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Two- and 3-Year-Olds Know What Others Have and Have Not Heard

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Recent studies have established that even infants can determine what others know based on previous visual experience. In the current study, we investigated whether 2- and 3-year-olds know what others know based on previous auditory experience. A child and an adult heard the sound of one object together, but only the child heard the sound of another (target) object. When later the sounds of both objects were played simultaneously, the adult reacted with surprise and excitement (''Oh, listen, what is that?''). In response, both 24- and 36-month-olds directed the adult's attention to the target more often than chance and more often than in a control condition in which the adult had heard neither sound. These results indicate that by 24 months of age, children's understanding of others' knowledge and ignorance is not limited to the visual domain but extends across perceptual domains.

For humans to interact effectively with each other, they need to keep track of what others do and do not know. Much attention has been devoted to the ontogenetic beginning of this ability. But in accordance with a general bias (the ''primacy of vision''), the main focus in developmental research has been on knowledge resulting from visual perception.

One of the first studies to show that young children know what others have seen was conducted by O'Neill (1996). In her study, 2-year-olds witnessed an adult place a desirable object (a sticker) in one of two out-of-reach containers. The children had to request help from their parent to obtain the sticker. In one condition, the parent was ignorant with regard to the sticker's location because she was absent or had her eyes closed during the hiding event. In the other condition, the parent was knowledgeable because she watched the hiding event. The result was that children gestured more often and more specifically to the location of the sticker when their parent was ignorant than when she was knowledgeable. This is evidence that by 2 years of age, young children know what others do and do not know in the sense of what they have and have not experienced in the immediate past (see also Akhtar, Carpenter, & Tomasello, 1996).

Further studies have shown that even 1-year-olds know what others have perceived visually in the recent past. In a study by Moll, Carpenter, and Tomasello (2007), an adult engaged in joint visual attention with 14-month-old infants around two novel toys in turn for 1 minute each. The

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adult then left the room, and during her absence, the infant explored a third novel object together with an assistant. Finally, the adult returned, looked at a tray containing all three objects, expressed excitement, and then made an ambiguous request for the infant to hand ''it'' to her. The result was that the infants handed the adult the object that she did not know from past experience significantly more often than they handed her the familiar objects. Similar findings were obtained in studies using different variants of this selection paradigm (e.g., Moll, Richter, Carpenter, & Tomasello, 2008). Looking-time studies also suggest that 1-year-olds are surprised when an adult acts in a way that is inconsistent with her previous observation (Onishi & Baillargeon, 2005; Surian, Caldi, & Sperber, 2007) and that even 7-month-olds keep track of what others have and have not seen (Kovács, Téglás, & Endress, 2010).

But again, all these studies have investigated infants' understanding of knowledge that stems from one perceptual modality: vision. The adult knew things (objects or their location) by having perceived them *visually*—sometimes coupled with tactile experience. This limitation poses a problem for interpretation because it leaves open the possibility that infants' and young children's knowledge reduces to the specific case of past visual perception, in which case it might not be legitimate to attribute to them a more general understanding of knowledge. If it could be shown, however, that children have the same ability across different sense modalities, then this would suggest that their understanding of knowledge and ignorance is more abstract.

Hearing is an especially interesting case because audible signals play a pivotal role in human communication. At the same time, however, audition has some features that may make it comparatively hard for young children to determine what others have heard. Whereas there are behavioral indicators such as postural and eye orientation that make an identification of what a person sees fairly easy, no such observable markers are available to detect others' auditory experiences. Additionally, compared with vision, the auditory sense is a lot less tightly coupled with touch and thus with action. We actively bring objects into our visual field to take a closer look and manipulate them. In contrast, the link between audition and touch is weak, mostly because many of the sounds we experience are ephemeral and beyond our control: We notice the ambulance pass by in the streets and hear the birds chirping in the trees, but we have no influence over this. It is therefore a lot harder to control what you hear than to control what you see. For these reasons, it might be more challenging for young children to understand what another person has and has not heard as compared with what another person has and has not seen. But despite the importance of hearing for interpersonal communication and learning what is happening in the environment, early knowledge of others' auditory perception has not been investigated much.

