memory, which underpinned the concurrent and long-term relation between VRM performance and more standard measures of IQ (e.g., Fagan, 1984; Rose & Feldman, 1995; Rose & Wallace, 1885). At the same time, she questioned the value of novelty detection as a measure of long-term memory, arguing that distraction by novel stimuli tells us nothing about what infants may or may not remember about familiar ones, particularly over the long term (Rovee-Collier, 2001; Rovee-Collier & Hayne, 1987; Wilk et al., 2001). Consistent with Pavlov's (1927) observations, Carolyn often made the following point regarding the confound created by using novelty detection as a measure of long-term memory: "You ask a male friend for directions to his house, but before he can speak, his attention is momentarily drawn to a passing fire engine. What does this

scenario reveal about his memory of the directions? Would you assume that he has forgotten them because he does not respond? Or more to the present point, would you assume that he remembers them because he does not respond, having been distracted by the fire engine (Rovee-Collier & Hayne, 1987, p. 188). Obviously, the fact that the person turns to look at the fire engine tells us nothing about what he remember about the directions—yet this same logic, that these two events are related, underpins the way in which we typically interpret VRM performance.

Over time, Carolyn was not alone in her trepidation about the interpretation of looking patterns in the VRM paradigm. A number of other researchers have also raised questions about the way in which infants' visual preferences in the VRM task are interpreted, particularly when it is used as a measure of long-term memory (Bahrick & Pickens, 1995; Bahrick, Hernandez-Reif, & Pickens, 1997; Richmond et al., 2007; Sophian, 1980). For example, Bahrick and her colleagues have argued that the direction of the visual preference that infants exhibit in the VRM task varies as a function of the retention interval. According to Bahrick's model, when the retention interval is short and the internal representation of the stimulus is strong, infants look longer at the novel stimulus during the test (i.e., novelty preference). When the retention interval is increased and the representation has faded (but is not gone), infants look longer at the familiar stimulus (i.e., familiarity preference). At two points along the forgetting function, infants exhibit no visual preference for one stimulus over the other (i.e., null preference)—after intermediate delays during the transition from a novelty preference to a familiarity preference, and again after very long delays when the stimulus has been completely forgotten. Thus, according to Bahrick's model, a null preference can be evidence of either remembering or forgetting, depending upon when in the forgetting function it occurs.

Several lines of research have provided empirical support for aspects of Bahrick's model (Bahrick & Pickens, 1995; Bahrick, Gogate, & Ruiz, 2002; Bahrick et al., 1997; Courage & Howe, 1998, 2001; Richmond et al., 2007; Spence, 1996). As predicted by the model, when infants or adults are familiarized with initially novel (and meaningless) stimuli, they exhibit a strong novelty preference when that now-more-familiar stimulus is paired with a completely novel one during the test. As the retention interval between familiarization and testing increases, infants' and adults' visual preferences shift from novelty to null to familiarity, in that order. The finding that participants exhibit differential looking (i.e., familiarity preferences) to the stimuli when they are tested after very long delays suggests that the null preference that occurs when participants are tested after intermediate delays is not indicative of complete forgetting. In the context of research on infant memory, these data raise concerns about the way in which null preferences have been used to define the limits of infant memory in the past.

These interpretive concerns are underscored by research conducted with human adults. When adults are tested in the VRM paradigm and are explicitly asked to point at the familiar stimulus, they accurately do so irrespective of the direction of their visual preference on a looking-only version of the task (Richmond et al., 2007). That is, novelty, null, and familiarity preferences assessed in the same way that is commonly done with infants are all associated with accurate recognition memory in adults. As such, null preferences cannot be used to define the limits of adults' retention. Similarly, in studies

conducted with infants, the null preferences that are typically defined as forgetting in the VRM task, are associated with memory for the same stimuli in different experimental procedures. For example, as described earlier, in both the mobile conjugate reinforcement paradigm and the deferred imitation paradigm, 6-month-old infants exhibit excellent retention when they are tested immediately, but the same infants exhibit null preferences when the target stimulus (e.g., the mobile or the puppet) is paired with a novel stimulus using VRM testing procedures (Gross et al., 2002). Once again, these data support the view that a null preference is not necessarily a hallmark of forgetting. Instead, both infants and adults have been shown to exhibit a null preference in the VRM task using the same encoding conditions under which they exhibit retention in another task.

The results of the present experiment provide additional support for the view that a null preference does not provide an unambiguous measure of forgetting. For example, there were numerous occasions in which the 3-year-olds in the looking condition exhibited a null preference for a particular stimulus category, however, the 3-year-olds in the pointing condition correctly identified the target stimulus during the test. Although it is possible that adding verbal instructions to the looking condition (i.e., "Where is Kelly [sibling]?") may have increased attention to the relevant target stimulus, these kinds of instructions are never given in the VRM paradigm. Instead, memory is inferred on the basis of spontaneous looking to the stimuli in the absence of explicit instruction. Hence, under conditions that are identical to those used in other studies of VRM, 3-year-olds did not "recognize" some targets based on measures of looking alone even when they could accurately point to them when asked to do so.

