Received: 16 June 2020 | Revised: 19 April 2021 | Accepted: 26 April 2021

DOI: 10.1002/icd.2234

RESEARCH ARTICLE

WILEY

The advantage of real objects over matched pictures in infants' processing of the familiar size of objects

Özlem Sensoy[1] | Jody C. Culham[2] | Gudrun Schwarzer[1]

[1]Department of Developmental Psychology, Justus-Liebig-University Giessen, Giessen, Germany

[2]Department of Psychology and Brain and Mind Institute, Western University, London, Canada

Correspondence
Özlem Sensoy, Department of Developmental Psychology, Justus-Liebig-University Giessen, Otto-Behaghel-Strasse, 10 F, 35394 Giessen, Germany.
Email: oezlem.sensoy@psychol.uni-giessen.de

Funding information
German Research Foundation, International Research Training Group (IRTG) (1901), "The Brain in Action–BrainAct" and Collaborative Research Center SFB TRR 135 2018/2, "Cardinal Mechanisms of Perception"

Abstract

We investigate when infants exhibit knowledge of the familiar size of well-known objects and whether this knowledge is affected by stimulus format, that is, whether the stimuli are presented as real objects or matched pictures. Infants (130 7- and 12-month-olds) saw everyday objects such as sippy cups and pacifiers in their familiar size and novel sizes (larger or smaller than the familiar size) placed pairwise within infants' reach. We used a preferential-looking paradigm to investigate whether infants are able to discriminate familiar from novel sizes. Although, infants of both age groups looked longer toward real objects that were smaller or larger than the familiar size, there were no looking preferences for the pictures. These results suggest that although 7- and 12-month-olds demonstrate familiar size knowledge for real objects, this understanding does not generalize to pictorial representations of those objects.

KEYWORDS

familiar size, infancy, object perception, pictures, preferential looking, real objects

Highlights

- We investigated under which conditions 7- and 12-month-olds exhibit knowledge of the familiar size of objects.

- By presenting real objects and matched pictures within reach, we found that infants of both age groups show familiar size knowledge, but only for the real objects.
- The activation of familiar size knowledge in infants seems to be dependent on stimulus format and actability.

1 | INTRODUCTION

Throughout our lives, we encounter thousands of real objects. Among other things, we learn that specific objects have a typical physical size, which we will refer to as "familiar size." For example, we all know that an apple is typically about 7–8 cm in diameter, even though its retinal size may vary based on its distance. Imagine seeing an apple that is much larger or smaller than usual. Adults would be puzzled when they encounter an apple that is as large as a watermelon or as small as a pea, but infants might not be as surprised because they encounter a variety of objects that differ from their familiar size. For instance, in their daily lives, infants see toy cars or stuffed animals that are much smaller or larger than their real-world counterparts. However, infants (and adults) are not only surrounded by real objects, but also by pictorial representations of these objects; in pictures, the sizes of objects can differ even more dramatically from their familiar sizes. For example, in children's picture books, the image of an apple and a cat may both be rendered at the same physical size on a page even though their familiar sizes differ by several orders of magnitude from each other and differ from the representational size on the page. Moreover, unlike real objects, cues to physical size cannot be inferred from touch on pictures. Nevertheless, infants are confronted with the challenge to learn the familiar size of objects through their experiences as this ability is crucial for our everyday lives. For example, in deciding whether it is safe to cross the street or not, children or adults may rely on their knowledge of the familiar size of cars in order to estimate the car's distance. The present study seeks to investigate when infants start to show familiar size knowledge of daily objects and whether this knowledge occurs for pictorial representations as well as real, tangible objects.

1.1 | Size processing in infants

To learn the familiar size of objects, size constancy has to be present in infants. Size constancy enables the perception of an object as having a constant physical size despite changes in retinal image size (based on distance). This in turn allows us to easily recognize an object from different distances. Previous studies suggest that by the age of 4 months, infants are able to perceive that objects maintain the same physical size despite changes in their viewing distance (Day & McKenzie, 1981; Granrud, 2006; McKenzie, Tootell, & Day, 1980; Slater, Mattock, & Brown, 1990), suggesting that they understand the relationship between physical size and distance.

Another indication that infants perceive the physical size of an object accurately from early on is that they show specific preferences for different physical sizes. Throughout the first year of life, infants direct their first looks toward physically larger objects when they view objects of different sizes simultaneously (Guan & Corbetta, 2012; Libertus et al., 2013; Newman, Atkinson, & Braddick, 2001; Sensoy, Culham, & Schwarzer, 2020). Shortly after birth, infants also spend more time looking at physically larger objects (Cohen, 1972; Fantz & Fagan III, 1975; Slater et al., 1990). With increasing age and developing abilities, infants' size preference for the largest object decreases (Guan & Corbetta, 2012; Libertus et al., 2013; Newman et al., 2001). For example, infants who are experienced in reaching prefer to look at smaller, more graspable objects that they can manually interact with compared to children less experienced at reaching, who prefer larger objects (Libertus et al., 2013). Thus, from the first months on, infants can successfully differentiate between different physical sizes of objects and understand their constancy.

1.2 | Familiar size

Prior research has shown that adults have knowledge of familiar size and consider it when estimating the distance of an object from themselves (Gogel, 1969; Gogel & Da Silva, 1987; Haber & Levin, 2001; Hastorf, 1950; Ittelson, 1951; Predebon, 1987). Knowledge about the familiar size of objects has been observed for both real objects and pictures (Bolles & Bailey, 1956; W. C. Gogel & Da Silva, 1987; Hastorf, 1950; Ittelson, 1951; Smith, 1953; Wagner, 2012).

However, familiar size is not only relevant for estimating the distance of an object, but also thinking about it and acting upon it. For instance, we understand what big and small mean in relation to an object (e.g., we know that a retinally small building is physically bigger than a retinally larger car). The size of an object also determines how we interact with an object (e.g., we can pick up a small needle by using a pincer grip, but we have to use both our arms to move around a piece of furniture). Generally, familiar size seems to be an important organizing principle in behavioural and neural object representations (Gabay, Leibovich, Henik, & Gronau, 2013; Gliksman, Itamar, Leibovich, Melman, & Henik, 2016; Konkle & Caramazza, 2013; Konkle & Oliva, 2012b; Paivio, 1975). When an object is recognized, the familiar size of an object is automatically activated by adults and 3- to 4-year-old preschoolers (Henik, Gliksman, Kallai, & Leibovich, 2017; Julian, Ryan, & Epstein, 2017; Konkle & Oliva, 2012a; Long, Moher, Carey, & Konkle, 2019). Patients with visual agnosia, who show severe impairments in object recognition, can still recognize real, tangible objects when the objects' physical sizes match their familiar sizes (Holler, Behrmann, & Snow, 2019). Hence, familiar size cues might trigger top-down object information and enhance object recognition.

Even though familiar size knowledge is important for our daily lives, studies investigating infants' familiar size knowledge are rare. These few studies found evidence that by the age of 4 months, infants show familiar size knowledge of depicted human faces, as measured by looking times (Tsuruhara, Corrow, Kanazawa, Yamaguchi, & Yonas, 2014). By 7 months of age, infants use the familiar size of a human face to estimate its distance to themselves and reach for the face they perceive to be closer (Yonas, Pettersen, & Granrud, 1982). Shortly thereafter, at 9 months of age, infants also demonstrate familiar size knowledge of human bodies (Heron & Slaughter, 2010).

However, as human faces and bodies are special for infants (Frank, Vul, & Johnson, 2009; Johnson, Dziurawiec, Ellis, & Morton, 1991; Libertus, Landa, & Haworth, 2017; Peelen & Downing, 2007; Reid et al., 2017; Slaughter, Stone, & Reed, 2004; Southgate, Csibra, Kaufman, & Johnson, 2008), infants' sensitivity to the familiar size of faces and bodies may not generalize to common objects. To our knowledge, only two studies have tested infants' familiar size knowledge of objects. Granrud, Haake, and Yonas (1985) investigated infants' familiar size knowledge of novel objects that infants encountered for the first time in the experiment. Five- and 7-month-old infants were familiarized with two novel objects of different sizes. Then, these objects were presented at the same size and distance in a monocular and binocular condition. In the binocular condition, there were no differences between 5- and 7-month-olds' reaches toward the objects. However, in the monocular condition, the 7-month-olds reached more often to the object that had been smaller in the familiarization phase and was thus later perceived as closer. Hence, 7-month-olds remembered the familiar size of a recently encountered object for a short duration of time.