In one study on children's understanding of perceptibility in various domains, 36-month-olds stated that a character (Ernie) can hear a sound like the squeaking of a pig from a distance but cannot touch or smell a distant flower (Yaniv & Shatz, 1988). Between the ages of 3 and 5 years old, children learn that an object's acoustic properties are discovered by listening, not looking (Pillow, 1993; see also O'Neill, Astington, & Flavell, 1992). Four-year-olds have been shown to understand that someone who was not whispered a secret in his ear is ignorant of it (Mossler, Marvin, & Greenberg, 1976). In a more recent study, 36-month-olds avoided noisy behavior when retrieving an object (by opening a silent door vs. one with a bell attached to it) in the presence of an adult who had prohibited them from accessing the object (Melis, Call, & Tomasello, 2010). Some studies have thus been conducted on children's understanding of hearing. But nothing seems to be known about children younger than 3 and the onset of an ability to track who heard what particular sounds in the past and how this affects people's familiarity with objects or events.

In the current study, therefore, we investigated whether 2- and 3-year-old children know what others have and have not heard in the immediate past. In the crucial condition, the child and an adult jointly attended to a sound coming from an out-of-sight object. Either before or after this event (depending on the type of trial), the child, but not the adult, also heard another sound coming from a different out-of-sight object. At test, the adult heard the sounds of both objects (i.e., the ones she had previously heard and not heard) in concert and asked excitedly, ''Wow, listen! What is that?'' The adult then made an ambiguous request for the child to show ''it'' to her. In the control condition, the adult was absent for both of the sounds, and so children could not know which specific object she was referring to.

METHOD

Participants

Ninety-six German children participated in this study. Participants were taken from a database of children whose parents had volunteered to participate in studies on child development. There were 48 (23 male, 25 female) 24-month-olds (age range = 1;11–2;2; $M_{\text{age}} = 2;0$) and 48 (23 male, 25 female) 36-month-olds (age range = 2;10–3;2; $M_{\text{age}} = 3;0$) in the final sample. Another 13 children (nine 24-month-olds, four 36-month-olds) were tested but excluded because they were uncooperative (three 24-month-olds) or failed to show a clear response on any of the three trials (six 24-month-olds, three 36-month-olds) or because of technical error (one 36-month-old).

Materials and Design

A stacking toy (17 cm high, 9 cm in diameter) consisting of a rod and differently colored wooden rings was used to play with the child in the testing room before the experiment began. For the experiment, three pairs of objects were used (their size ranged between approximately 8 cm × 4 cm × 4 cm and 14 cm × 10 cm × 18 cm). One pair consisted of a small black toy train and a plush rooster, a second pair consisted of a grey mobile phone and a plush horse, and the third consisted of a white plastic alarm clock and a plush toy sheep. Figure 1 shows a sample of the objects. Naturalistic sounds that corresponded to these objects (e.g., the steam sound of a train, a rooster-crowing sound, etc.) were played from two speakers (Creative I-Trigue 2200, approximately 21 cm × 5 cm × 8 cm) using an iPod (nano, G4).

Children were randomly assigned to either the experimental condition, in which one sound was not heard by the experimenter, or the control condition, in which both sounds were not heard by the experimenter, in a between-subjects design. From here on, we refer to the ''target'' as the object whose sound the adult had previously not heard in the experimental condition or its corresponding object (same identity, same spatial and temporal position but for a different child) in the control condition. Different pairs of objects and their corresponding sounds were used in each of three trials. The temporal order of the presentation of the target object (first vs. second) was counterbalanced to detect any order effects. That is, a given child received either two consecutive trials in which the target was the first one in the sequence and a third trial in which it was the second one or vice versa (first-first-second vs. second-second-first). The order of object

FIGURE 1 Sample of the stimuli used in the study. (Color figure available online.)

pairs, the order of objects within the pairs, and the objects' spatial location at test (target left or right) were also counterbalanced.

