Categorization Ability, but Not Theory of Mind, Contributes to Children's Developing Understanding of Expertise

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Abstract

Children as young as age 3 understand that different people have different areas of expertise (i.e., the division of cognitive labor) and they choose information sources accordingly (e.g., Lutz & Keil, 2002). However, it is unclear whether this understanding depends primarily on social cognitive skills, such as an appreciation of others' mental states, or non-social cognitive skills, such as the ability to categorize different types of entities. To address this question, children ages 3 to 5 (n=63) completed tasks measuring social and non-social cognitive skills, and made inferences about what two unfamiliar experts would know. The results demonstrate that developmental differences in children's understanding of expertise are mediated through concomitant differences in categorization ability, but not theory of mind.

Keywords: Theory of mind; categorization; expertise; conceptual development; social cognition.

Introduction

It is impossible for one person to know everything. Instead, individuals have non-overlapping knowledge bases such that each person acquires some information firsthand but must rely on other people to access additional information. Because young children are very limited in their direct access to information and they must rely primarily on others for answers, it is unsurprising that the ability to evaluate potential information sources emerges early in life (see Harris, 2012). One way that children can evaluate informants is by considering their areas of expertise. By age 3, children demonstrate a basic understanding of expertise and its relevance for choosing informants. They prefer to consult a car mechanic over a doctor to learn about fixing a bicycle (Lutz & Keil, 2002; Shenouda & Danovitch, 2013) and they trust a dog expert to teach them about dogs, but not about artifacts (Koenig & Jaswal, 2011). By age 5, children can identify which of three familiar experts is best suited to answering a question (Aguiar, Stoess, & Taylor, 2012). Children this age not only infer that an expert is likely to know about phenomena closely related to his or her area of expertise, but they also extend the expert's knowledge to more distantly related phenomena that involve the same underlying causal principles. For example, children indicate that a bicycle expert would also know about how other vehicles, such as trains and cars, work and would even have a superior understanding of other mechanical devices, such as yo-yos and ladders, relative to an individual with expertise in a biological domain. These findings suggest that by age 5 children already have an understanding of how knowledge clusters in other minds, without having necessarily received explicit instruction about the domains of expertise involved.

Although children make quite sophisticated judgments about expertise by age 5, this ability emerges gradually over the preschool years. Lutz and Keil (2002) found that 3-year-olds restricted expert knowledge to phenomena involving topics closely related to an expert's area of interest (what Lutz & Keil call the "near" category, e.g., judging that an eagle expert knows how ducks swim). By age 4, children extended expert knowledge to questions about more distantly related phenomena (the "middle" category, e.g., how dogs breathe) and, by age 5, they did so for questions about even more distantly related phenomena with the same underlying causal principles (e.g., why apples are sweet). How do children make these inferences without prior instruction or familiarity with scientific domains? According to Lutz and Keil, children do not base their judgments on mere semantic associations or associations between the topics in question. Instead, children's choices reflect their application of cognitive schemas that tap into the common principles underlying phenomena in domains such as biology and physics. Children refine these schemas and apply them more flexibly as they mature, resulting in increasingly sophisticated judgments about expertise throughout middle childhood (Danovitch & Keil, 2004; Keil et al., 2008).

Children's reasoning about expertise becomes more sophisticated and nuanced between ages 3 and 5, yet the sources of developmental differences in their reasoning remain unexplored. What skills contribute to children's ability to draw inferences about the way knowledge clusters in expert minds? The current study explores several potential contributors to developmental and individual differences in inferring expert knowledge, with a special emphasis on children's social cognitive understanding and their categorization skill.

