Children's Understanding of the Link Between Sensory Perception and Knowledge

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Abstract

Over the preschool years, children develop an understanding of the relationship between their senses and the kinds of knowledge those senses acquire. This development may be supported by sensory experiences or may be linked to theory-of-mind development. 64 preschoolers were asked to identify which of 2 confederates knew the identity of a toy animal when each had differential perceptual access to the animal. In the "seeing" condition, one confederate looked at the animal and one did not, and in the "hearing" condition, one confederate listened to the animal's sound and one did not. 4-year-olds outperformed 3-year-olds in both conditions, and all children performed equally well on both vision and hearing trials suggesting that children come to understand the seeing-knowing and hearing-knowing connections simultaneously. Findings provide initial evidence that theory-of-mind rather than experiential learning is most closely related to developing an understanding of the link between sensory perception and knowledge.

Keywords: cognitive development; experiential learning; sensory perception; theory-of-mind

Introduction

Children learn by gathering information about the world through their senses. Research on children's understanding of sensory modalities primarily focuses on the relationship between seeing and knowing, with limited attention paid to how children come to understand the four other senses as sources of knowledge (O'Neill & Chong, 2001; O'Neill & Gopnik, 1991; Melis, Call & Tomasello, 2010). The objective of the current study is to investigate the development of the link between hearing and knowing alongside the development of seeing and knowing.

Although infants show an early sensitivity to others' eye gaze, and toddlers even modify their behavior when their caregiver does not share the same visual access, it is not until their preschool years that children develop a deeper understanding of the link between perceptual information and knowledge acquisition (Butler, Caron, & Brooks, 2000; Doherty, 2006; P. Dunham, F. Dunham, & O'Keefe, 2000; O'Neill, 1996). Through following eye gaze, eighteen-month-olds demonstrate an understanding that people's eyes allow them to interact with objects in the world. However, this behavior is not evidence that they grasp that looking informs mental states. Doherty (2006) has suggested that 18-month-olds are aware of the spatial relationship between object and viewer but do not demonstrate an understanding of the psychological nature of the relationship. In fact, their understanding of eye gaze is equivalent to that of chimpanzees, who follow eye gaze but do not modify behavior based on what an experimenter is able to see or where the experimenter's gaze is directed (Doherty, 2006). Infants like chimpanzees, then, understand that eye gaze is linked to objects but fail to grasp the mentalistic nature of this relationship.

Beginning at 12 months of age, children modify their behavior based on the sensory access of another person. They gesture more about the location of an object when a parent did not see it fall of a table than when the parent did (Liszkowski, Carpenter, & Tomasello, 2008). Similarly, by the age of 2 years, children gesture more and use more specific language in communicating with their mothers when their mothers cannot see a hiding event than when they can (P. Dunham, F. Dunham, & O'Keefe, 2000; O'Neill, 1996). However, O'Neill (1996) has claimed that these young children are not knowledgeable about the visual experience of their mothers, but rather have a more basic understanding that their mothers have disengaged from the task, thus children's increased gestures and language serve to update their mothers on what they missed during their disengagement. This argument is consistent with the evidence that children cannot take the most basic visual perspectives of others until beyond the age of 2 years (Flavell, 2004).

Before the age of 3, children appear to believe that the mind contains an exact copy of information from the world that was deposited into the brain rather than taken in through senses and processed cognitively (Chandler & Boyes, 1982; Flavell, 1988). In contrast, older preschool children perform well on seeing-knowing tasks in which they have to determine that a confederate with visual access to an object also knows the identity of the object (O'Neill, Astington & Flavell, 1992; Pillow, 1989; Pratt & Bryant, 1990). Rather than believing that people have an exact copy of the world in their minds, these older preschoolers demonstrate an understanding that one's unique set of sensory experiences determines one's knowledge state. Younger preschoolers, on the other hand, do not necessarily grasp the causal relationship between seeing and knowing, as they do not perform consistently on these tasks. In a different paradigm in which either the child or a peer peeked inside a box, 3-year-olds were unable to determine whether the peer knew the contents of a box, even though they were consistently able to report whether they themselves knew the contents (Wimmer, Hogrefe, & Perner, 1988). Furthermore, older preschoolers who understand the relationship between seeing and knowing overgeneralize this understanding, concluding that a confederate who can only see part of an object knows the full identity of the object (Chandler & Boyes, 1982; Taylor, 1988). Thus the preschooler's knowledge of the connection between seeing and knowing is incomplete and depends on the nature of the task.