Procedure

Children were tested individually in a child research laboratory. The entire session lasted about 30 minutes. Before the experiment, both experimenters (E1 and E2) played with the child in a play room until the child seemed comfortable with the situation. Then, E1, E2, the parent, and the child entered the testing room (4.20 m × 4.20 m). The experimenters and the child sat on the floor in the center of the room; the parent sat behind the child in a chair. The experimenters and the child then played together with the stacking toy. When all the rings were stacked on the rod twice, in both conditions, E1 got up and announced that she had to leave. She waved goodbye and left the room. E2 remarked on E1's absence and announced that she (E2) and the child would continue to play. She retrieved the first pair of objects and showed them to the child, saying, for example: ''Look what I've got: a train and a rooster!'' Together, E2 and the child then went to the back of the room and placed each of the objects in turn behind a curtain on the wall opposite from the door, in two designated positions next to the speakers (see Figure 1). Because the speakers remained covered by the curtain, the child did not see them. After the objects were placed, E2 moved the curtain so that it covered the entire wall again, including the objects. She and the child returned to the center of the room and the child was positioned in a child seat facing the curtain at a distance of approximately 3.30 m from the speakers and objects. E2 sat down approximately 1 m across from the child. (These were the standardized positions from which the child and both experimenters listened to all sounds).

At this point, the experimental manipulation began. In the target-first version of the experimental condition, E1 remained absent. E2 surreptitiously activated the first sound—for example, the train sound—using a remote control. The sound emerged from the speaker that was positioned next to its corresponding object (e.g., the train). E2 jointly attended to the sound with the child, saying, ''Oh, listen, [*name of child*], listen! That is the [*name of object*]! That's great!'' While she said this, she put her index finger up to her ear, which is a German gesture for ''Listen!''

They listened to the sound together for 20 seconds. After the sound had stopped, E1 entered the room and sat down facing the child (see Figure 2). E2 then activated the second sound (e.g., the rooster sound), which emerged from the speaker next to the other corresponding object. E1 jointly attended to the sound with the child in the same manner and for the same amount of time (20 seconds) as E2 had done with the first sound.

After this second sound had stopped, E2 activated a sound file in which both sounds (e.g., the train and the rooster) emerged in quick alternation. This ''concert'' came from both speakers and marked the beginning of the response phase. E1 exclaimed with surprise and excitement, ''Oh, wow! What is that?'' and then asked ambiguously, ''Can you show it to me, please?'' Throughout the response phase, which was identical in the two conditions and lasted for 30 seconds (which was the duration of the ''concert'' as well), E1 looked straight at the child, thereby avoiding giving any gaze cues.

In the target-second version of the experimental condition, the procedure was identical until E2 and the child sat down on the floor after having placed the objects behind the curtain. E1 returned to the room at this point and sat down in the ''listening position'' (see previous page). She then jointly attended to the first sound with the child in the same manner and for the same duration as described above. E1 then announced that she had to leave again and left the room. While E1 was absent, E2 and the child listened to the second sound together. After the end of this sound, E1 returned and sat down across from the child. The test phase began and proceeded exactly as described above.

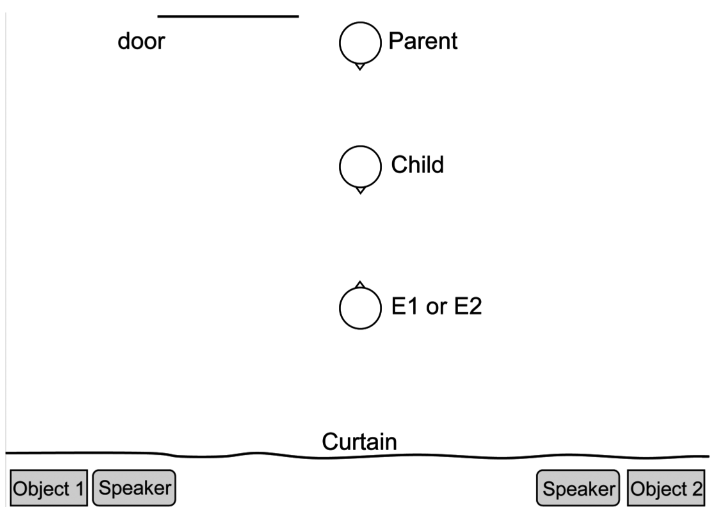

FIGURE 2 Overhead view of the experimental setup during the listening phase.