Sensoy et al. (2020) investigated 7- and 12-month-olds' familiar size knowledge of two common objects—sippy cups and pacifiers. This allowed them to investigate infants' familiar size knowledge that is acquired through infants' own daily experiences with these objects. They used a preferential-looking-paradigm and presented a familiar-sized object next to a larger- or smaller-than-familiar-size version of the same object out of infants' reach. The 12-month-olds looked longer at the objects that were smaller or larger compared to the familiar-sized ones, indicating that they have familiar size knowledge. The 7-month-olds, however, did not show such a visual preference, in contrast to Granrud et al. (1985). One reason for the divergent results may be that Granrud et al. (1985) presented objects within reach, whereas Sensoy et al. (2020) presented objects out of reach. There are indications that infants' object processing is enhanced when infants are able to manually interact with objects (e.g., Jovanovic, Duemmler, & Schwarzer, 2008; Kaufman, Mareschal, & Johnson, 2003; Möhring & Frick, 2013; Wilcox, Woods, Chapa, & McCurry, 2007). Having objects within reach allows infants to visually and manually explore the objects. This provides infants with the opportunity to experience the same information in more than one modality and link visual and manual information to each other, which consequently could lead to a more in-depth and elaborated object processing. Real objects within reach might be more likely to engage the dorsal visual stream, which is linked to the planning and controlling of actions (Erlikhman, Caplovitz, Gurariy, Medina, & Snow, 2018; Freud, Behrmann, & Snow, 2020; Goodale & Milner, 1992; Milner & Goodale, 2008). Consequently, the opportunity to manually interact with objects might specifically enhance size processing as it is necessary for successfully grasping the objects. This in turn might help infants to recognize the familiar size more easily.

1.3 | Real objects versus pictures

When considering whether infants have knowledge about the familiar size of objects, it is reasonable to ask whether this knowledge depends on the format of the objects, real objects, or matched pictures. Recent research in adults has indicated that neural and behavioural processing of real objects and pictures differ, indicating a processing advantage for real objects. In a functional magnetic resonance imaging (fMRI) study in adults, Snow et al. (2011) showed that repetition suppression (the reduction of fMRI responses with repeated stimulus presentations) is weaker or even absent for real objects compared to matched pictures of these objects. They argued that real objects are processed longer or more deeply than pictures, perhaps because only real objects afford actions such as grasping. Consistent with this suggestion, Marini, Breeding, and Snow (2019) showed that, compared to pictures, real objects elicited a stronger neural correlate of automatic motor preparation in an electroencephalography (EEG) study. Behaviourally, recall and recognition performance is better for real objects compared to pictures in healthy participants (Snow, Skiba, Coleman, & Berryhill, 2014) as well as in patients with visual agnosia (e.g., Chainay & Humphreys, 2001; Hiraoka, Suzuki, Hirayama, & Mori, 2009). In addition to the opportunities they provide for interaction, tangible real objects also stimulate multiple senses, which improve 3-year-olds' performance on an executive task compared to pictures (Beaucage, Skolney, Hewes, & Vongpaisal, 2020). Thus, affordances, actability or multisensory processing might provide the basis for the real-object advantage.

The processing advantage for real objects can also be observed in infant studies. Carver, Meltzoff, and Dawson (2006) showed that 18-month-olds are able to differentiate between familiar and unfamiliar toys both with real objects and with pictures. However, with real objects, the differentiation occurred in an early exogenous sensory component (N2), whereas with pictures, the differentiation occurred in a middle latency attention component (Nc). The authors conclude that the discrimination between familiar and unfamiliar occurs earlier and faster with real objects compared to pictures. Rose, Gottfried, and Bridger (1983) showed that 12-month-olds' recognition for real objects is less dependent on encoding time than their recognition of pictures. Even 5-month-olds' recognition performance might be better for real objects than pictures (Ruff, Kohler, & Haupt, 1976). However, it is possible that the 5-month-olds did not fully recognize the pictures because they could not perceive monocular depth cues properly, an ability that seems to develop between 5- and 7-months of age (DeLoache, Strauss, & Maynard, 1979; Dirks & Gibson, 1977; Gottfried, Rose, & Bridger, 1977; Jowkar-Baniani & Schmuckler, 2011; Kavšek, Granrud, & Yonas, 2009; Kavšek, Yonas, & Granrud, 2012; Rose et al., 1983; Slater, Morison, & Rose, 1984).

One reason for a processing advantage for real objects in infants could be that real objects are more attention-grabbing than pictures of the same objects. Infants as young as 5 months spontaneously look longer at real objects compared to pictures (DeLoache et al., 1979). Even after being habituated to a real object, 7- and 9-month-olds showed a strong visual preference for the real objects that they were habituated to compare to a photorealistic picture of the same object (Gerhard, Culham, & Schwarzer, 2016). In the same study, infants also spent more time looking at the real objects than at the pictures on the initial exposure trials. In a recent study, Gomez, Skiba, and Snow (2018) found that real objects are also more attention-grabbing than pictures for adults. Interestingly, when the real objects were presented behind a barrier or out of reach, this effect disappeared. This suggests that real objects are processed differently depending on whether they are in or out of reach, which might be linked to the possibility to interact.

In sum, previous research shows that infants can discriminate between real objects and pictures and that they can recognize familiar objects when presented as pictures (DeLoache et al., 1979; Gerhard et al., 2016). However, that does not necessarily indicate that they fully understand the characteristics of pictures compared to real objects. For example, infants at 9-months attempt to grasp depicted objects (DeLoache, Pierroutsakos, Uttal, Rosengren, & Gottlieb, 1998), with more realistic pictures evoking more attempts at interaction (Pierroutsakos & DeLoache, 2003). On the other hand, 9-month-old infants show different manual exploration behaviours toward a real object and a picture of the same real object, indicating that they perceive the different affordances of real objects and pictures to some extent (Shuwairi, 2019; Yonas, Granrud, Chov, & Alexander, 2005; Ziemer, Plumert, & Pick, 2012; Ziemer & Snyder, 2016). As they gain experience with pictures, infants increasingly make fewer attempts to manually explore the depicted objects and make more communicative pointing gestures toward the represented objects (Pierroutsakos & Troseth, 2003). Thus, it appears that infants need to learn that actability differs between real objects and pictures, despite the similarities in colour, form and size between the two formats. Thus, it seems that infants develop an increasingly differentiated and correct knowledge that the same stimulus presented as a real object or a photograph has both similarities and differences.

1.4 | The current study

The aim of the current study was two-fold. First, we wanted to investigate whether presenting real common objects within reach and giving the chance to manually interact with these objects enables younger infants (7-month-olds) to process and recognize the familiar size of the objects. Sensoy et al. (2020) presented real objects out of reach and found that only 12-month-olds, but not 7-month-olds showed familiar size knowledge of common objects. Granrud et al. (1985), however, showed that 7-month-olds are sensitive to the familiar size of objects, which were presented within reach. Therefore, in the present study, we used the same method as Sensoy et al. (2020), but presented objects within reach.

Second, we wanted to examine whether stimulus format—presenting real objects or matched pictures—would influence infants' recognition of the familiar size of common objects. Studies on adults' and pre-schoolers' familiar size knowledge have shown that the familiar size of objects is activated when real objects and also pictures of those are recognized (e.g., Gabay et al., 2013; Gliksman et al., 2016; Henik et al., 2017; Ittelson, 1951; Konkle & Oliva, 2012a; Long et al., 2019). However, to our knowledge, there are no infant studies that tested whether infants are also sensitive to familiar size when looking at pictures of objects.