While children seem to develop an understanding of seeing and knowing over the course of the preschool years, we, cannot generalize their understanding of this relationship to that of their other senses. In a task focused on hearing and knowing, 4- and 5-year-olds, but not 3-year-olds, understood that being deprived of auditory input limits one's understanding of a videoclip (Mossler, Marvin, & Greenberg, 1976). In a different task, three-year-olds also could not understand that only a confederate who felt an object knew the texture of an object (O'Neill et al., 1992). These two findings suggest that understanding the link between perception and knowledge does not necessarily develop at the same rate for all the senses. However, tasks that target senses aside from vision have not followed a seeing-knowing paradigm and may be more complex than the seeing-knowing task, in that memory and language demands tend to be greater and modality specific properties (e.g., texture) of objects rather than object identities are investigated. Thus firm conclusions based on previous research cannot be drawn regarding the development of understanding that sensory perception across modalities leads to knowledge.

Crucially, both older and younger preschoolers understand the function of each of their five senses (Johnson & Kendrick, 1984; O'Neill & Gopnik, 1991). Yet understanding the causal relationship to knowledge formation remains elusive for 3-year-olds. Understanding this relationship may be closely related to either children's developing theory-of-mind or their increasing experience using their senses to gain information about the world.

Theory-of-mind refers to an understanding of others' mental states and is one area of cognitive development that changes dramatically between the ages of 3 and 5 years (Wellman, Cross, & Watson, 2001). An important part of theory-of-mind is false-belief understanding, which involves the understanding that other people can hold false beliefs about the world. Passing a false-belief task is considered a hallmark of theory-of-mind understanding, and is often the only measure used to assess whether a child has a theory-of-mind (Wellman & Liu, 2004). However, in order to understand how a belief can become false, children must first understand how one forms a belief. Seeing-knowing tasks tap this understanding, as children must make the connection between visual access to an object and knowledge about the object. In order for children to pass a seeing-knowing task, they must understand that the knowledge states of other people differ depending on what sensory information they possess.

Wellman and Liu (2004) have argued that theory-of-mind consists of a gradual progression of knowledge of mental states rather than a stark shift leading to an understanding of all types of theory-of-mind tasks. They created a scale of theory-of-mind tasks and demonstrated that children generally succeeded on these tasks in a set developmental sequence, such that no subsequent task was passed before the previous tasks in the sequence were mastered. One task in their scale, the "knowledge access" task, resembles the seeing-knowing task and in that it requires children to determine whether a doll knows the contents of a drawer before the doll looked inside the drawer. Importantly, the knowledge access task was mastered immediately before false-belief tasks and following success on an understanding of contrastive desires and beliefs (Wellman & Liu, 2004). Wellman and Liu's scale situates seeing and knowing tasks squarely in the domain of theory-of-mind reasoning. However, because their knowledge access task targeted only the sense of vision, we cannot rightly conclude that knowledge access via all senses precedes false-belief understanding.

Although an understanding of sensory access and knowledge may depend on earlier developments in theory of mind, an alternative possibility is that children come to understand the link between perception and knowledge through their interactions with objects in the world independent of a broader understanding of mental states. This explanation is consistent with Piaget's belief in the importance of experiential learning (Piaget, 1952). Weinberger and Bushnell (1994) reported that 4-year-olds were able to use vision to solve perceptual tasks and explain how they used vision to solve problems, but struggled to do the same for their other senses; they concluded children's earlier success with vision relative to their other senses stems from the fact that visual information is the most salient and consistent sensory information we receive. Specifically, they argued that when children interact with an object by feeling, hearing, tasting, or smelling it, they are almost always seeing the object simultaneously. Indeed preschoolers seem to have a weaker grasp on the connection between feeling or hearing and knowledge relative to their understanding of seeing and knowledge (Mossler et al., 1976; O'Neil et al., 1992).

The current study investigates children's understanding of hearing and seeing as sources of knowledge in order to extend the literature on sensory perception and to test whether an understanding of mental states or a greater degree of sensory experience best explains the pattern of children's development in this domain. We tested children on analogous tasks that targeted an understanding of hearing and seeing. If children master the connection between seeing and knowing before hearing and knowing, then we can infer that sensory experience plays a greater role than theory–of-mind in this development. However, if children perform equally well on the seeing and hearing trials, then the theory-of-mind explanation may be more accurate.

Methods

Participants

Sixty-four preschoolers (*M* = 4.0 years, range: 3.08-5.17 years, 34 females) from preschools in the Northeast region of the United States participated in this study. The sample consisted of thirty-three 3-year-olds (*M* = 3.47 years, range: 3.08-4.0 years) and thirty-one 4-year-olds (*M* = 4.57 years, range: 4.08-5.17 years).

