Published in final edited form as:

J Exp Child Psychol. 2017 December ; 164: 239–249. doi:10.1016/j.jecp.2017.07.009.

Adding sound to theory of mind: Comparing children's development of mental-state understanding in the auditory and visual realms

Anita A. Hasni^a, Lauren B. Adamson^a, Rebecca A. Williamson^a, and Diana L. Robins^b

^aDepartment of Psychology, Georgia State University, Atlanta, GA, United States

^bA.J. Drexel Autism Institute, Drexel University, Philadelphia, PA, United States

Abstract

Theory-of-mind (ToM) gradually develops during the preschool years. Measures of ToM usually target visual experience, but auditory experiences also provide valuable social information. Given differences between the visual and auditory modalities (e.g., sights persist, sounds fade) and the important role environmental input plays in social-cognitive development, we asked whether modality might influence the progression of ToM development. The current study expands Wellman and Liu's (2004) ToM scale by testing 66 preschoolers using five standard visual ToM tasks and five newly-crafted auditory ToM tasks. Age and gender effects were found, with 4- and 5-year-old children demonstrating greater ToM abilities than 3-year-olds, and girls passing more tasks than boys; there was no significant effect of modality. Both visual and auditory tasks formed a scalable set. These results indicate that there is considerable consistency in when children are able to use visual and auditory inputs to reason about various aspects of others' mental states.

Keywords

Theory of Mind; False Belief; Cognition; Auditory; Social Understanding; Preschool

By age five, most children can reason about others' thoughts and feelings, a capacity referred to as theory of mind (ToM; Premack & Woodruff, 1978; Wimmer & Perner, 1983). ToM abilities enable children to predict others' desires, beliefs, and behaviors based on internal mental states even though mental states cannot be seen, heard, or felt (Scholl & Leslie, 1999). While most early research on mental-state understanding represented ToM as a single cognitive ability, indexed by false belief tasks, several contemporary researchers emphasize the importance of capturing a broader view that includes understanding of desires, knowledge, true and false beliefs, and emotions.

Address for correspondence: Anita A. Hasni, Georgia State University Department of Psychology, 140 Decatur Street, Atlanta, GA 30303-3083; ahasni1@student.gsu.edu.

Publisher's Disclaimer: This is a PDF file of an unedited manuscript that has been accepted for publication. As a service to our customers we are providing this early version of the manuscript. The manuscript will undergo copyediting, typesetting, and review of the resulting proof before it is published in its final citable form. Please note that during the production process errors may be discovered which could affect the content, and all legal disclaimers that apply to the journal pertain.

Wellman and Liu (2004) argued that ToM development is not a single cognitive achievement, but rather a series of increasingly difficult insights about the mind (see also Bloom & German, 2000; Fabricius & Khalil, 2009). They designed five tasks—Diverse Desires, Diverse Beliefs, Knowledge Access, False Belief, and Real-Apparent Emotions—to determine whether ToM insights develop in sequence. Using Guttman's (1944) scalogram analysis, they found that the five tasks formed a scale. That is, achievement on some tasks consistently preceded achievement on others such that once a task is failed all subsequent tasks along the scale likely are also failed. Since its debut, the ToM scale (Wellman & Liu, 2004) has been used to chart emerging mental-state abilities in children with developmental delays (Peterson, Wellman, & Liu, 2005; Zhang, Shao, & Zhang, 2016) and across cultures (Shahaeian, Peterson, Slaughter, & Wellman, 2011).

However, a key limitation to ToM assessment is the emphasis on the visual modality. Using predominantly visual tasks leaves open the possibility that ToM may emerge at a different rate or in a different sequence when children are reasoning about information they hear rather than see. Sounds contain properties that are private (MacLachlan, 1989) just like internal mental states, thus, assessing ToM abilities using auditory tasks can provide insight into how children reason about beliefs, desires, and emotions using information that they hear but do not see, a situation that is likely common for typically developing preschoolers. Furthermore, research using the current set of visual ToM tasks indicates that children with sensory challenges such as congenital blindness (Peterson, Peterson, & Webb, 2000) or autism spectrum disorder (ASD; Baron-Cohen, Leslie, & Frith, 1985) show substantial delays in developing ToM abilities. Our auditory ToM tasks may allow for a fuller assessment of how children with developmental difficulties understand others' minds.