Therefore, we presented common real objects (a sippy cup and a pacifier) to one group of 7- and 12-month-old infants and visually matched pictures of the same real objects to another group of 7- and 12-month-olds, with all stimuli presented within reaching distance. On each trial, two real objects or two pictures were presented side-by-side: one was at the familiar size and the other was at a novel size, either 50% larger or 50% smaller than the familiar size. We measured the amount of time each infant spent looking toward each of the two stimuli. Although Sensoy et al. (2020) found that only 12-month-olds showed a preference to look longer toward the novel-sized objects, here, we expected that with the objects placed within reach, infants of both age groups may be able to distinguish novel from familiar sizes. For pictures, however, there were two possible predictions. By one view, if infants can infer physical size from the display, they should also show a preference for novel-sized objects in pictures. Sufficient information is available to infer true object size because the objects were depicted at the same physical sizes as their real counterparts, and because infants could determine the distance based on full visual cues and manual interactions (including proprioception and size comparisons with the hand as a reference; Linkenauger, Leyrer, Bülthoff, &

Mohler, 2013). By another view and as mentioned above, if infants do not fully understand that the size depicted on the picture matches the familiar size of the real-world counterpart of that object, then the size of depicted objects may have little or no effect on their behaviour.

2 | MATERIAL AND METHODS

2.1 | Ethics statement

The present study was conducted in accordance with the German Research Foundation's Research Ethics Guidelines. The local ethics committee of the of the Psychology department of the Justus-Liebig University Giessen approved the study. For each infant, informed consent was obtained from the parents prior to their participation.

2.2 | Participants

The final sample consisted of 130 healthy and full-term 7- and 12-month-old infants. In a between-subjects design, infants of the two age groups were randomly assigned to two different stimulus formats. Real objects were presented to 31 7-month-olds (mean age = 7 months 12 days; *SD* = 9 days; 16 girls) and 33 12-month-olds (mean age = 12 months, 13 days; *SD* = 9 days; 16 girls). Pictures were presented to 33 7-month-olds (mean age = 7 months, 14 days; *SD* = 9 days; 19 girls) and 33 12-month-olds (mean age = 12 months, 14 days; *SD* = 8 days; 16 girls). In addition, 14 7-month-old and 8 12-month-old infants were excluded from the final sample due to fussiness (12) (crying or trying to crawl on the table), experimenter error (7) (missing recording, pictures upside down) or parental interference such as pointing at the objects or making comments about the size of the objects (3). We based our sample size on the sample size of the thematically related study by Sensoy et al. (2020). Infants were recruited from public birth records in Giessen and surrounding areas. After the participation, each infant was rewarded with a certificate and a small gift.

Parents were asked whether their baby uses a pacifier and a sippy cup with handles on a daily basis to make sure that all participating infants were familiar with our stimuli. Additionally, parents were asked to indicate the number of months that an infant had had experience with a pacifier or sippy cup, which we used to define exposure time. We conducted a statistical test to ensure that infants assigned to the real objects group and those assigned to the pictures group did not differ with regard to their experiences with pacifiers and sippy cups. Specifically, we conducted a repeated-measures ANOVA on Exposure Time as a function of Stimulus Identity (pacifier vs. sippy cup) as a within-subjects variable and Age (7 vs. 12-month-olds) and Stimulus Format (real objects vs. pictures) as between-subjects variables. We found significant main effects for Stimulus Identity, $F(1, 126) = 146.97$, $p \le .001$, $\eta_p^2 = .54$, and Age, $F(1, 126) = 59.04$, $p \le .001$, $\eta_p^2 = .32$. There were no other significant main effects or interactions (all *F*s < 2). Infants of both age groups were more familiar with pacifiers (*M* = 6.7 months, *SD* = 3.8 months) compared to sippy cups (*M* = 3.2 months, *SD* = 2.4 months) and the 12-month-olds were more familiar with both objects (*M* = 4.2 months, *SD* = 1.8 months) than the 7-month-olds (*M* = 3.4 months, *SD* = 1.9 month). Thus, there was no difference in exposure time between infants in the real objects and pictures groups.

2.3 | Stimuli

As in Sensoy et al. (2020), we used pacifiers and sippy cups because these objects are highly familiar for infants. Moreover, pacifiers and sippy cups have a specific familiar size because they are only used for a specific age range. A commercially available pacifier and sippy cup were first 3D-scanned and then 3D-printed. 3D-scanning and -printing allowed us to ensure that all stimuli had an accurate shape and that the form and material were constant regardless of physical size. Stimuli were printed in three different sizes: familiar sizes, "maxi" sizes, and "mini" sizes (see Figure 1). The familiar size was identical to the physical size of the purchased pacifier and sippy cup. Maxi-sized objects were 50% larger than the familiar size and mini-sized objects were 50% smaller. The familiar-sized pacifier was 3.50 cm high × 5.50 cm wide, the maxi-sized was 5.25 cm high × 8.25 cm wide and the mini-sized was 1.75 cm high × 2.75 cm wide. The familiar-sized sippy cup with its handles was 11.20 cm high × 10.80 cm wide, the maxi-sized was 16.80 cm high × 16.20 cm wide and the mini-sized cup was 5.60 cm high × 5.40 cm wide. All stimuli were sanded and primed to prepare them for colouring. Water-based acrylic paint without solvents was used for colouring. All stimuli were coated with acrylic gloss varnish. All materials were non-toxic and safe for children.

For the pictures-group, we took pictures of the different-sized objects with a digital single-lens reflex (DSLR) camera (Sony EOS 1200D). The pictures were taken from the infants' point of view in the lab so that the viewpoint as well as the lighting conditions were the same for the pictures and real objects. The pictures were colour- and size-matched to the real objects using a raster graphics editor (GIMP 2.8). Because pictures are typically rendered on a background on printed pages (as in books), we printed the pictures on a grey background. The size of the background was matched to the size of the depicted object and thus differed between depictions; however, the relation of the background and depicted object was the same for all pictures.

Presentation on a rectangular background (as opposed to showing pictures as flat cut-outs) also ensured that the physical edges did not convey form and the object could not be interacted with in the same way as a real tangible object. Lastly, to give the pictures a similar glossy finish as the real objects, we laminated all pictures. Pictures were presented upright in a clear stand-up display. Using a clear stand-up display allowed us to match the viewpoint in the real object and picture condition, so that the apparent shape of the stimuli between the real object and picture condition was matched.

2.4 | Apparatus and procedure

All infants were tested in individual sessions of about 30 minutes. Infants were seated at a table on their caregiver's lap. The first experimenter sat across of the infant on the other side of the table, while a second experimenter stood

FIGURE 1 Sippy cups (in the back) and pacifiers (in the front) as real objects in the three different sizes. From left to right: mini, familiar and maxi size. The 2 Euro coin serves as real-world size reference

behind the infant. The first experimenter was responsible for the stimulus presentation. The first experimenter was instructed to look at the infant with a steady friendly face and not at the stimuli during presentation to avoid experimenter-induced bias. The second experimenter recorded the duration for each trial with a stopwatch. One camcorder was placed in front of the infants to record infants' looking behaviour. Another camcorder was placed sideways behind the infant to record the presented stimuli. Parents were blind to our hypothesis and were asked to not comment or point at the objects to avoid parent-induced bias.

The procedure for the real-objects-group and the pictures-group was the same. Each experimental session consisted of two warm-up trials and four test trials. Each trial had a total duration of 20 s, which is longer than the 10-s period used in the study of Sensoy et al. (2020). This extended period was necessary to enable infants more time to manually interact with the presented objects, which was not possible for the objects placed beyond reach in the earlier study. For all trials, the first experimenter presented objects/pictures in pairs, either a familiar-sized object/picture paired with a maxi-sized or a familiar-sized object/picture paired with a mini-sized (see Figure 2). Objects/pictures were placed on a table at marked positions (a maximum of 15 cm from the edge of the table closest to the infant). If infants were not able to reach the objects/pictures successfully during the warm-up trials, we moved them closer to the infants for the experimental trials.

For the warm-up trials, foam dice or matched pictures (yellow or red, 6 cm high × 6 cm wide) were used to familiarize infants with the experimental procedure. Test trials followed immediately after the warm-up trials.