Children are motivated from infancy to seek out other people and to understand other minds (see Flavell & Miller, 1998), and it seems likely that judging expertise requires at least a basic appreciation that other minds are different from

one's own, known as theory of mind (ToM). Specifically, deciding which of two experts to consult may require knowing that 1) different experts have different, sometimes non-overlapping, knowledge bases, and 2) an expert is more likely to provide accurate answers to questions related to his or her expertise than a non-expert. ToM skills undergo dramatic improvement between ages 3 and 5 (see Wellman, Cross, & Watson, 2001) and there is some evidence that children with a more advanced ToM are more adept at evaluating informants based on past accuracy (Fusaro & Harris, 2008, but see Pasquini et al., 2007). Thus, children's developing ability to infer what a particular expert knows may be closely tied to their emerging understanding of others' mental states.

A different type of skill that may underlie children's understanding of expertise is a form of non-social reasoning: the ability to categorize objects. Within their first few years, children group objects into categories (e.g., Mandler & Bauer, 1988) and use these categories as a basis for inductive judgments (see Gelman, 2003). For example, if a novel animal is categorized as a dog, children assume it shares more characteristics with other dogs than with cats. Categorization skill may play a critical role in children's inferences about who is likely to provide the best answer to a question by enabling the child to connect areas of expertise with the phenomenon in question without necessarily knowing much about the phenomenon themselves. For instance, in order to determine whether an eagle or a bicycle expert knows more about how flowers bloom, a child might begin by categorizing both eagles and flowers as living things and bicycles as non-living artifacts. Thus, despite the fact that judgments about knowledge and expertise involve people, children's understanding of the division of cognitive labor may be rooted in their non-social-cognitive skills.

The objective of the current study was to determine to what extent categorization ability (CA) and ToM contribute to children's developing understanding of the division of cognitive labor and account for developmental differences in their understanding. The current study also addresses two additional factors that could potentially mediate or contribute directly to children's understanding of expert knowledge: executive function (EF) and language skills. There is evidence that EF, broadly defined as the ability to regulate one's own behavior, is linked to children's understanding of false-beliefs (e.g., Carlson & Moses, 2001, Sabbagh et al., 2006). It could also be important for categorization if one assumes that children must successfully inhibit responses grounded in more simple heuristics, such as perceptual similarity, in order to categorize objects in terms of more abstract features. Although there are many ways of defining and measuring EF, we selected tasks that tap into inhibitory control (e.g., the day/night stroop; Gerstadt, Hong, & Diamond, 1994), and attention shifting and flexibility (e.g., the dimensional card sort; Frye, Zelazo, & Palfai, 1995), as we predicted that these skills would have the closest link to categorization. A

measure of children's receptive language was also included because verbally skillful children are likely to have higher ToM scores (e.g., Happe, 1995) and they may consequently be better at comprehending statements and questions about the topic of an individual's expertise.

Because a basic understanding of the topics in question seems necessary for making judgments about expertise, in addition to evidence that older children use schemas to cluster knowledge (e.g., Keil et al., 2008), CA was hypothesized to predict young children's understanding of expertise to some extent. However, hypotheses for the role of ToM were less clear. Because reasoning about expertise is intimately related to predicting and representing knowledge in other people's minds, ToM seems necessary to infer expert knowledge. On the other hand, ToM could be a relatively minor contributor to understanding expertise if children can potentially make correct judgments about an unfamiliar expert's knowledge simply by linking the topic of expertise (e.g., eagles, bicycles) to the topic of the question (e.g., ducks, elevators) without necessarily appreciating the expert's mental states. The purpose of this investigation was to clarify the role of CA and ToM with respect to understanding the division of cognitive labor. Because CA, ToM, and children's understanding of expertise were all expected to improve with age, and with improving verbal and EF abilities, the analyses focus on whether CA and ToM mediate age-related differences in children's understanding of the division of cognitive labor.

Method

Participants

Nineteen 3-year-olds ranging from 3.07 to 3.84 ($M = 3.52$, 7 males), 26 4-year-olds ranging from 4.02 to 4.98 ($M = 4.55$, 16 males), and 18 5-year-olds ranging from 5.09 to 5.63 ($M = 5.40$, 8 males) participated at preschools in a mid-sized Midwestern city. The majority of the children were identified by their parents as Caucasian-American and non-Hispanic.