Our goal was to investigate if the rate and sequence of ToM development are influenced by whether a child reasons using auditory or visual information. Like visual information, auditory information is central to interpersonal communication and learning. For example, Yaniv and Schatz (1998) found that 3-year-old children understand that someone who is unable to see something may still be able to hear it, and Williamson, Brooks, and Meltzoff (2013) found that children as young as age 2 years consider another's ability to perceive sound when trying to either wake or not wake a sleeping baby. In addition, Moll, Carpenter, and Tomasello (2014) demonstrated that 2-year-old children can track what sounds others have heard.

But several differences between the visual and auditory modalities may affect ToM reasoning. While visual input provides fast, reliable information from early infancy, speech gradually becomes the dominant source of information, especially about past and future events. Sounds offer cues unavailable to sight (Kirk, Diefendorf, Pisoni & Robbins, 1995); however, in contrast to visual stimulation, they fade rapidly, leaving the child to reason without sustained input. These differences might make ToM tasks more difficult when children hear rather than see relevant information.

To date, few studies of ToM have directly compared children's use of visual and auditory information. Existing studies emphasize children's ability to understand the link between sensory perception and knowledge access (Melis, Call, & Tomasello, 2010; Schmidt &

Pyers, 2014). For example, Melis et al. (2010) found that 3-year-olds can account for what others see and hear before committing a transgression. Further, Wimmer, Hogrefe, and Perner (1988) found that 3- to 5-year-old children perform similarly on knowledge access tasks that are presented verbally or visually. Yet, it remains unclear when children begin using auditory information to reason about desires, beliefs, and emotions.

The present study extended Wellman and Liu's (2004) ToM scale, which asked preschool children to reason about mental states based on visual cues. We investigate when and in what sequence preschoolers begin to understand others' mental states based on auditory information. We crafted auditory tasks that probe the same five aspects of ToM as Wellman and Liu (2004), and presented 3-, 4-, and 5-year-old children with our new tasks in addition to Wellman and Liu's visual ones. The five auditory tasks were designed to parallel the format and content of Wellman and Liu's tasks in their validated ToM scale using target stimuli that were sounds rather than sights. Regardless of modality, the experimenter first presented a vignette, next solicited the child's own mental state, then revealed the protagonist's mental state, and finally asked the child to predict how the protagonist would behave.

We asked whether and when preschool children are able to reason about mental states in the auditory realm. We hypothesized that children would perform similarly on the tasks assessing the same mental state regardless of modality. But given the differences between auditory and visual information, we expected that some tasks might be more difficult in the auditory realm, thus children might pass some auditory tasks later than the comparable visual tasks. We also asked whether our auditory tasks are scalable and, if so, whether children demonstrate the same sequence on both the auditory and visual tasks. We expected that the auditory ToM tasks would form a scalable set and that children would pass tasks in the same sequence in both the auditory and the visual realm.

Materials and Methods

Participants

Sixty-six typically developing children (30 girls) participated in this study: 22 3-year-olds ($range=35$ to 47 months; $M=37.7$, $SD=2.0$), 22 4-year-olds ($range=48$ to 59 months; $M=52.6$, $SD=3.9$) and 22 5-year-olds ($range=60$ to 69 months; $M=63.2$, $SD=3.2$). Children were recruited by contacting parents who volunteered for the university's developmental psychology subject pool. The sample consisted of 74% European Americans, 20% African Americans, 2% Asian Americans, and 4% biracial children. Three additional children were excluded from the final sample due to procedural error.

Procedure

Children completed the 10 ToM tasks during a 15-minute laboratory session. Each child was seated at a small table across from the experimenter and tested individually. The session was video-recorded from two cameras; one camera captured the child and stimuli and the other provided a profile view of the experimenter, child, and stimuli. All stimuli were kept out of sight until the relevant task was introduced.

Each child was randomly assigned to one of four presentation orders. Following Wellman and Liu's (2004) recommendations, each order began with a Diverse Desires task (auditory or visual) to ease the child into the tasks and ended with a Real-Apparent Emotions task (auditory or visual) since it was deemed the hardest task. The remaining eight tasks were randomly ordered with the constraint that the auditory and visual tasks assessing a given ToM construct were separated by at least one other task.