Order of presentation (pacifiers or sippy cups first), pairing (familiar size with maxi first or familiar size with mini first) and position of objects (right or left from the infants' point of view) was counterbalanced between infants. A sample trial order for the real-objects-group could look like the following: Two same-sized yellow dice were presented first (a) and then followed by the presentation of two same-sized red dice (b). After the warm-up, the familiar-sized sippy cup was presented and paired with the maxi-sized sippy cup (c), and then in the next trial, the familiar-sized sippy cup was paired with the mini-sized sippy cup (d). Afterwards, the familiar-sized pacifier was presented and paired with the maxi-sized pacifier (e) and then paired with the mini-sized pacifier in the next trial (f). After each trial, the first experimenter removed the objects from the infants' line of sight. As all stimuli were presented within infants' reach, infants were able to touch and manipulate the real objects in the real-objects-group and the pictures in the pictures-group. In case an infant lost interest during a given trial, the first experimenter simultaneously tapped on the table right behind the stimuli and said “Look”.

2.5 | Coding and data analysis

As our stimuli were placed within reach, all infants could and did manually interact with the real objects and pictures (see Figure 3). Such interactions would provide additional information about the distance of the objects and the size of the objects relative to the hand.

Prior research has shown that infants' manual interactions with real objects and pictures can differ dependent on stimulus format so that they sometimes use different manual procedures when they explore real objects than pictures which makes it difficult to compare the manual procedures across stimulus format (DeLoache et al., 1979; DeLoache et al., 1998; DeLoache, Pierroutsakos, & Uttal, 2003; Shuwairi, 2019; Yonas et al., 2005; Ziemer et al., 2012; Ziemer & Snyder, 2016). Therefore, we used infants' looking behaviour as our dependent measure for both groups. Looking times included periods of looking at the objects accompanied by manually exploring the objects or pictures. Looking durations were defined as the time between the first and last fixation of an object.

Videos from different perspectives for each infant were synchronized (Adobe Premiere Pro CC 2017) and coded offline from video recordings using a frame-by-frame coding approach (Datavyu 1.5). The beginning and end of each trial were determined according to the sound of the stopwatch. An additional coder who was blind to hypotheses scored more than 50% ($n = 69$) of the data to verify the reliability. The inter-observer reliabilities exceeded 0.90 (Pearson's r).

FIGURE 2 Example of the familiar-maxi-pairing on the left side and familiar-mini-pairing on the right side for the sippy cups as real objects on the top and for the pacifiers as pictures in the stand-up displays on bottom. In the experiment itself, real objects and pictures were presented on a table and not in front of a white wall

FIGURE 3 Example of our experimental session for the real objects (left) and for the pictures (right)

Average looking durations were calculated for the familiar-, maxi-, and mini-sized objects for each trial. In preliminary analyses, we tested whether differences in looking durations between familiar and maxi size and familiar and mini size, stimulus identity (pacifier vs. sippy cup) and sex had a significant influence on infants' looking behaviour. We conducted a repeated-measures ANOVA on the difference in looking durations between familiar and maxi size and familiar and mini size with pairing (familiar-maxi vs. familiar-mini) and stimulus identity (sippy cup vs. pacifier) as within-subjects variables and sex as between-subjects variable. This analysis did not reveal any significant main effects or interactions (all *F*s < 2). Thus, data were collapsed across the pairings for subsequent analyses; accordingly, average looking durations for the maxi- and mini-sized objects were combined and are referred as looking durations toward the novel-sized objects in the following. Data were also collapsed across sippy cups and pacifiers and girls and boys.

3 | RESULTS

3.1 | Looking durations

In order to examine whether infants' looking durations differed with regard to object size, infants' age and stimulus format, a repeated-measures ANOVA with Size (familiar vs. novel) as a within-subjects variable and Age (7 vs. 12-month-olds) and Stimulus Format (real objects vs. pictures) as between-subjects variables was conducted. This ANOVA on the mean looking durations revealed significant main effects for Size, $F(1, 126) = 6.53$, $p = .012$, $\eta_p^2 = 0.05$, Stimulus Format, $F(1, 126) = 12.54$, $p \leq .001$, $\eta_p^2 = 0.09$, and Age, $F(1, 126) = 16.61$, $p \leq .001$, $\eta_p^2 = 0.12$. We also found a significant two-way interaction between Size × Stimulus Format, $F(1, 126) = 6.57$, $p = .012$, $\eta_p^2 = 0.05$. No other significant interactions were found (all *F*s < 3). The main effect of age showed that 12-month-olds looked significantly longer ($M = 5.30$ s, $SD = 2.15$ s) than the 7-month-olds ($M = 3.91$ s, $SD = 1.89$ s).

To investigate the significant two-way interaction of Size × Stimulus Format, we performed *post-hoc* paired *t*-tests (Bonferroni corrected, two-tailed) for each stimulus format (see Figure 4). For the real-objects-group, the paired *t*-test revealed a significant difference in average looking durations between familiar- and novel-sized real objects, $t(63) = -3.66$, $p \leq .001$, Cohen's $d = -0.59$. Infants of both age groups looked longer toward the novel-sized real objects ($M = 6.03$ s, $SD = 2.89$ s) compared to familiar-sized real objects ($M = 4.45$ s, $SD = 2.47$ s). For the pictures-group, the paired *t*-test showed no significant difference in average looking durations between familiar- and novel-sized pictures of the real objects, $t(65) = 0.01$, $p = .996$. Infants of both age groups spent the same amount of time looking at the familiar- ($M = 4.01$ s, $SD = 2.70$ s) and novel-sized pictures ($M = 4.02$ s, $SD = 2.67$ s). Additionally, two *post-hoc* unpaired *t*-tests (Bonferroni corrected, two-tailed) were run to analyse whether average looking durations differed for familiar and novel sizes between real objects and pictures. The *t*-test for the familiar sizes showed no significant difference in average looking durations for the familiar sizes between real objects and pictures, $t(128) = 0.97$, $p = .332$, with infants of both age groups looking equally long at the familiar-sized real objects and pictures of those on average. The *t*-test for the novel sizes revealed a significant difference in average looking durations

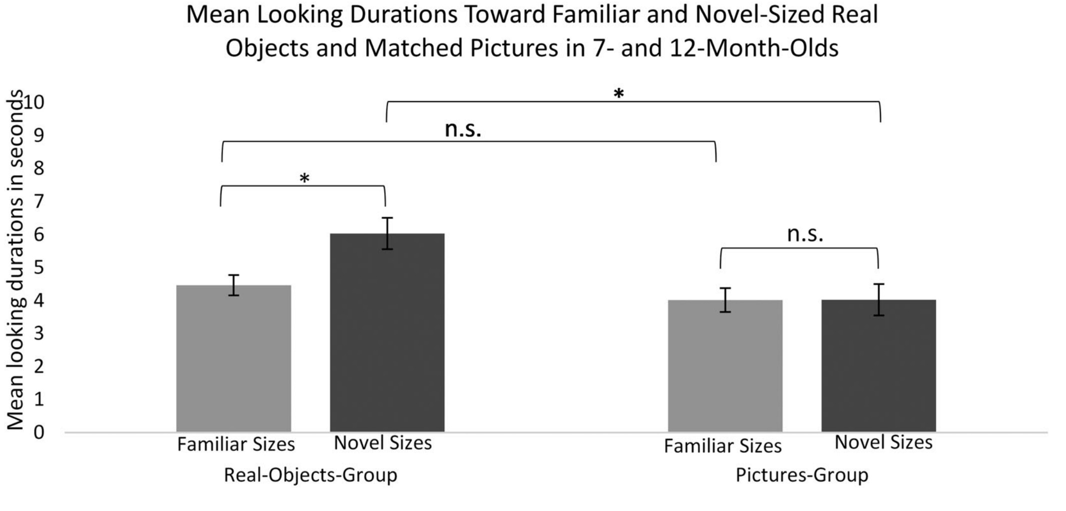

FIGURE 4 Mean looking durations in s for the familiar and novel sized objects for both age groups together separated by stimulus format. Error bars are SEM.
Note: *$p \leq .001$, n.s. not significant

for the novel sizes between real objects and pictures, $t(128) = 4.12$, $p \leq .001$, Cohen's $d = 0.72$, with infants looking longer at the novel-sized real objects compared to the pictures.