TABLE 1
Main Procedural Steps in the Study as a Function of Condition and the Target's Temporal Position

	Procedure	
Condition	*Target first*	*Target second*
Experimental	E1 leaves the room. E2 and child place objects behind curtain. ***E2 shares sound of first object (target) with child.*** ***E1 returns and shares sound of second object with child.*** Response phase	E1 leaves the room. E2 and child place objects behind curtain. ***E1 returns and shares sound of first object with child.*** ***E1 leaves again. E2 shares sound of second object (target) with child. E1 returns.*** Response phase
Control	E1 leaves the room. E2 and child place objects behind curtain. E2 shares sound of ***first object (target)*** with child. E2 shares sound of second object with child. E1 returns. Response phase	E1 leaves the room. E2 and child place objects behind curtain. E2 shares sound of first object with child. E2 shares sound of ***second object (target)*** with child. E1 returns. Response phase

In the control condition, E1 remained outside after E2 and the child had placed the two objects behind the curtain. While E1 was absent, E2 and the child jointly attended to the first and then the second sound following the exact same procedure as described for the experimental condition. The crucial difference with the experimental condition is thus that E1 was absent for the sounds of both objects. She returned immediately before the response phase, which was identical to the response phase in the experimental condition. (See Table 1 for a short description of the procedure in the two conditions.) Note that in both conditions, E1 never saw the objects, as they were always introduced and placed behind the curtain during her absence at the beginning of the trial. Children thus could not pass the test based on an understanding of what E1 had seen.

Coding and Reliability

The videotaped response phases of each trial were scored by the first author who was unaware of condition and the location of the objects (she never saw the procedural steps preceding the response phase). She coded to which of the two objects the children directed E1's attention. Directing E1's attention was coded if children *retrieved the object* (i.e., locomoted toward the object and withdrew it from behind the curtain), clearly *pointed* in the direction of the object's location, *named the object*, or *imitated its sound*.

If children displayed more than one of these behaviors and/or directed the adult's attention to both objects in turn, their first response was coded. If children showed none of these behaviors, the trial was dropped from the analyses. This was the case in 11 (6 control, 5 experimental) out of 144 (7%) trials from the 2-year-olds and 7 (5 control, 2 experimental) out of 144 (5%) trials from the 3-year-olds. Three additional trials from 3-year-olds had to be excluded due to failure of the technical equipment (1), parental influence (1), or uncooperative behavior (1). Mean proportions are therefore reported. To assess interrater reliability, a research assistant who was

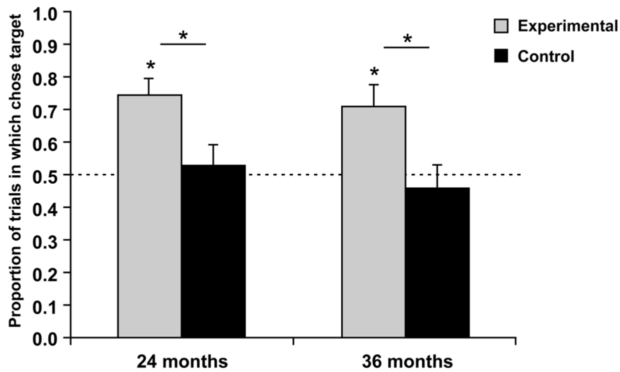

FIGURE 3 Mean proportion of trials (with standard errors) in which children chose the target object.

unaware of the condition and the location of the target and distractor scored a random sample of 12 children (25%) from each age group (6 from each condition). The two raters agreed in 94% of the trials, leading to a Cohen's kappa of .90.

RESULTS

Figure 3 shows the mean proportion of trials in which children directed E1's attention to the target as a function of age and condition. Neither the children's gender ($p = .40$) nor the order of target and distractor ($p = .25$) had an effect, and so these factors were disregarded in further analyses. In the main analysis, a univariate analysis of variance was conducted with age (24- vs. 36-month-olds) and condition (experimental vs. control) as independent variables, with the mean proportion of target choices as the dependent measure. There was no effect of age, $F(1, 92) = 0.68$, $p = .41$, $\eta^2_p = .01$, and no interaction between age and condition, $F(1, 92) = 0.08$, $p = .79$, $\eta^2_p = .00$. However, there was a significant effect of condition, $F(1, 92) = 13.60$, $p < .001$, $\eta^2_p = .13$, with children directing the adult's attention to the target more often in the experimental than in the control Condition.

In a second analysis, we compared the mean proportion of trials in which children (at each age separately) directed E1's attention to the target in each condition to chance (0.50) using one-sample *t*-tests. In the experimental condition, the 24-month-olds directed the adult's attention to the target more often than would be expected by chance, $t(23) = 4.85$, $p < .001$. The same was found for the 36-month-olds, $t(23) = 3.12$, $p < .01$. In the control condition, neither the 24-month-olds, $t(23) = 0.47$, $p = .66$, nor the 36-month-olds, $t(23) = 0.58$, $p = .57$, directed the adult's attention to the target at a level differing from chance.