Tasks

We created a set of five auditory tasks using five visual tasks in Wellman & Liu's (2004) ToM scale as a model in order to discern how young children reason about mental-state representations in the auditory realm. As in Wellman & Liu's (2004) visual tasks, in each auditory task an experimenter first presented a brief vignette, next solicited the child's own mental state, then revealed the protagonist's mental state, and finally prompted the child to respond to two types of questions, control and target, to predict how the protagonist would behave (see Appendix A). For example, the Diverse Desires task assessed the child's understanding that people may have desires different than their own by introducing a doll named Mr. Jones who was presented with a choice. The child was first asked to indicate which object he or she desired (control). The experimenter then confirmed that the child's choice was a good one but that Mr. Jones desired the other one. In the visual task, the child was told Mr. Jones needed to choose one of two snacks represented by pictures of a carrot and a cookie; in the auditory task, the child was told Mr. Jones needed to choose between two instruments represented by sounds of a piano and a drum. The target question asked the child to indicate which one snack/instrument Mr. Jones would choose. To pass the task, the child had to inhibit his or her own desire and identify Mr. Jones' desire.

All responses were scored using a binary system (pass/fail). Both spoken and gestured responses were accepted. The task was scored a 1 if the child passed both questions correctly and a 0 if the child answered only one or neither correctly. Alternative answers (e.g., indicating that an "ambiguous" animal sound was a horse given the choices of cow and sheep) were also scored as 0. We calculated composite scores (maximum 10) based on the child's responses to each task as well as scores for the number of auditory (maximum 5) and number of visual (maximum 5) tasks passed.

Inter-observer Agreement

Two observers independently scored video records of the responses of 15 (23%) children, randomly selected across the three age groups. Observers agreed 95% of the time; Cohen's kappa (Cohen, 1960) was .92.

Results

Comparing Performance in the Visual and Auditory Modalities

Children passed a comparable number of auditory ($M_{score}=2.39$, $SD=1.30$) and visual tasks ($M_{score}=2.50$, $SD=1.34$), see Table 1.

Age and gender significantly affected children's performance, but modality did not. A 3 (age) $\times$ 2 (gender) $\times$ 2 (modality) repeated-measures analysis of variance (ANOVA) showed that, as expected, children passed significantly more tasks with increasing age,

$F(2,60)=21.34, p<.001, \eta_p^2=.416$ (see Figure 1). On average, 3-year-olds passed fewer than half of the 10 tasks ($M_{score}=3.0, SD=1.6$), 4-year-olds passed approximately half of the tasks ($M_{score}=5.6, SD=2.4$), and 5-year-olds passed more than half of all tasks ($M_{score}=6.7, SD=1.8$). Both 4- and 5-year-olds performed significantly better than 3-year-olds ($p<.001$); there was no significant difference in performance between 4- and 5-year-old children (Bonferroni post-hoc analyses). Gender also significantly affected children's performance, $F(1, 60)=4.12, p<.047, \eta_p^2=.064$, with girls ($M_{score}=5.5, SD=2.1$) outperforming boys ($M_{score}=4.4, SD=2.6$) on the number of tasks passed, $t(64)=-2.10, p=.04$.

Scaling Theory-of-Mind Development

The ToM scale (Wellman & Liu, 2004) was established based on the number of children who passed each task. Thus, the tasks were ordered with increasing difficulty as follows: Diverse Desires, Diverse Beliefs, Knowledge Access, False Belief, and Real-Apparent Emotions. We assessed children's performance on the visual and auditory tasks using the same order to determine whether each child fit strict Guttman (1944) patterns. Patterns ranged from passing none of the tasks (-----), to passing one (+----), two (++---), three (+++--), four (++++-), or all five tasks (+++++) in a given modality. A child who passed a harder task along the scale, but failed even one easier task demonstrated an alternative pattern and was categorized as "other."

Results were similar for the visual and auditory tasks. We found a strong relationship between Guttman scale score and age (months) for the visual ($r(66)=.60, p<.01$) and auditory tasks ($r(66)=.50, p<.01$). Most preschoolers either fit a Guttman scale pattern in both modalities (56%; 37 of 66) or did not fit the pattern for either (13.5%; 9 of 66). Children who only fit the scale in one modality more often conformed to patterns for the visual modality (70%; 14 of 20) than the auditory modality (30%; 6 of 20; see Appendix B). Overall, we found understanding Diverse Beliefs prior to Diverse Desires in the visual (43.8%; 7 of 16) and auditory (27.3%; 6 of 22) modalities to be the most common alternative pattern. In addition, we found that the coefficient of reproducibility (*Rep*, Green, 1956) was .95 and .92 for the visual and auditory tasks, respectively; values greater than .90 indicate scalable items.