For the average looking durations, infants of both age groups looked longer at the mini- and maxi-sized compared to the familiar-sized stimuli when they were presented as real objects. Additionally, infants of both age groups looked equally long at the familiar-sized objects across both stimulus formats, but looked longer at the novel-sized objects in the real-objects group. In the pictures group, however, infants of both age groups did not show a difference in looking durations toward familiar and novel-sized stimuli.

3.2 | Novelty scores

We also calculated novelty scores to compare the preference for the novel-sized objects between the real-objects and pictures group. An unpaired *t*-test (two-tailed) revealed a marginally significant difference in novelty scores between both groups, $t(122.01) = 1.86$, $p = .065$, Cohen's $d = 0.34$. The novelty score for the real-objects group ($M = 58.11$, $SD = 18.08$) was higher than the novelty score for the pictures group ($M = 51.29$, $SD = 23.35$). However, compared against chance level, the *t*-test for the real-objects group confirmed that the preference for the novel-sized real objects significantly differed from chance level, $t(63) = 3.59$, $p \leq .01$, Cohen's $d = 0.45$. The *t*-test for the pictures group showed that the preference for the novel-sized pictures did not differ from chance level, $t(63) = 0.45$, $p = .655$.

3.3 | Comparison of the real-objects group to Sensoy et al. (2020)

The study of Sensoy et al. (2020) also presented familiar- and novel-sized objects to 7- and 12-month-old infants. In contrast to the study at hand, Sensoy et al. (2020) presented the objects out of reach, so that infants were only able to visually explore the objects. Their results show that only the 12-month-olds, but not the 7-month-olds successfully discriminate between familiar- and novel-sized objects. To compare the results of both studies, we ran a univariate ANOVA with Novelty Scores as dependent variables and Distance (out of reach as in Sensoy et al. (2020) vs. within reach as in this study) as the independent variable for each age group. For the 7-month-olds, the ANOVA revealed a marginally significant main effect for Distance, $F(1, 62) = 3.31$, $p = .074$, $\eta_p^2 = 0.05$. Novelty scores for the 7-month-olds were higher, when objects were within reach ($M = 58.18$, $SD = 21.73$) compared to out of reach ($M = 49.57$, $SD = 15.81$). For the 12-month-olds, the ANOVA revealed no significant main effect for Distance, $F(1, 63) = 1.09$, $p = .300$. Novelty scores did not differ between objects being within reach ($M = 54.94$, $SD = 9.19$) and out of reach ($M = 58.05$, $SD = 14.17$) for the 12-month-olds. Taken together, 7-months-olds seem to be able to successfully discriminate between familiar and novel sizes, only when objects are within reach, whereas 12-month-olds successfully discriminate between sizes irrespective of distance.

3.4 | Exploratory description of infants' manual behaviour

Even though, we decided against statistically comparing infants' manual behaviour in the real-objects and pictures group, we wanted to include some qualitative descriptions of infants' manual interactions with the stimuli. From observation of our videos, infants in the real-objects group and pictures group reached for both the real objects as well as the pictures. They performed some actions that were similar between real objects and pictures such as banging the object or picture on the table. Infants also performed actions such as rubbing or patting with the real objects and with the pictures (if infants put the pictures on the table in front of themselves beforehand). However, most of the time infants kept the picture in their hand and looked at it. Some infants also turned the pictures around to observe the back. Moreover, most infants quickly learned that they are able to pick up the picture and reached for the edges of the picture to grasp it. Infants would also touch the depicted object with one or more fingers, but we have not observed any attempts to pick the depicted object. Interestingly, infants performed actions such as drinking out of the sippy cups or sucking at the pacifier only with the real objects, but never with the pictures.

4 | DISCUSSION

The principal motivation of the present study was to investigate infants' familiar size knowledge of common objects when they were presented within reach, in contrast to Sensoy et al. (2020), who presented the same objects out of reach. Moreover, we wanted to examine whether and how stimulus format (real objects or matched pictures) affects infants' recognition of the familiar size of common objects. Our results revealed that both 7- and 12-month-olds show familiar size knowledge of common objects when they see real objects within reach. When the objects were depicted as pictures and presented within reach, infants of both age groups did not show knowledge of the familiar size of those common objects.

These new findings suggest that younger infants, 7 months of age, can distinguish real objects in novel vs. familiar sizes but only when those objects are within reach. Several factors could explain this finding. First, it may be that familiar size is only relevant to 7-month-olds when they can act upon objects, which might lead to evaluations of affordances ("will the pacifier fit in my mouth?") and reward ("how much juice might be in the sippy cup?"). Second, because infants could interact with the objects when in reach, they could better gauge physical size based on proprioceptive cues (Chen, Sperandio, & Goodale, 2018) and relative size comparisons with the hand (Linkenauger et al., 2013). Moreover, the within-reach presentation allowed the infants to visually and manually explore the objects, which all infants in our study did. Thus, infants got bimodal information about the objects, which might have led to a more elaborated object processing (Beaucage et al., 2020; Jovanovic et al., 2008; Kaufman et al., 2003). Additionally, infants might have paid more attention to the different sizes, when they grasped or reached for the objects than when they only looked at the objects as in the study of Sensoy et al. (2020). Thus, manual interaction might have supported the activation of familiar size knowledge in 7- and 12-month-olds, which they had gained from their everyday experiences. Our results show that in the first year of life, infants' processing of object size is clearly affected by infants' knowledge about the familiar size of objects and the opportunity to manually explore an object's size.

Our findings extend existing research in multiple ways. First, when visual and manual exploration was allowed, 7- and 12-month-olds showed familiar size knowledge compared to only the 12-month-olds in the study of Sensoy et al. (2020). Second, Granrud et al. (1985) did not find a difference in first reaches toward familiar and novel sizes in their binocular condition, whereas we found a difference in looking durations and hence a successful discrimination between familiar and novel sizes under binocular viewing conditions. First reaches might indicate a more spontaneous reaction than looking behaviour and might not be suitable to measure infants' discrimination between familiar and novel sizes in the binocular condition, when infants perceive that both objects have the same size and are equidistant. In contrast, looking durations might indicate a more in-depth processing and therefore might be more eligible to measure such a discrimination. Note that there were various other differences between both studies that might have contributed to the different results as well (different objects in the same size vs. the same object in different sizes; novel vs. common objects, trials end after first contact vs. fixed duration of trials). However, similar to our findings, Granrud et al. (1985) found a reaching preference for novel sizes, when 7-month-olds viewed the objects monocular.

One could wonder in how far the monocular viewing condition of real objects in the study of Granrud et al. (1985) is also comparable to the binocular viewing of pictures in our study. In the study of Granrud et al. (1985), 7-month-olds showed a reaching preference for the novels-sized objects in the monocular condition, when all but pictorial cues to depth and 3D object shape were eliminated. In contrast, we did not find any difference in looking durations between novel- and familiar-sized depicted objects in our study. Viewing pictures binocular as in our study is not easily comparable to viewing real objects monocular as in Granrud's study. Even though infants viewed the real objects monocular, they are still able to perceive depth and the 3D object shape through pictorial cues as infants are able to do so between 5 and 7 months of age (Kavšek et al., 2012). Infants were also able to move their heads and even tiny head movements can generate impressions of depth. Hence, they do not perceive the real object as flat as a picture. The idea of the study by Granrud et al. (1985) is that infants reach for the object that they perceive to be closer, however, in our study, infants can perceive that both objects are equidistant, so that the logic behind the study by Granrud et al. (1985) does not apply to our study.

Hence, while infants of both age groups looked longer toward novel than familiar sizes for real objects, no such preference was found when stimuli were pictorial representations. Note that for the pictures, as for the real objects, infants had comparable cues to distance and size, including visual cues (stereopsis and parallax), proprioceptive and motor cues and relative size in comparison to the hand. Thus, differences in performance cannot be explained by differences in the information available. Rather, several intriguing possibilities remain.