Materials

Materials for this task included a blue wooden box with two large hinged doors on the top, and a small, hinged door at the back, 8 stuffed toy animals that make their respective sounds when squeezed, a set of pictures of the toy animals, a set of headphones, and a blindfold.

Procedure

Familiarization Session Children completed a training session to become familiar with the materials, the confederates, and the actions of seeing and hearing. The experimenter introduced the child to the two confederates and showed the child the box, a toy cat, and a toy dog. The experimenter presented the animals to the confederates, who each told the child that they could see each animal and hear each make its respective noise when squeezed. After seeing and hearing each animal, each confederate identified the animal, e.g. "It's a cat. I see it" or, "It's a dog. I hear it." The experimenter then hid one animal in the box, and one confederate wore a blindfold while the other looked inside the box. While looking in the box the confederate said, "I see the dog/cat". The experimenter then hid the other animal in the box, and one confederate covered her ears while the other confederate wore headphones and said, "I hear the dog/cat."

Seeing And Hearing Conditions Our task was derived from tasks used by Pratt and Bryant (1990) and O'Neill et al. (1992). In the three seeing trials, one confederate wore a blindfold and one did not. Two more toy animals, such as a stuffed pig and horse, were shown to the child, and then one was placed in the box without the confederates or the child seeing. One confederate peered inside the box while the other sat wearing a blindfold. After the confederate looked in the box, the second confederate slid the blindfold off of her eyes, but left it on her head to serve as a reminder to the child of who had been blindfolded. Then the child was asked whether each confederate knew what was inside the box (e.g., "Remember there is a pig or a horse in the box. Does confederate A know? Does confederate B know?"). After the child responded, the experimenter asked the confederates what was inside the box, and each confederate held up a picture of one of the two animals. The confederate who saw the toy animal held up the correct picture while the confederate who did not see the animal held up the incorrect one. The child was asked to choose which confederate was right. Throughout all trials, children were not informed of the identity of the hidden animal in order to avoid a situation in which children could simply select the reliable confederate (e.g., Jaswal & Neeley, 2006).

In the three hearing trials, one confederate wore a pair of headphones and one covered her ears. After listening to the animal through the headphones, the confederate slid the headphones off her ears and left them around her neck to serve as a reminder to the child of who had worn the headphones. Otherwise the hearing trials followed the same format as seeing trials. Condition, knowledgeable confederate, and which confederate was asked the questions first were counterbalanced across four random orders.

Scoring

Separate scores for the seeing and hearing conditions were computed. Within each condition we derived two scores, one for the responses to the knowledge state of each confederate, and one for the responses to identifying which confederate held up the correct picture of the animal hidden inside the box. The first score reflects a combination of the child's responses to the questions "Does she (confederate A) know" and "Does she (confederate B) know." A child who correctly answered that the confederate who had sensory access to the object also knew the identity of the object and that the confederate who did not have access to the object did not know the identity of the object earned 1 point for this two-part question, for a maximum score of 3 for the seeing condition and 3 for the hearing condition. For the second score, a child earned one point for correctly identifying the confederate who held up the correct object for a maximum score of 3 for each condition.

Results

Hearing four-year-olds (mean rank of 45.48) outperformed three-year-olds (mean rank of 20.30) on hearing and seeing trials when scores across the seeing and hearing conditions were collapsed for the "Does she know?" question (Mann Whitney U= 109, z = -5.62, p < .0001, r = .70). Four-year-olds (mean rank of 40.08) also outperformed three-year-olds (mean rank of 25.38) when scores were collapsed across seeing and hearing conditions for the "Who is right?" question (Mann Whitney U = 276.50, z = -3.25, p = .001, r = .41). When scores on hearing and seeing trials were analyzed separately, a similar pattern emerged. Four-year-olds (mean rank of 44.06) had superior performance to three-year-olds (mean rank of 21.64) on seeing trials for the "Does she know?" question (Mann Whitney U = 153, z = -5.13, p <.0001, r = .64). Four-year-olds (mean rank of 39.39) also had superior performance to three-year-olds (mean rank of 26.03) on seeing trials for the "Who is right?" question (Mann Whitney U = 298, z = -3.05, p =.002, r = .38). The difference between 4-year-olds' (mean rank of 44.5) and 3-year-olds' (mean rank of 21.23) performance on the hearing trials was significant for the "Does she know?" question (Mann Whitney U = 139.5, z = -5.43 p <.0001, r = .68). The difference between 4-year olds' (mean rank of

Table 1: Number of children who earned maximum score of 3 on seeing and hearing trials.