Regardless of modality, Diverse Beliefs was significantly easier than False Beliefs (McNemar's $\chi^2(1)=25.93$ and $32.24, p<.001$ for auditory and visual, respectively), Knowledge Access was significantly easier than False Belief (McNemar's $\chi^2(1)=8.65$ and $8.45, p<.004$ for auditory and visual, respectively) and False Belief was significantly easier than Real-Apparent Emotions (McNemar's $\chi^2(1)=5.04$ and $5.06, p<.025$ for auditory and visual, respectively). Diverse Desires, however, was not significantly easier than Diverse Beliefs in either modality (McNemar's $\chi^2(1)=.45$ and $.01, p=ns$ for auditory and visual, respectively).

Assessing Difficulty of Tasks

To assess whether a task was failed because a child did not understand the narrative, we examined whether children who failed the target question also failed the control question. We found that most children who failed a target question nevertheless passed the control questions for Knowledge Access (74% auditory, 65% visual) and False Belief (85% auditory, 94% visual). In contrast, most children who failed the target question for Real-Apparent Emotions also failed at least one of its two control questions. Thus, children seemed to understand Knowledge Access and False Belief – but not the Real-Apparent Emotions—even if they did not extend their knowledge to the protagonist.

Discussion

Our study is the first to investigate children's abilities to reason about ToM using auditory information through five novel tasks that parallel Wellman and Liu's (2004) ToM scale. Consistent with previous research in the visual realm, we found that children's abilities to reason about others' mental states in the auditory realm increases with age. Moreover, the majority of children passed a comparable number of visual and auditory tasks, suggesting that a child who is able to reason about others' mental states of visual experiences can also reason about others' mental states of auditory experiences. Furthermore, Guttman (1944) scalogram analysis and Green's coefficient of reproducibility confirmed that our auditory tasks, like Wellman and Liu's (2004) visual ones, form a scalable set. Based on our sample, the most common pattern children fit in the Guttman scalogram was of Diverse Desires and Diverse Beliefs (Pattern 3) in the visual realm, and Diverse Desires, Diverse Beliefs, and Knowledge Access (Pattern 4) in the auditory realm.

Although the results of our study replicated Wellman and Liu's (2004) findings that children demonstrate ToM abilities prior to age four and have greater ability to reason about mental states with increasing age, there were some notable differences. First, considerably more children in Wellman & Liu's (2004) study passed the visual tasks at each age (see Table 1). Likely this is due in part to sample differences. Three-year-old children in our sample averaged 6 months younger than those of Wellman and Liu's (2004) sample, and although the average age of five-year-old children was similar, Wellman and Liu's study included children as old as six- and- a-half-years, while our oldest child was five years and nine months of age. Additionally, children in Wellman and Liu's sample were recruited from local preschools, whereas our sample was composed of volunteers from the community, which may have resulted in greater variability in demographic attributes such as parental education, child's educational environment, and income level.

Second, we found that more children in our sample than in Wellman and Liu's (2004) passed Diverse Beliefs prior to Diverse Desires in the visual modality. This reversal was most common at age three, which may indicate slight variations in the developmental course of ToM abilities. This possibility is worth exploring further; especially given findings that show culture can influence the emergence of different ToM abilities. Shahaeian, Peterson, Slaughter, and Wellman (2011), for instance, found reversals between children's emerging understanding of Diverse Beliefs and Knowledge Access when comparing Iranian and

Australian children, which they suggest may reflect variations in children's experiences in individualistic and collectivist cultures.

Third, unlike Wellman and Liu (2004), we found that girls passed significantly more tasks than boys, regardless of age or modality. Although the effect was relatively weak, it is consistent with previous studies (e.g., Charman, Ruffman, & Clements, 2002; Nelson, Adamson, & Bakeman, 2008). One possible explanation is that it reflects early gender differences in experience with talking about emotions (Dunn, Brown, & Beardsall, 1991; Taumoepeau & Ruffman, 2008).

Our new auditory ToM tasks may help clarify why some children display marked delays in acquiring ToM abilities. In particular, future studies may probe whether children with congenital blindness, who often display substantial delays in false belief understanding (Peterson, Peterson, & Webb, 2000), fail to pass a given task because they lack the ability to reason about the mental state construct or because the existing tasks emphasize visual experiences. Similarly, the new auditory tasks might provide fuller insight into the ToM deficits that young children with ASD often display (Peterson, Wellman, & Liu, 2005; Sodian, Schuwerk, & Kristen, 2015).