First, depicted objects do not enable actions. Put simply, upon palpation, the infant may realize that they cannot suck on the depicted pacifier or drink from the depicted sippy cup even though these items have strong affordances for infants as they fulfil basic needs such as drinking and soothing. Hence, infants might recognize the familiar size more easily and be more interested in the novel sizes, when presented with real sippy cups and pacifiers that are within reach and can be acted upon compared to pictures of these objects that lack affordances and consequently might be less appealing. As such, the familiar size of depicted objects may be irrelevant, just as it was for 7-month-olds when real stimuli were placed beyond reach in the study of Sensoy et al. (2020). This would not explain, however, why 12-month-olds, who previously could discriminate novel- from familiar-sized real objects even without the potential for action (Sensoy et al., 2020), did not do so here when the objects were presented on pictures and within reach.

It seems likely, as already mentioned, that even older infants must learn through their everyday experience that specific stimulus characteristics referring to a real object can not only differ from the corresponding characteristic when presented as picture, but that such characteristics can also be the same in real objects and pictures, such as familiar size. Thus, it could be that the infants in our study were still too young to understand that the depicted object size on the picture represents the actual familiar size of a pacifier or sippy cup in the real world. Alternatively, it might be that even though we had comparable cues to distance and size in both conditions, the information in the pictures about the familiar size of the depicted objects might have been insufficient to infer the real-world size of the depicted object. Infants knew the distance of themselves to the picture; however, they had no information about the distance of the depicted object. Nonetheless, there are indications that by 3 years of age, children's object representations include object size information that is automatically activated when seeing pictures of objects (Long et al., 2019). Future studies should investigate infants aged between 12 and 36 months to see when infants or toddlers start to show knowledge of the familiar size of objects when presented with pictures.

Second, it may be that infants treat the picture stimuli simply as flat objects of a constant size, namely the size of the background. That is, infants may fail to fully realize that the physical picture not only is an object, but that it *represents* another object. It would be interesting to see in future studies whether using a background for the pictures influences infants' visual discrimination of the different sizes. If the pictures are presented as cutouts without a background, infants might perceive them less like pictures and more like real objects, which might help them to activate their familiar size knowledge of objects. Alternatively, because even cutout pictures are flat and lack the full actability of real objects, infants may remain insensitive to size.

Another reason for the real-object advantage reported in prior studies is that real objects are more attention-grabbing for infants than pictures (DeLoache et al., 1979; Gerhard et al., 2016). However, this does not seem to be true for our study. Infants of both age groups spent the same amount of time looking at the familiar-sized real objects and matched pictures of the familiar-sized objects (see Figure 4 above). Hence, infants do not seem to be less interested in pictures of familiar-sized sippy cups and pacifiers than in the familiar-sized real counterparts. Rather, they are more interested in the novel-sized real objects than in the pictures of the novel-sized objects. The infants may be expressing that they have experienced much more often that object sizes vary in pictures than in real objects. It might be that the attention-grabbing aspect of the real object advantage is more relevant, when real objects and matched pictures are presented side by side as it was the case in the studies by DeLoache et al. (1979) and Gerhard et al. (2016). In our study, however, infants saw either two different-sized real objects or pictures, but they never saw a pair of real object and matched picture.

One could argue that a further reason for the lack of recognition of the familiar size on depicted objects is that it is difficult to infer the familiar size of a depicted object without having a referential context. However, as infants were allowed to manually interact with the objects, they were able to process the size of the object in relation, for example, to their own hands. Even though the manual interaction of real objects and the pictures of those differs in many ways, some visual experiences are similar. For instance, the mini-sized real pacifier and its picture counterpart can be fully covered by an infants' hand, whereas the maxi-sized real pacifier and the picture of it are too big for that. Nevertheless, having a referential context such as a hand reaching for the object or an infant drinking out of the sippy cup or sucking at the pacifier on the picture itself might help infants recognize the familiar size.

In sum, our findings provide further insight into the specific conditions under which infants are able to recognize the familiar size of common objects. Our results show that even infants in a younger age group than previously demonstrated, at the age of 7 to 12 months, can recognize the familiar size of commonly known stimuli when they are presented as real objects and at a reachable distance so that infants can not only see but also manually explore them. However, when those stimuli are depicted on pictures even when presented within reach, infants of this age range are no longer show recognition of the familiar size. Taken together, these results suggest that the understanding of familiar size in infants is dependent on both actability and stimulus format.

ACKNOWLEDGEMENTS

We give special thanks to Amelie Benner and Nele Zscherper for their help with the recruitment of participants as well as data collection and coding. We are grateful to all the parents who kindly agreed to have their infants participate in the study.

This work is supported by the German Research Foundation, International Research Training Group (IRTG) (1901), "The Brain in Action–BrainAct" and Collaborative Research Center SFB TRR 135 2018/2, "Cardinal Mechanisms of Perception," partnered with a Natural Sciences and Engineering Research Council of Canada (NSERC) Collaborative Research and Training Environment (CREATE) grant (44931–2014).

DATA AVAILABILITY STATEMENT

Data available on request from the authors.

ORCID

Özlem Sensoy https://orcid.org/0000-0002-7344-8936

REFERENCES

Beaucage, N., Skolney, J., Hewes, J., & Vongpaisal, T. (2020). Multisensory stimuli enhance 3-year-old children's executive function: A three-dimensional object version of the standard dimensional change card Sort. *Journal of Experimental Child Psychology*, *189*, 104694. https://doi.org/10.1016/j.jecp.2019.104694

Bolles, R. C., & Bailey, D. E. (1956). Importance of object recognition in size constancy. *Journal of Experimental Psychology*, *51*(3), 222–225. https://doi.org/10.1037/h0048080

Carver, L. J., Meltzoff, A. N., & Dawson, G. (2006). Event-related potential (ERP) indices of infants' recognition of familiar and unfamiliar objects in two and three dimensions. *Developmental Science*, *9*(1), 51–62. https://doi.org/10.1111/j.1467-7687.2005.00463.x

Chainay, H., & Humphreys, G. W. (2001). The real-object advantage in agnosia: Evidence for a role of surface and depth information in object recognition. *Cognitive Neuropsychology*, *18*(2), 175–191. https://doi.org/10.1080/02643290042000062

Chen, J., Sperandio, I., & Goodale, M. A [Melvyn Alan] (2018). Proprioceptive distance cues restore perfect size constancy in grasping, but not perception, when vision is limited. *Current Biology: CB*, *28*(6), 927-932.e4. https://doi.org/10.1016/j.cub.2018.01.076

Cohen, L. B. (1972). Attention-getting and attention-holding processes of infant visual preferences. *Child Development*, *43*(3),869. https://doi.org/10.2307/1127638

Day, R. H., & McKenzie, B. E. (1981). Infant perception of the invariant size of approaching and receding objects. *Developmental Psychology*, *17*(5), 670–677. https://doi.org/10.1037/0012-1649.17.5.670

DeLoache, J. S., Pierroutsakos, S. L., & Uttal, D. H. (2003). The origins of pictorial competence. *Current Directions in Psychological Science*, *12*(4), 114–118. https://doi.org/10.1111/1467-8721.01244

DeLoache, J. S., Pierroutsakos, S. L., Uttal, D. H., Rosengren, K. S., & Gottlieb, A. (1998). Grasping the nature of pictures. *Psychological Science*, *9*(3), 205–210. https://doi.org/10.1111/1467-9280.00039

DeLoache, J. S., Strauss, M. S., & Maynard, J. (1979). Picture perception in infancy. *Infant Behavior and Development*, *2*, 77–89. https://doi.org/10.1016/S0163-6383(79)80010-7

Dirks, J., & Gibson, E. J. (1977). Infants' perception of similarity between live people and their photographs. *Child Development*, *48*(1), 124. https://doi.org/10.2307/1128890