Materials and procedure

Theory of Mind tasks. The ToM tasks consisted of four measures of children's understanding of other people's mental states, drawn from Wellman and Liu's (2004) ToM scale: diverse desires, diverse beliefs, knowledge access and contents false belief. Tasks were administered and scored exactly as described by Wellman and Liu, with 1 point awarded for correct responses to the entire measure (including control questions). Summing the scores from each task yielded a total ToM score of 0 to 4 for each child.

Expert knowledge. The script for the expert knowledge task was drawn verbatim from Lutz and Keil (2002, Experiment 2). Questions involved 8 "near" phenomena involving a closely related category (e.g., "who would know more about how chickens lay eggs?"), 8 "middle" phenomena involving a more distantly related category

Table 1

Means, standard deviations, and Pearson correlations for primary study measures.

	M	*S.D.*	1.	2.	3.	4.	5.	6.	7.
1. Age	4.48	.77	-	-	-	-	-	-	-
2. PPVT	115.90	15.38	-.05	-	-	-	-	-	-
3. Categorization	15.71	3.95	.327**	.239	-	-	-	-	-
4. Theory of Mind	2.68	1.06	.421**	.106	-.037	-	-	-	-
5. Executive function	.60	.31	.428**	.420**	.203	.270*	-	-	-
6. Expert knowledge: near	5.82	1.47	.291*	.141	.443**	.016	.134	-	-
7. Expert knowledge: middle	5.17	1.65	.400**	.285*	.406**	.060	.304*	.526**	-
8. Expert knowledge: underlying principles	4.76	1.57	.174	.196	.298*	-.104	.185	.479**	.445**

Note. * indicates $p < .05$, ** indicates $p < .01$

(e.g., "who would know more about how elevators go up and down?"), and 8 phenomena involving the same underlying principles of biology or physics (e.g., "who would know more about what makes grass green?"). (The classification of questions into "near," "middle," and "underlying principles" was drawn directly from Lutz & Keil). The order in which the experts were introduced was balanced across participants and the questions were intermixed and presented in one of two orders. Correct responses were totaled to yield scores of 0 to 8 for each category of items.

Categorization. In the categorization task, children were presented with images of an eagle and a bicycle (from the expert knowledge task) on a sheet of paper. Children then viewed a card with an image of an object and were told: "This is a [object name]. Which one does a [object] go with?" Images were black-and-white line drawings. The 24 objects corresponded to the subject of each question in the expert knowledge task (e.g., chicken, elevator, grass). The location of the target pictures on the paper were balanced across participants and the object images were presented in one of two random orders. Responses were scored as correct if the choice of object corresponded to the correct response on the expert knowledge task (e.g., pairing the chicken with the eagle).

Language ability. Children completed the Peabody Picture Vocabulary Test, Form B (PPVT-4; Dunn & Dunn, 2007), a measure of receptive language. Standardized scores were used for data analysis.

Executive function. Participants completed the day/night stroop (Gerstadt, Hong, & Diamond, 1994) with their score being the proportion correct out of 16 trials and the dimensional change card sort task (Frye, Zelazo, & Palfai, 1995; Zelazo, Frye, & Rapus, 1996) with their score being the proportion correct of 8 post-switch trials. A mean EF score was calculated based on the proportion of correct responses generated in each task.

Order of presentation. Data was collected over 2 sessions. Fifty-six participants completed the sessions exactly 7 days apart, 6 participants completed them 8 days apart, and 1 participant completed them 6 days apart. During one session, children completed the categorization tasks, diverse beliefs task, knowledge access task, and language measures. During the other session, they completed the expert knowledge, day/night, contents false belief, diverse desires, and dimensional change card sort task. The order of the sessions was balanced across participants.

Results

Preliminary analyses showed no effect of session order on children's performance on any of the measures.