Additionally, using more tasks, and especially tasks that present information in varied ways, may provide a nuanced view of changes in ToM skills (see Steele, Joseph, & Tager-Flusberg, 2003). Also, more tasks may help identify specific points in ToM development where the course deviates from that of typically-developing children. Interestingly, Zhang, Shao, and Zhang (2016) found that Chinese children with ASD not only demonstrated significantly poorer performance than typically-developing Chinese children, but also that the children with ASD passed the Knowledge Access task prior to the Diverse Beliefs task. In addition to increasing the number of available tasks, our auditory tasks may provide an important methodological advance for exploring ToM development in children with ASD as they often display unusual sensory propensities (Ben-Sasson et al., 2007; Wiggins, Robins, Adamson, & Bakeman, 2009).

In conclusion, our novel ToM tasks extend research on children's emerging understanding of minds into the auditory realm. The addition of five new scalable auditory tasks enables researchers to probe the underlying constructs of ToM from a second modality. Our results confirm that children are able to reason about others' mental states prior to age four (Gelman & Au, 1996; Wellman & Liu, 2004) using auditory as well as visual information. We also find that the five aspects of ToM assessed in this study emerge in the visual and auditory modalities around the same age. And finally, although some children did not fit the Guttman patterns, our auditory tasks form a scalable set, indicating that ToM development is not a single cognitive achievement, but rather a series of abilities that emerge during the preschool years in both visual and auditory realms. Taken together, our results underscore the cognitive foundation for ToM development by demonstrating that once children master a given aspect of ToM, their ability to reason about others' internal mental states transcends modality. At the core, preschoolers' emerging abilities to reason about desires, beliefs, and other mental states are internal to the child and not directly observable. In showing that children are able to reason about multiple mental states in the auditory realm, this study broadens our current

understanding of children's emerging ToM abilities and opens a new line of research on social cognition.

Appendix A: Auditory and Visual Task Descriptions

Task	Auditory version	Visual version
Diverse Desires	C was introduced to Mr. Jones (figurine) and a sound clip of a piano and a sound clip of drums. E said: "It's music time and Mr. Jones wants to choose an instrument to hear. Here are two different instruments: the piano and the drums. Which instrument would you like best? (own desire) Would you like to hear the piano or the drums best?" After C made a selection, E said: "Well, that's a good choice, but Mr. Jones really likes ____ (opposite of C's desire). He doesn't like ____ (C's desire). What he likes best is/are _____. So, now it's music time. Mr. Jones can only choose one instrument, just one. Which instrument will Mr. Jones choose? The piano or the drums?" (target) To be scored as correct, C must answer the target opposite from his/her answer to the own-desire.	C was introduced to Mr. Jones (figurine) and a sheet of paper depicting a carrot and a cookie. E said: "It's snack time and Mr. Jones wants to choose a snack to eat. Here are two different snacks: a carrot and a cookie. Which snack would you like best? (own desire) Would you like a carrot or a cookie best?" After C made a selection, E said: "Well, that's a good choice, but Mr. Jones really likes ____ (opposite of C's desire). He doesn't like ____ (C's desire). What he likes best is/are _____. So, now it's time to eat. Mr. Jones can only choose one snack, just one. Which snack will Mr. Jones choose? The carrot or the cookie?" (target) To be scored as correct, C must answer the target opposite from his/her answer to the own-desire.
Diverse Beliefs	C was introduced to Linda (figurine) and hears an ambiguous sound clip. E said: "Here's Linda. Linda wants to find out what this sound is (play sound). The sound might be a cow or it might be a sheep. What do you think the sound is? (own belief) A cow sound or a sheep sound? After C makes a selection, E said: "Well, that's a good idea, but Linda thinks it's a ____ (opposite of C's belief). She thinks it sounds like a _____. (opposite of C's belief). "So, what does Linda think the sound is? (target) A cow sound or a sheep sound? To be scored as correct C must answer the target question opposite from his/her answer to the own-belief question.	C was introduced to Linda (figurine) and a sheet of paper depicting bushes and a garage. E said: "Here's Linda. Linda wants to find her cat. Her cat might be hiding in the bushes or it might be hiding in the garage. Where do you think the cat is hiding? (own belief) In the bushes or in the garage?" After C makes a selection, E said: "Well, that's a good idea, but Linda thinks her cat is in the ____ (opposite of C's belief). She thinks her cat is in the _____. (opposite of C's belief). "So, where will Linda look for her cat? In the bushes or in the garage? (target) To be scored as correct C must answer the target opposite from his/her answer to the own-belief question.
Knowledge Access	C was introduced to Polly (figurine) and a nondescript, sealed, opaque box containing pennies (not visible). E said: "Here's a box. What do you think is inside the box? C was asked to guess, then E said: "Let's listen (rattle box), there are really pennies inside! Okay, so what's in the box? (control). After C correctly identified the contents of the box. E said: "Polly has never ever heard what's inside this box. Now here comes Polly. So, does Polly know what is in the box? (target) Did Polly hear what's inside this box?" (control) To be scored as correct C must answer both the target and control questions "no".	C was introduced to Polly (figurine) and a nondescript, box containing a toy dog (not visible). E said: "Here's a box. What do you think is inside the box? C was asked to a guess, then E said: "Let's see, there's really a dog inside! E opened the box to reveal a toy dog, and then closed it to restrict C's view. E asked: "Okay, so what's in the box?" (control) After C correctly identified the contents of the box, E said: "Polly has never ever seen inside this box. Now here comes Polly. So, does Polly know what is in the box? (target) Did Polly see inside this box?" (control) To be scored as correct C must answer both the target and control questions "no".
False Belief-Contents	C was introduced to Peter (figurine) and a stuffed animal toy dog containing the audio recording of a cat meowing. E said: "Here is a toy. What sound do you think this toy will make? Let's listen (play sound), that's really a cat meowing! Okay, so what sound does this toy make?" Then E said: "Peter has never ever heard the sound this toy makes. Now here comes Peter. So, what sound does Peter think the toy will make? (target) A cat sound or a dog sound? Did Peter hear the sound this toy makes?" (control). To be scored correct C	C was introduced to Peter (figurine) and a Band-Aid box containing a toy pig (not visible). E said: "Here is a Band-Aid box. What do you think is inside the Band-Aid box? Let's see, there's really a pig inside!" After revealing the contents of the box, E said: "Okay, so what's in the box?" Then E said: "Peter has never ever seen inside this Band-Aid box. Now here comes Peter. So, what does Peter think is in the box? (target) Band-Aids or a Pig? Did Peter see inside this box?" (control) To be scored