Erlikhman, G., Caplovitz, G. P., Gurariy, G., Medina, J., & Snow, J. C. (2018). Towards a unified perspective of object shape and motion processing in human dorsal cortex. *Consciousness and Cognition*, *64*, 106–120. https://doi.org/10.1016/j.concog.2018.04.016

Fantz, R. L., & Fagan, J. F., III. (1975). Visual attention to size and number of pattern details by term and preterm infants during the first six months. *Child Development*, *46*(1), 3. https://doi.org/10.2307/1128828

Frank, M. C., Vul, E., & Johnson, S. P. (2009). Development of infants' attention to faces during the first year. *Cognition*, *110*(2), 160–170. https://doi.org/10.1016/j.cognition.2008.11.010

Freud, E., Behrmann, M., & Snow, J. C. (2020). What does dorsal cortex contribute to perception? *Open Mind*, *4*, 40–56. https://doi.org/10.1162/opmi_a_00033

Gabay, S., Leibovich, T., Henik, A., & Gronau, N. (2013). Size before numbers: Conceptual size primes numerical value. *Cognition*, *129*(1), 18–23. https://doi.org/10.1016/j.cognition.2013.06.001

Gerhard, T. M., Culham, J. C., & Schwarzer, G. (2016). Distinct visual processing of real objects and pictures of those objects in 7- to 9-month-old infants. *Frontiers in Psychology*, *7*, 827. https://doi.org/10.3389/fpsyg.2016.00827

Gliksman, Y., Itamar, S., Leibovich, T., Melman, Y., & Henik, A. (2016). Automaticity of conceptual magnitude. *Scientific Reports*, *6*, 21446. https://doi.org/10.1038/srep21446

Gogel, W. C. (1969). The effect of object familiarity on the perception of size and distance. *The Quarterly Journal of Experimental Psychology*, *21*(3), 239–247. https://doi.org/10.1080/14640746908400218

Gogel, W. C., & Da Silva, J. A. (1987). A two-process theory of the response to size and distance. *Perception & Psychophysics*, *41*(3), 220–238. https://doi.org/10.3758/bf03208221

Gomez, M. A., Skiba, R. M., & Snow, J. C. (2018). Graspable objects grab attention more than images do. *Psychological Science*, *29*(2), 206–218. https://doi.org/10.1177/0956797617730599

Goodale, M. A [Melvyn A.], & Milner, A. (1992). Separate visual pathways for perception and action. *Trends in Neurosciences*, *15*(1), 20–25. https://doi.org/10.1016/0166-2236(92)90344-8

Gottfried, A. W., Rose, S. A., & Bridger, W. H. (1977). Cross-modal transfer in human infants. *Child Development*, *48*(1), 118. https://doi.org/10.2307/1128889

Granrud, C. E. (2006). Size constancy in infants: 4-month-olds' responses to physical versus retinal image size. *Journal of Experimental Psychology. Human Perception and Performance*, *32*(6), 1398–1404. https://doi.org/10.1037/0096-1523.32.6.1398

Granrud, C. E., Haake, R. J., & Yonas, A. (1985). Infants' sensitivity to familiar size: The effect of memory on spatial perception. *Perception & Psychophysics*, *37*(5), 459–466. https://doi.org/10.3758/BF03202878

Guan, Y., & Corbetta, D. (2012). What grasps and holds 8-month-old infants' looking attention? The effects of object size and depth cues. *Child Development Research*, *2012*(3), 1–10. https://doi.org/10.1155/2012/439618

Haber, R. N., & Levin, C. A. (2001). The independence of size perception and distance perception. *Perception & Psychophysics*, *63*(7), 1140–1152. https://doi.org/10.3758/BF03194530

Hastorf, A. H. (1950). The influence of suggestion on the relationship between stimulus size and perceived distance. *The Journal of Psychology*, *29*(1), 195–217. https://doi.org/10.1080/00223980.1950.9712784

Henik, A., Gliksman, Y., Kallai, A., & Leibovich, T. (2017). Size perception and the Foundation of Numerical Processing. *Current Directions in Psychological Science*, *26*(1), 45–51. https://doi.org/10.1177/0963721416671323

Heron, M., & Slaughter, V. (2010). Infants' responses to real humans and representations of humans. *International Journal of Behavioral Development*, *34*(1), 34–45. https://doi.org/10.1177/0165025409345047

Hiraoka, K., Suzuki, K., Hirayama, K., & Mori, E. (2009). Visual agnosia for line drawings and silhouettes without apparent impairment of real-object recognition: A case report. *Behavioural Neurology*, *21*(3), 187–192. https://doi.org/10.3233/BEN-2009-0244

Holler, D. E., Behrmann, M., & Snow, J. C. (2019). Real-world size coding of solid objects, but not 2-D or 3-D images, in visual agnosia patients with bilateral ventral lesions. *Cortex; a Journal Devoted to the Study of the Nervous System and Behavior*, *119*, 555–568. https://doi.org/10.1016/j.cortex.2019.02.030

Ittelson, W. H. (1951). Size as a Cue to distance: Static localization. *The American Journal of Psychology*, *64*(1), 54. https://doi.org/10.2307/1418595

Johnson, M. H., Dziurawiec, S., Ellis, H., & Morton, J. (1991). Newborns' preferential tracking of face-like stimuli and its subsequent decline. *Cognition*, *40*(1–2), 1–19. https://doi.org/10.1016/0010-0277(91)90045-6

Jovanovic, B., Duemmler, T., & Schwarzer, G. (2008). Infant development of configural object processing in visual and visual-haptic contexts. *Acta Psychologica*, *129*(3), 376–386. https://doi.org/10.1016/j.actpsy.2008.09.003

Jowkar-Baniani, G., & Schmuckler, M. A. (2011). Picture perception in infants: Generalization from two-dimensional to three-dimensional displays. *Infancy*, *16*(2), 211–226. https://doi.org/10.1111/j.1532-7078.2010.00038.x

Julian, J. B., Ryan, J., & Epstein, R. A. (2017). Coding of object size and object category in human visual cortex. *Cerebral Cortex (New York, N.Y.: 1991)*, *27*(6), 3095–3109. https://doi.org/10.1093/cercor/bhw150

Kaufman, J., Mareschal, D., & Johnson, M. H. (2003). Graspability and object processing in infants. *Infant Behavior and Development*, *26*(4), 516–528. https://doi.org/10.1016/j.infbeh.2002.10.001

Kavšek, M., Granrud, C. E., & Yonas, A. (2009). Infants' responsiveness to pictorial depth cues in preferential-reaching studies: A meta-analysis. *Infant Behavior & Development*, *32*(3), 245–253. https://doi.org/10.1016/j.infbeh.2009.02.001

Kavšek, M., Yonas, A., & Granrud, C. E. (2012). Infants' sensitivity to pictorial depth cues: A review and meta-analysis of looking studies. *Infant Behavior & Development*, *35*(1), 109–128. https://doi.org/10.1016/j.infbeh.2011.08.003

Konkle, T., & Caramazza, A. (2013). Tripartite organization of the ventral stream by animacy and object size. *The Journal of Neuroscience: The Official Journal of the Society for Neuroscience*, *33*(25), 10235–10242. https://doi.org/10.1523/JNEUROSCI.0983-13.2013

Konkle, T., & Oliva, A. (2012a). A familiar-size Stroop effect: Real-world size is an automatic property of object representation. *Journal of Experimental Psychology. Human Perception and Performance*, *38*(3), 561–569. https://doi.org/10.1037/a0028294

Konkle, T., & Oliva, A. (2012b). A real-world size organization of object responses in occipitotemporal cortex. *Neuron*, *74*(6), 1114–1124. https://doi.org/10.1016/j.neuron.2012.04.036

Libertus, K., Gibson, J., Hidayatallah, N. Z., Hirtle, J., Adcock, R. A., & Needham, A. (2013). Size matters: How age and reaching experiences shape infants' preferences for different sized objects. *Infant Behavior & Development*, *36*(2), 189–198. https://doi.org/10.1016/j.infbeh.2013.01.006