From a theoretical perspective, the present data add another wrinkle to our ability to interpret visual preference data in the VRM paradigm. According to both Sokolov's and Bahrick's models, a novelty preference provides the most unambiguous measure of memory, yet in the present experiment, when participants were tested exclusively with stimuli from their own environment--stimuli which were presumably meaningful to them in some way--they exhibited familiarity preferences, not novelty preferences, during the test. These familiarity preferences were associated with recognition of the same stimuli in the explicit pointing task adding weight to the conclusion that the familiarity preferences were indicative of memory. In contrast to interpretations of visual attention data based exclusively on the orienting response which uncouple interest and memory, the present data suggest that when participants have acquired an association with a particular stimulus, interest and memory are more tightly associated and result in longer looking at the familiar stimulus. This is exactly the prediction that we would make on the basis of almost any well-established theory of memory retrieval (Estes, 1973, Spear, 1978, Tulving, 1983).

In conclusion, the results of the present experiment illustrate that when stimuli are meaningful in some way, older infants and young children are more likely to look more, rather than less, at those stimuli during the test. When considered in conjunction with the pointing data, we conclude that these familiarity preferences are indicative of memory. These findings raise new opportunities to measure age-related changes in memory in preverbal and early verbal participants, in particular, their ability to recognize

old stimuli in new contexts—a skill that enhances the likelihood that early memories will be retrieved and retained over time.

Like Carolyn Rovee-Collier, we boldly embrace the challenge faced by generations of psychobiologists who have continued to develop nonverbal measures of complex, psychological constructs. But, also like Carolyn Rovee-Collier, we recognize the inherent danger of confusing our measures of memory with the construct *per se*. On the basis of nonverbal behavior, we must keep in mind that it is always safer to draw conclusions about what infants or young children remember than it is to draw conclusions about what they forget; this danger is not exclusive to visual attention, but extends to other measures of physiological and brain function as well. The critical distinction between measures and constructs is not merely semantic. It goes to the heart of how we conceptualize the process of memory development. For those of us who had the great privilege of working with Carolyn Rovee-Collier, this message was repeated often. It is one we are unlikely to forget and one that we feel obliged to pass on in her memory.

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Notice: This is the author's version of a work that was accepted for publication in *Developmental Psychobiology*. A definitive version was subsequently published in *Developmental Psychobiology*, 58, 808-816. DOI: 10.1002/dev.21455

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Table 1. Number of Participants tested with each Stimulus Type, Novelty Preference

Score (SD), and *t*-values as a Function of Age for Participants in the Looking Condition.

Stimulus Type	n	Novelty pref. (%)	t
1-year-olds			
Child	20	48.60 (14.43)	-0.43
Mum	20	45.20 (16.90)	-1.27
^a Dad	5	34.62 (20.53)	---
House	20	46.07 (17.82)	-0.99
Car	17	44.41 (18.98)	-1.21
Sibling	8	50.04 (9.55)	0.01
Security Object	12	41.89 (16.41)	-1.71
Toy	19	42.23 (17.74)	-1.91
Pet	13	46.10 (13.94)	-1.01
2-year-olds			
Child	20	44.08 (16.76)	-1.58
Mum	20	39.78 (20.69)	-2.21*
^a Dad	3	27.93 (15.37)	---
House	20	37.45 (18.79)	-2.99*
Car	19	36.19 (15.38)	-3.92*
Sibling	7	31.38 (19.25)	-2.56*
Security Object	19	36.15 (14.45)	-4.18*
Toy	20	47.17 (27.95)	-0.45
Pet	10	39.00 (19.31)	-1.80
3-year-olds			
Child	20	39.79 (13.95)	-3.27*
Mum	19	48.81 (21.32)	-0.24
Dad	7	41.65 (16.52)	-1.34
House	19	35.38 (16.46)	-3.87*
Car	18	40.46 (13.86)	-2.92*
Sibling	11	41.07 (19.43)	-1.53
Security Object	15	34.92 (16.22)	-3.60*
Toy	18	43.07 (16.63)	-1.77
Pet	15	45.82 (18.82)	-0.86

An asterisk indicates that the group's novelty preference score was significantly different from 50% (i.e., null preference). ^aGiven that very few participants were tested with the

Dad stimulus, we did not compare those novelty preference scores against 50%.

Table 2. Percentage of Participants tested in the Pointing Condition who Accurately Identified the Familiar Stimulus. The Number in Brackets indicates the Number of Participants who were Tested with each Stimulus Type.

Stimulus Type	1-year-olds	2-year-olds	3-year-olds
Child	20 (20)	61.11 (18)	94.74 (19)*
Mum	16.67 (18)	80 (20)*	87.50 (16)*
^a Dad	28.57 (7)	100 (6)	100 (6)
House	10.53 (19)	80 (20)*	94.74 (19)*
Car	11.76 (17)	75 (20)*	94.12 (17)*
Siblings	60 (10)	70 (10)	91.67 (12)*
Security Object	20 (15)	92.31 (13)*	100 (12)*
Toys	16.67 (24)	63.15 (19)	90.48 (21)*
Pets	20 (10)	50 (16)	72.22 (18)*

An asterisk indicates accuracy rates that were significantly above chance (sign test, $p < .05$). ^aGiven that very few participants were tested with the Dad stimulus, we did not compare those accuracy rates against chance.

Figure Captions

Figure 1. Experimental setup and apparatus. **Top Panel:** A 2-year-old participant in the looking condition. **Bottom Panel:** A 3-year-old participant in the pointing condition.

Figure 2. Left Panel: Novelty preference scores for individual participants in the looking condition as a function of age group and stimulus type. A shaded bar indicates that the group's novelty preference score was significantly different from .50 (i.e., null preference). **Right Panel:** The percentage of participants in the pointing condition who accurately identified the familiar stimulus, as a function of age group and stimulus type. A shaded bar indicates an accuracy rate that was significantly above chance.