Task	Auditory version	Visual version
	must answer the target “dog” and the control “no.”	correct C must answer the target “Band-Aids” and the control “no.”
Real-Apparent Emotion	<p>C was introduced to Matt (figurine), specifically the back of Matt's head to avoid revealing any emotion. E said: “This story is about Matt. Matt's aunt is on the phone. She promised that she would take Matt to visit the zoo today, but when she called she told Matt that she is taking him to the mall instead. Matt doesn't like going to the mall. What Matt really wants to do is go to the zoo, but Matt has to hide how he feels because if his aunt knows his real feelings she will never take him anywhere again.” E asked C: “So, where did Matt's aunt say she was taking him? (control) What will Matt's aunt do if she knows how Matt really feels? (control) Then E said: “So, how did Matt really feel when his aunt called to tell him where they were going—Happy, Sad, or Okay? How did Matt try to sound in his voice when he was talking to his aunt—Happy, Sad, or Okay? To be scored as correct C's answer to the really-feel question had to be more negative than his/her answer to the look question.</p>	<p>C was introduced to Matt (figurine), specifically the back of Matt's head to avoid revealing any emotion. E said: “This story is about Matt. Matt's aunt just got back from a trip. She promised that she would buy Matt a toy car, but, she got Matt a book instead. Matt doesn't like books. What Matt really wants is a toy car, but Matt has to hide how he feels, because if his aunt knows his real feelings, she'll never buy him anything again.” E asked C: “So, what did Matt's aunt buy for him? (control) What will Matt's aunt do, if she knows how Matt really feels?” (control) Then, E said: “So, how did Matt really feel when his aunt gave him the book—Happy, Sad, or Okay? How did Matt try to look on his face when his aunt gave him the book— Happy, Sad, or Okay? To be scored as correct C's answer to the really-feel question had to be more negative than his/her answer to the look question</p>

Note. C represents the child and E represents the experimenter.