	Seeing	Hearing
Does she know?		
3-year-olds	3	5
4-year-olds	19	20
Who is right?		
3-year-olds	5	6
4-year-olds	17	19

37.5) and 3-year-olds' (mean rank of 27.89) performance was also significant following the "Who is right?" question (Mann Whitney $U = 359.5$, $z = -2.15$, $p = .03$, $r = .27$).

Only 6 out of 33 three-year-olds showed mastery in the hearing condition with a score of 3 following the "Who is right?" question whereas 17 out of 31 four-year-olds showed mastery (See Table 1). Similarly, only 5 out of 33 three-year-olds showed mastery in the seeing condition following the "Who is right?" question whereas 17 out of 31 four-year-olds showed mastery. Thus, overall, the comparison of 4-year-olds' performance to 3-year-old's performance indicates that 4-year-olds have a strong grasp of the connection between both hearing and knowing as well as seeing and knowing while 3-year-olds lack this understanding.

Additionally, there was no difference between performance on the hearing and seeing trials within participants, as children either performed well in both conditions or poorly in both conditions in both age groups. Specifically, Wilcoxon signed rank tests indicated that there was no difference between the seeing and hearing scores for 3-year-olds ($z = -.09$, $p = .93$) or 4-year-olds ($z = -.73$, $p = .47$) following the "Who is right?" question. Similarly, Wilcoxon signed rank tests indicated that there was no difference between the seeing and hearing scores for 3-year-olds ($z = -.07$, $p = .94$) or 4-year-olds ($z = -1.14$, $p = .25$) following the "Does she know" question. Crucially, mastery in one condition corresponded with mastery in the other. For the "Does she know?" question, no children answered all questions correctly in the seeing, but not the hearing condition. Only 2 children answered all questions in the hearing condition correctly but all questions in the seeing condition incorrectly. Similarly, for the "Who is right?" question, only 2 children answered all questions in the seeing, but not hearing condition correctly. Only 2 children answered all questions in the hearing condition correctly and all questions in the seeing condition incorrectly. These results indicate that across age groups, children have the same understanding of the connection between hearing and knowing as they do of seeing and knowing.

Discussion

The strong performance of 4-year-olds on all trials and relatively poorer performance of 3-year-olds indicates that children develop an understanding of both the seeing-knowing relationship and the hearing-knowing relationship between the ages of 3 and 4 years. This finding differs from some previous studies reporting that 3-year-olds perform well on seeing-knowing tasks (O'Neill et al., 1992; Pillow, 1989; Pratt & Bryant, 1990).

Some methodological differences may account for our discrepant finding. First, the mean age of the 3-year-old group in Pratt and Bryant's (1990) study is higher than ours (4.2 years vs. 3.5 years). Thus, younger but not older 3-year-olds may struggle to understand the relationship between seeing and knowing.

Second, our study used adult confederates while other studies used puppets or other children (O'Neill et al., 1992; Pillow, 1989; Pratt & Bryant, 1990). It could be the case that 3-year-olds overestimate the reliability of adult informants (e.g., Jaswal, Croft, Setia, & Cole, 2010). Indeed, the majority of 3-year-olds who failed the seeing and hearing trials incorrectly reported that both confederates knew the identity of the animal in the box. Our results, then, could indicate that young 3-year-olds may struggle to determine the knowledge states of trustworthy adults and not that they struggle to understand the relationship between seeing and knowing. This alternative explanation, however, does not likely account for the difference we observed between 3-year-olds and 4-year-olds: we never had a case where a child reported that both confederates were right.

A third reason for the difference between our findings and other studies is that in at least one other study children were involved in the hiding process and had sensory access to the hidden toy, which may have made the task easier for them to pass (O'Neill, et al., 1992). Finally some hidden objects used in previous studies had the same identity but were different colors, and the experimenter reminded the of the color difference, emphasizing that vision was the necessary sense to determine the correct answer (Pillow, 1989). Regardless, in our more difficult task, a clear developmental trajectory can be observed: young 3-year- olds struggle to understand the relationship between perception and knowledge, whereas 4-year-olds do not.