On the expert knowledge task, all three age groups performed above chance on the near category items, ts ≥ 4.916, ps ≤ .001 (Bonferroni corrected). The 4- and 5-year olds performed above chance on the middle category items, ts ≥ 4.294, ps ≤ .001 (Bonferroni corrected). The 5-year olds also performed well on the underlying principles items, $t(17) = 2.701$, $p = .015$, although this value was not significant following the Bonferonni correction.

A 3(Item Type) X 3(Age Group) repeated-measures ANOVA indicated significant main effects of Item Type, $F(2, 120) = 14.442$, $p < .001$, $\eta_p^2 = .194$, and Age, $F(2, 60) = 3.148$, $p = .050$, $\eta_p^2 = .095$, but no significant interaction. Post-hoc Bonferroni tests revealed that the effect of age was driven by differences between 3- and 5-year-olds' scores, $p = .045$. Paired-samples t-tests collapsed across age revealed significant differences between children's scores on the near and middle category items, $t(62) = 3.386$, $p = .001$, and between the near and underlying principles items, $t(62) = 5.432$, $p < .001$. There was also a marginally significant difference between scores on middle and underlying principles items, $t(62) = 1.926$, $p = .059$.

Treating children's exact age (calculated at the first session) as a continuous variable showed a strong positive

correlation with performance on all measures, except for standardized language scores, as expected (see Table 1). Thus, we positioned age and language as predictor variables in our model. Since the literature clearly links age to EF, we inserted it as a mediating variable between age and our mediators of interest, ToM and CA, whose influences on children's performance on near, middle, and underlying principles we attempted to predict (see Figure 1). Path analysis revealed that age was a positive predictor of EF, ToM, and CA, and that PPVT scores predicted CA, but not ToM. Surprisingly, ToM was not a significant predictor of children's performance on any of the expert knowledge task categories. CA was a significant, and marginally significant, positive predictor of performance on near and middle items, respectively, but it did not predict performance on underlying principles items. CA clearly predicted performance on the expert knowledge task overall, but it did not fully mediate the effects of age and language, and language was only a marginally significant positive predictor of performance on middle items. Generally, age and CA were predictive of performance on the expert knowledge task and language, EF, and ToM were not. The model accounted for 23% of the variance in overall scores on near items, $F(5, 57) = 3.40$, $p = .009$, 25% of the variance in overall scores on middle items, $F(5, 57) = 5.20$, $p = .001$, and 15% of the variance in overall scores on middle items, $F(5, 57) = 2.01$, $p = .091$. For near and middle category items, the model accounted for significantly more variance than age alone (all $ps < .05$), but the increase in predictive power that these additional variables brought to predicting children's scores on underlying principles items was only marginally significant

($p = .106$).

Discussion

Children's ability to categorize objects predicted their understanding of expert knowledge for near and middle items, but not for items focused on underlying principles. Deciding whom to consult for the answer to a question is an inherently social judgment, but the current findings suggest that this competency is also strongly grounded in an understanding of the categorical association between a person's domain of expertise and the topic of the question. Critically, CA, but not ToM, partially mediated age-related improvements in understanding expertise, and also independently predicted children's performance. Thus, categorization skills play a critical role in enabling children to make sophisticated social judgments.

Children may have used a number of different strategies to solve the categorization task. They could have relied on the living kind/artifact distinction (e.g., a skunk and an eagle are both alive), perceptual similarities (e.g., a yo-yo and a bicycle both have circular parts), or generated other conceptual associations. For example, although children were not asked to explain their choices, a child who incorrectly paired the elevator with the eagle spontaneously explained that he did so because they both "go up." Regardless of how children paired the items in the categorization task, there was no evidence that their choices transferred directly to the expert knowledge task, nor did children who completed the categorization task in the first session show superior performance on the expert knowledge task in the second session or vice versa.