Appendix B: Patterns for the Visual and Auditory ToM Guttman Scales and Number of Children who Fit Each Pattern

	P1	P2	P3	P4	P5	P6	Other
Diverse Desires	-	+	+	+	+	+	
Diverse Beliefs	-	-	+	+	+	+	
Knowledge Access	-	-	-	+	+	+	
False Belief-Contents	-	-	-	-	+	+	
Real-Apparent Emotion	-	-	-	-	-	+	
<i>Visual</i>							
3-year-olds	4	3	8	1	0	0	6
4-year-olds	0	0	5	3	4	2	8
5-year-olds	0	1	2	9	5	3	2
Total	4	4	15	13	9	5	16
<i>Auditory</i>							
3-year-olds	3	3	3	1	0	0	12
4-year-olds	1	1	5	6	4	0	5
5-year-olds	0	1	2	6	6	2	5
Total	4	5	10	13	10	2	22

Note. A minus sign (-) indicates that the child failed the task; a plus sign (+) indicates the child passed. Any child who did not exhibit one of the six patterns (P) presented above was categorized as “Other.” $N = 66$, 22 children in each age group.

References

- Baron-Cohen S, Leslie AM, Frith U. Does the autistic child have a “theory of mind”? *Cognition*. 1985; 21(1):37–46. [PubMed: 2934210]
- Ben-Sasson A, Cermak SA, Orsmond GI, Tager-Flusberg H, Carter AS, Kadlec MB, Dunn W. Extreme sensory modulation behaviors in toddlers with autism spectrum disorders. *American Journal of Occupational Therapy*. 2007; 61(5):584–592. [PubMed: 17944296]
- Bloom P, German TP. Two reasons to abandon the false belief task as a test of theory of mind. *Cognition*. 2000; 77:B25–B31. DOI: 10.1016/S0010-0277(00)00096-2 [PubMed: 10980256]
- Charman T, Ruffman T, Clements W. Is there a gender difference in false belief development? *Social Development*. 2002; 11(1):1–10. DOI: 10.1111/1467-9507.00183
- Cohen J. A coefficient of agreement for nominal scales. *Educational and Psychological Measurement*. 1960; 20:37–46.
- Dunn J, Brown J, Beardsall L. Family talk about feeling states and children's later understanding of others' emotions. *Developmental Psychology*. 1991; 27(3):446–455.
- Fabricius WV, Khalil SL. False beliefs or false positives? Limits on children's understanding of mental representation. *Journal of Cognition and Development*. 2009; 4(3):239–262. DOI: 10.1207/S15327647JCD0403_01
- Gelman, R., Au, TKF. *Perceptual and Cognitive Development*. San Diego, CA: Academic Press; 1996.
- Green BF. A method of scalogram analysis using summary statistics. *Psychometrika*. 1956; 21:79–88.
- Guttman L. A basis of scaling quantitative data. *American Sociological Review*. 1944; 9:139–150.
- Kirk KI, Diefendorf AO, Pisoni DB, Robbins AM. Assessing speech perception in children. *Research on Spoken Language Processing*. 1995; 20:163–198.
- MacLachlan, DLC. *Philosophy of Perception*. Englewood Cliffs, NJ: Prentice Hall; 1989.
- Melis AP, Call J, Tomasello M. 36-month-olds conceal visual and auditory information from others. *Developmental Science*. 2010; :479–489. DOI: 10.1111/j.1467-7687.2009.00892.x [PubMed: 20443968]
- Moll H, Carpenter M, Tomasello M. Two- and Three-Year-Olds know what others have and have not heard. *Journal of Cognition and Development*. 2014; 15(1):12–21. DOI: 10.1080/15248372.2012.710865
- Nelson PB, Adamson LB, Bakeman R. Toddlers' joint engagement experience facilitates preschoolers' acquisition of theory of mind. *Developmental Science*. 2008; 11(6):847–852. DOI: 10.1111/j.1467-7687.2008.00733.x [PubMed: 19046153]
- Peterson CC, Peterson JL, Webb J. Factors influencing the development of a theory of mind in blind children. *British Journal of Developmental Psychology*. 2000; 18:431–447. DOI: 10.1348/026151000165788
- Peterson CC, Wellman HM, Liu D. Steps in theory-of-mind development for children with deafness or autism. *Child Development*. 2005; 76(2):502–517. DOI: 10.1111/j.1467-8624.2005.00859.x [PubMed: 15784096]
- Premack D, Woodruff G. *Behavioral Brain Science*. 1978; 1:515–526.
- Schmidt E, Pyers J. First-hand sensory experience plays a limited role in children's early understanding of seeing and hearing as sources of knowledge: Evidence from typically hearing and deaf children. *British Journal of Developmental Psychology*. 2014; 32:454–467. DOI: 10.1111/bjdp.12057 [PubMed: 25138156]
- Scholl BJ, Leslie AM. Modularity, Development, and ‘Theory of Mind’. *Mind & Language*. 1999; 14(1):131–153.
- Shahaeian A, Peterson CC, Slaughter V, Wellman HM. Culture and the sequence of steps in theory of mind development. *Developmental Psychology*. 2011; 47(5):1239–1247. DOI: 10.1037/a0023899 [PubMed: 21639620]
- Sodian, B., Schuwerk, T., Kristen, S, Fitzgerald, Michael, editor. *Implicit and Spontaneous Theory of Mind Reasoning in Autism Spectrum Disorders*. Autism Spectrum Disorder-Recent Advances (Chapter 7). 2015. Retrieved from: <http://dx.doi.org/10.5772/59393>