We observed no difference in performance between the seeing and hearing conditions, indicating that children come to understand these two senses as sources of knowledge at the same time. Researchers in this field have argued that vision is the most salient sense and thus should be the easiest for children to understand and explain (O'Neill et al., 1992; Weinberger & Bushnell, 1994). However, previous tasks that have targeted multiple senses have been more complex than the paradigm used in this study, with greater memory and language demands and with a focus on modality-specific properties of objects rather than a focus on object identities. Additionally, no study has created an analogous seeing-knowing task for the sense of hearing. The results of this study then, provide initial evidence that an early understanding of the link between seeing and knowledge formation and hearing and knowledge formation develop simultaneously, and that the arguably more salient experience with seeing, relative to hearing, does not lead to children's accelerated understanding of vision as a source of knowledge.

In order to determine how others use their senses to gain information about the world, children must be able to understand that different people can know different information based on their experiences. Four-year-olds, who typically pass an array of theory-of-mind tasks, performed well on both seeing and hearing trials. However three-year-olds, who typically do not pass such tasks, performed poorly on both seeing and hearing trials. The results of the present study are compatible with Wellman and Liu's (2004) suggested scale of theory-of-mind tasks. Passing a false-belief task, the classic theory-of-mind measure, requires children to initially determine how others gain knowledge based on their sensory access. While Wellman and Liu (2004) have investigated only children's understanding that vision leads to knowledge, the present study suggests that understanding how multiple senses lead to knowledge may be a precursor to understanding how false beliefs are formed, and as such, researchers should consider the ability to recognize that sensory perception leads to knowledge as an early form of theory-of-mind.

Although this study provides valuable preliminary support for the relative importance of understanding mental states over general experience with the senses in making the link between perception and knowledge, a more direct approach to test these alternatives is to test children who lack access to one of their senses. Without complete access to auditory information, deaf children may come to understand the capabilities of the auditory sense differently. They may make inaccurate assumptions regarding the capabilities of audition. The literature has established that deaf children of hearing parents are delayed in theory-of-mind understanding, but research has almost exclusively focused on false-belief tasks. While 5-year-old deaf children of deaf parents succeed on false-belief tasks, 7-year-old deaf children of hearing parents do not perform well on such tasks (Courtin & Melot, 1998; de Villiers & Pyers, 2001; Peterson & Siegal, 1995; Schick, P. de Villiers, J. de Villiers, & R. Hoffmeister, 2007; c.f. Wellman, Fang, & Peterson, 2011).

The performance of deaf children with hearing parents on the hearing and knowing task would serve as an indicator of whether sensory experience is necessary for understanding the connection between perception and knowledge or whether theory-of-mind is more closely related to this understanding. That is, if sensory experience plays a greater role we should see a dramatic dissociation between performance in the seeing and hearing conditions. Alternatively if an understanding of mental states plays a greater role, then this population of deaf children should be impaired on seeing and hearing trials.

Recent research has documented that deaf children are delayed in understanding that seeing leads to knowing (Wellman et al., 2011) and that they master the seeing-knowing connection before they master false-belief tasks. However, the language demands of the "knowledge access" task targeting seeing were great, and the deaf children may not have understood the task. Further, these children were required to infer the knowledge state of a doll before the doll interacted with an object. Inference is more difficult for children than recognizing the senses as sources of knowledge after witnessing another person's sensory interaction (O'Neill & Gopnik, 1991; Robinson, Haigh, & Pendle, 2008). Additionally children in the Wellman et al. (2011) study knew the object's identity before predicting the knowledge state of the doll. People often make more errors in determining the knowledge states of others when they themselves are knowledgeable about a given event (Birch & Bloom, 2007). For these reasons, the results of the Wellman et al. (2011) study may overestimate the delay in deaf children. Furthermore, without testing deaf children's understanding of hearing as a source of knowledge, conclusions cannot be firmly made regarding whether understanding the perception-knowledge connection is indeed one step to a mature theory-of-mind.

The consistent performance across modalities in combination with the age difference in performance points to the close relationship between theory-of-mind and the understanding of the connection between sensory perception and knowledge. Although young children learn much about the world through their own experiences, understanding that interacting with an object leads to knowledge about that object may require a grasp of mental states of the self and of others that 3-year-olds do not yet possess. Certainly these two explanations—theory of mind and sensory experience—are not mutually exclusive and likely work together in development, but our study supports the argument that sensory experience is insufficient on its own to be the driving force behind children's development of an understanding that sensory experiences inform knowledge states.

While our study highlights the importance of mastering the basic mental-state process of knowledge formation, preschool curriculum often focuses solely on the sensory experience of young children with stimulating materials that allow children to use all their senses. The current study suggests that what is equally important is to talk to children about what one learns from using the eyes, nose, ears, and hands. These sorts of conversations about mental states, especially when geared toward sensory perception, may help children to develop an understanding of the causal connection between perception and knowledge, which has implications for their own cognitive development.

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