DISCUSSION

In the present study, 24- and 36-month-old children demonstrated that they knew what another person had and had not heard in the immediate past. When an adult who had previously heard just one of two sounds (experimental condition) reacted with surprise and excitement (''What is that?'') as she suddenly heard both sounds together, children directed her attention to the previously unheard object. But when the adult reacted with the same surprise and excitement as she heard both sounds together for the very first time (control condition), children directed her attention to the objects randomly.

Because the vast majority of studies on children's understanding of perception focuses on vision, not much was known about toddlers' understanding of auditory perception. The few studies that have been conducted looked at children's understanding of how factors like distance impact perceptibility in different modalities (Yaniv & Shatz, 1988), the role that hearing plays in knowledge acquisition (Pillow, 1993), or children's avoidance of noise when performing a prohibited act (Melis et al., 2010). The present study is the first to show that very young children keep track of others' prior auditory experiences and inform them of the ones that they failed to hear. They distinguish between what others have and have not heard. In analogy to Flavell's (1992) distinction of two levels in visual perspective taking, this could be called "level 1 past auditory perspective taking."

The current findings also add to a growing body of evidence that infants and young children know what other people do and do not know in the sense of what they have experienced perceptually (e.g., Kovács et al., 2010; Moll et al., 2007; Onishi & Baillargeon, 2005; Surian et al., 2007). In the previous tasks, however, for the adult to know something meant that she had perceived it visually. But of course people can also come to know about things by hearing them. I know there is an ambulance in the street when I hear its siren, or that a person enters the apartment when I hear footsteps and the door opening—even when I see none of this happening. In the experimental condition of the current study, the adult saw neither of the objects; she only heard one, but not the other. This study is thus the first to establish that by 24 months of age, children not only know what others know from visual experience, but also what they know from past auditory experience.

It seems especially important for young children to develop—in addition to an understanding of others' visual experiences—some understanding of others' auditory experiences. Children and their parents routinely hear suddenly emerging sounds, such as a dog barking, the doorbell or telephone ringing, or a person entering the house. Most important of all, in humans, "the function of hearing *par excellence* is, of course, linguistic communication" (Sweetser, 1997, p. 41). For infants to learn to communicate effectively with others, they not only need to be able to establish joint auditory attention with their interlocutors during the communicative act, but they also have to keep track of what others have and have not heard to judge whether they know a specific piece of linguistically expressed information. Any adequate use of pronouns and elliptical constructions, for example, requires that the speaker be aware of what was said before and has therefore entered the "discourse background."

More generally, the current results give us more confidence that young children actually recognize others' knowledge and ignorance. On the basis of the previous studies of visual experience, this conclusion is not necessarily warranted. Infants might have solved those tasks based on knowledge specifically about others' past *visual* perception—what they have seen in the past, not what they know. However, the current findings suggest that by 24 months of age, children are aware of others' states of knowledge and ignorance abstractly across different perceptual domains. Future investigations should broaden the scope further and explore an analogous understanding of knowledge from tactile experiences.

A pressing developmental question is what comes first: an understanding of others' visual or auditory perception. Vision has always been credited with a privileged position among the senses.

Because of its close ties with action, it is regarded as a more active sense than hearing. It also seems most strongly involved in knowledge formation, as the many visual metaphors for understanding or rationality (e.g., ''enlightenment,'' ''illumination,'' ''I see!'') demonstrate. While auditory information can leave the hearer guessing as to what is producing the sound and where it is coming from, vision delivers fast and reliable information about the ''what'' and ''where'' of objects and events in the environment. In line with this and evidence suggesting a ''primacy of the visual'' in early interactions between children and adults (Clark, 1976; Wierzbicka, 1996), it is likely that infants first learn to assess others' knowledge in social interactions around jointly visible (and manipulable) objects. A visual analog of the present test is already solved by 14 months of age (Moll et al., 2007). But procedural differences between the visual and auditory experiments and the absence of any auditory studies with children younger than 2 years make it impossible to draw conclusions regarding the developmental order at this point; future research is needed. What the present study unequivocally demonstrates is that by 24 months, children can determine what sounds others have and have not heard in the recent past.

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