Libertus, K., Landa, R. J., & Haworth, J. L. (2017). Development of attention to faces during the first 3 years: Influences of stimulus type. *Frontiers in Psychology*, *8*, 1976. https://doi.org/10.3389/fpsyg.2017.01976

Linkenauger, S. A., Leyrer, M., Bülthoff, H. H., & Mohler, B. J. (2013). Welcome to wonderland: The influence of the size and shape of a virtual hand on the perceived size and shape of virtual objects. *PLoS One*, *8*(7), e68594. https://doi.org/10.1371/journal.pone.0068594

Long, B., Moher, M., Carey, S., & Konkle, T. (2019). Real-world size is automatically encoded in preschoolers' object representations. *Journal of Experimental Psychology. Human Perception and Performance*, *45*(7), 863–876. https://doi.org/10.1037/xhp0000619

Marini, F., Breeding, K. A., & Snow, J. C. (2019). Distinct visuo-motor brain dynamics for real-world objects versus planar images. *NeuroImage*, *195*, 232–242. https://doi.org/10.1016/j.neuroimage.2019.02.026

McKenzie, B. E., Tootell, H. E., & Day, R. H. (1980). Development of visual size constancy during the 1st year of human infancy. *Developmental Psychology*, *16*(3), 163–174. https://doi.org/10.1037/0012-1649.16.3.163

Milner, A. D., & Goodale, M. A [M. A.] (2008). Two visual systems re-viewed. *Neuropsychologia*, *46*(3), 774–785. https://doi.org/10.1016/j.neuropsychologia.2007.10.005

Möhring, W., & Frick, A. (2013). Touching up mental rotation: Effects of manual experience on 6-month-old infants' mental object rotation. *Child Development*, *84*(5), 1554–1565. https://doi.org/10.1111/cdev.12065

Newman, C., Atkinson, J., & Braddick, O. (2001). The development of reaching and looking preferences in infants to objects of different sizes. *Developmental Psychology*, *37*(4), 561–572. https://doi.org/10.1037//0012-1649.37.4.561

Paivio, A. (1975). Perceptual comparisons through the mind's eye. *Memory & Cognition*, *3*(6), 635–647. https://doi.org/10.3758/BF03198229

Peelen, M. V., & Downing, P. E. (2007). The neural basis of visual body perception. *Nature Reviews. Neuroscience*, *8*(8), 636–648. https://doi.org/10.1038/nrn2195

Pierroutsakos, S. L., & DeLoache, J. S. (2003). Infants' manual exploration of pictorial objects varying in realism. *Infancy*, *4*(1), 141–156. https://doi.org/10.1207/S15327078IN0401_7

Pierroutsakos, S. L., & Troseth, G. L. (2003). Video Verité: Infants' manual investigation of objects on video. *Infant Behavior and Development*, *26*(2), 183–199. https://doi.org/10.1016/S0163-6383(03)00016-X

Predebon, J. (1987). Familiar size and judgments of distance: Effects of response mode. *Bulletin of the Psychonomic Society*, *25*(4), 244–246. https://doi.org/10.3758/BF03330344

Reid, V. M., Dunn, K., Young, R. J., Amu, J., Donovan, T., & Reissland, N. (2017). The human fetus preferentially engages with face-like visual stimuli. *Current Biology: CB*, *27*(12), 1825–1828.e3. https://doi.org/10.1016/j.cub.2017.05.044

Rose, S. A., Gottfried, A. W., & Bridger, W. H. (1983). Infants' cross-modal transfer from solid objects to their graphic representations. *Child Development*, *54*(3), 686. https://doi.org/10.2307/1130056

Ruff, H. A., Kohler, C. J., & Haupt, D. L. (1976). Infant recognition of two- and three-dimensional stimuli. *Developmental Psychology*, *12*(5), 455–459. https://doi.org/10.1037/0012-1649.12.5.455

Sensoy, Ö., Culham, J. C., & Schwarzer, G. (2020). Do infants show knowledge of the familiar size of everyday objects? *Journal of Experimental Child Psychology*, *195*. https://doi.org/10.1016/j.jecp.2020.104848

Shuwairi, S. M. (2019). Haptic exploration of depicted and real objects by 9-month-old infants. *Infant and Child Development*, *28*(2), e2125. https://doi.org/10.1002/icd.2125

Slater, A., Mattock, A., & Brown, E. (1990). Size constancy at birth: Newborn infants' responses to retinal and real size. *Journal of Experimental Child Psychology*, *49*(2), 314–322. https://doi.org/10.1016/0022-0965(90)90061-C

Slater, A., Morison, V., & Rose, D. (1984). New-born infants' perception of similarities and differences between two- and three-dimensional stimuli. *British Journal of Developmental Psychology*, *2*(4), 287–294. https://doi.org/10.1111/j.2044-835X.1984.tb00936.x

Slaughter, V., Stone, V. E., & Reed, C. (2004). Perception of faces and bodies. *Current Directions in Psychological Science*, *13*(6), 219–223. https://doi.org/10.1111/j.0963-7214.2004.00312.x

Smith, W. M. (1953). A methodological study of size-distance perception. *The Journal of Psychology*, *35*(1), 143–153. https://doi.org/10.1080/00223980.1953.9712847

Snow, J. C., Pettypiece, C. E., McAdam, T. D., McLean, A. D., Stroman, P. W., Goodale, M. A [Melvyn A.], & Culham, J. C. (2011). Bringing the real world into the fMRI scanner: Repetition effects for pictures versus real objects. *Scientific Reports*, *1*, 130. https://doi.org/10.1038/srep00130

Snow, J. C., Skiba, R. M., Coleman, T. L., & Berryhill, M. E. (2014). Real-world objects are more memorable than photographs of objects. *Frontiers in Human Neuroscience*, *8*, 837. https://doi.org/10.3389/fnhum.2014.00837

Southgate, V., Csibra, G., Kaufman, J., & Johnson, M. H. (2008). Distinct processing of objects and faces in the infant brain. *Journal of Cognitive Neuroscience*, *20*(4), 741–749. https://doi.org/10.1162/jocn.2008.20052

Tsuruhara, A., Corrow, S., Kanazawa, S., Yamaguchi, M. K., & Yonas, A. (2014). Infants' ability to respond to depth from the retinal size of human faces: Comparing monocular and binocular preferential-looking. *Infant Behavior & Development*, *37*(4), 562–570. https://doi.org/10.1016/j.infbeh.2014.07.002

Wagner, M. (2012). Sensory and cognitive explanations for a century of size constancy research. In G. Hatfield & S. Allred (Eds.), *Visual experience* (pp. 63–86). Oxford University Press. https://doi.org/10.1093/acprof:oso/9780199597277.003.0004

Wilcox, T., Woods, R., Chapa, C., & McCurry, S. (2007). Multisensory exploration and object individuation in infancy. *Developmental Psychology*, *43*(2), 479–495. https://doi.org/10.1037/0012-1649.43.2.479

Yonas, A., Granrud, C. E., Chov, M. H., & Alexander, A. J. (2005). Picture perception in infants: Do 9-month-olds attempt to grasp objects depicted in photographs? *Infancy*, *8*(2), 147–166. https://doi.org/10.1207/s15327078in0802_3

Yonas, A., Pettersen, L., & Granrud, C. E. (1982). Infants' sensitivity to familiar size as information for distance. *Child Development*, *53*(5), 1285. https://doi.org/10.2307/1129018

Ziemer, C. J., Plumert, J. M., & Pick, A. D. (2012). To grasp or not to grasp: Infants' actions toward objects and pictures. *Infancy*, *17*(5), 479–497. https://doi.org/10.1111/j.1532-7078.2011.00100.x

Ziemer, C. J., & Snyder, M. (2016). A picture you can handle: Infants treat touch-screen images more like photographs than objects. *Frontiers in Psychology*, *7*, 1253. https://doi.org/10.3389/fpsyg.2016.01253

How to cite this article: Sensoy, Ö., Culham, J. C., & Schwarzer, G. (2021). The advantage of real objects over matched pictures in infants' processing of the familiar size of objects. *Infant and Child Development*, *30*(4), e2234. https://doi.org/10.1002/icd.2234