- Steele S, Joseph RM, Tager-Flusberg H. Brief Report: Developmental change in theory of mind abilities in children with autism. *Journal of Autism and Developmental Disorders*. 2003; 33(4): 461–467. DOI: 10.1023/A:1025075115100 [PubMed: 12959426]
- Taumoepeau M, Ruffman T. Stepping stones to other's minds: Maternal talk relates to child mental state language and emotion understanding at 15, 24, and 33 months. *Child Development*. 2008; 79(2):284–302. DOI: 10.1111/j.1467-8624.2007.01126.x [PubMed: 18366424]
- Wellman HM, Liu D. Scaling of theory-of-mind tasks. *Child Development*. 2004; 75(2):523–541. DOI: 10.1111/j.1467-8624.2004.00691.x [PubMed: 15056204]
- Wiggins LD, Robins DL, Bakeman R, Adamson LB. Brief report: Sensory abnormalities as distinguishing symptoms of autism spectrum disorders in young children. *Journal of Autism and Developmental Disorders*. 2009; 39(7):1087–1091. [PubMed: 19283461]
- Williamson RA, Brooks R, Meltzoff AN. The sound of social cognition: Toddlers' understanding of how sound influences others. *Journal of Cognition and Development*. 2013; 16(2):252–260. DOI: 10.1007/s10803-009-0711-x
- Wimmer H, Hogrefe GJ, Perner J. Children's understanding of informational access as source of knowledge. *Child Development*. 1988:386–396.
- Wimmer H, Perner J. Beliefs about beliefs: Representation and constraining function of wrong beliefs in young children's understanding of deception. *Cognition*. 1983; 13:103–112. DOI: 10.1016/0010-0277(83)90004-5 [PubMed: 6681741]
- Yaniv, I., Schatz, M. Children's understanding of perceptibility. In: Astington, JW, Harris, PL., Olson, DR., editors. *Developing Theories of Mind*. Cambridge: Cambridge University Press; 1988. p. 93–108.
- Zhang T, Shao Z, Zhang Y. Developmental steps in theory of mind of typical Chinese children and Chinese children with autism spectrum disorder. *Research in Autism Spectrum Disorders*. 2016; 23:210–220. DOI: 10.1016/j.rasd.2015.10.005

Research Highlights

- Wellman and Liu's (2004) theory-of-mind (ToM) scale was expanded to include five novel tasks that assess mental-state understanding in the auditory realm.
- Preschool children's ability to reason about mental states was significantly affected by age and gender, but not by modality (auditory or visual) of the task.
- The auditory tasks form a scalable set that can be used to chart emerging theory-of-mind abilities.

Figure 1.

Proportion of children correct on each task by modality (auditory or visual) and age. The 10 tasks are abbreviated above as: Diverse Desires (DD), Diverse Beliefs (DB), Knowledge Access (KA), False Belief (FB), Real-Apparent Emotion (RAE). $N = 66$.

Table 1
Numbers (and Percentages) of Children who Passed the ToM Tasks

	<i>Auditory Tasks N = 66</i>	<i>Visual Tasks N = 66</i>	<i>Wellman & Liu (2004) N = 75</i>
Diverse Desires	48 (72.7)	52 (78.8)	71 (95)
Diverse Beliefs	52 (78.8)	54 (81.8)	63 (84)
Knowledge Access	32 (48.5)	32 (48.5)	55 (73)
False Belief-Contents	18 (27.3)	18 (27.3)	44 (59)
Real-Apparent Emotion	8 (12.1)	8 (12.1)	24 (32)

Note. The table shows the total number (and percentage) of children correct on each task, ordered from the easiest to the hardest, as per the theory-of-mind scale. Wellman and Liu's (2004) results include data from 75, 3-, 4-, and 5-year-olds.