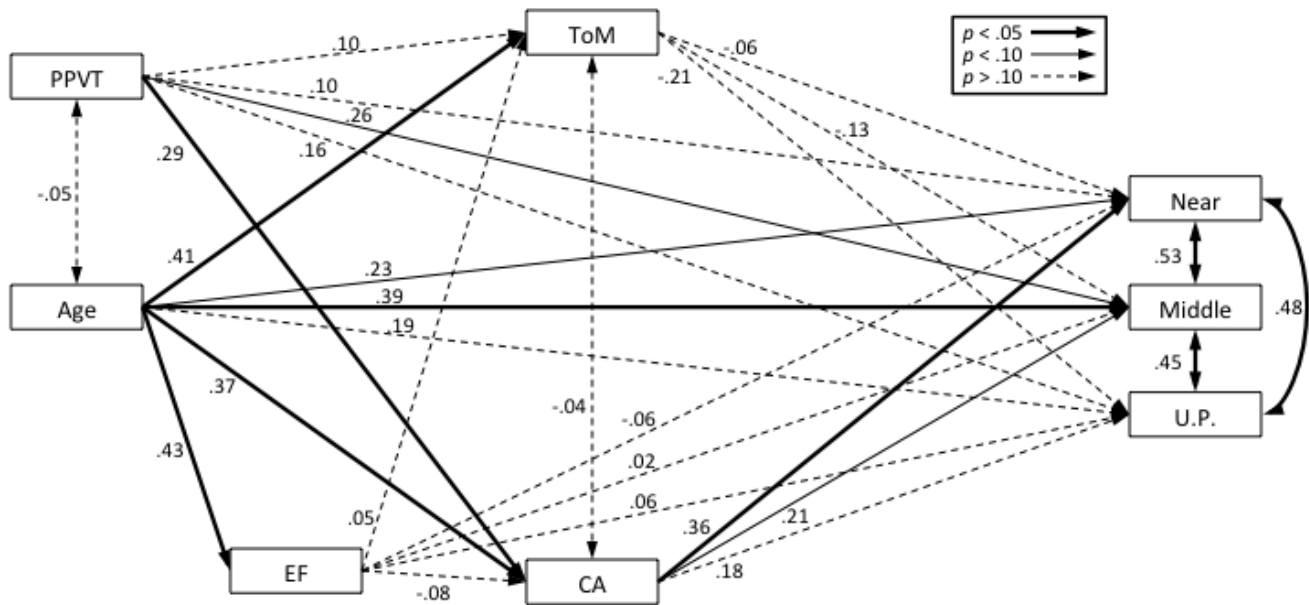There are a number of potential explanations for why

Figure 1. Path analysis of the relationship between study variables.

ToM was not a significant predictor in our model. One possibility is that even though Wellman and Liu's (2004) scale is a well-accepted measure of ToM, the tasks focus on children's reasoning about beliefs and desires, typically as a result of immediate access to information (e.g., knowing what is inside a box). Perhaps children's understanding of expertise relies on a different aspect of theory of mind, in that expertise involves acquisition of a large and persisting body of knowledge. Thus, other measures of social reasoning may be better predictors of how well children make inferences about the division of cognitive labor. Another explanation is that ToM, broadly construed, is indeed tangential to understanding expertise, although further research is necessary in order to confirm this possibility. For example, employing the current study's methods with a group with impaired ToM, such as high functioning children with autism, would provide an excellent test case for the role of ToM in representing the knowledge of others, as children with autism are typically motivated to seek out information and their categorization skills are largely intact despite their impaired social cognition (Tager-Flusberg, 1985). If children with autism draw conclusions similar to those of typical children about expert knowledge, this would suggest that strong non-social reasoning skills might compensate for, or even completely circumvent, social cognitive deficits when making certain types of social judgments.

Likewise, the non-significant role of EF in our model may be a function of the EF measures we employed. Because there were only two measures of EF and these measures focused exclusively on inhibition and cognitive flexibility, our EF data may not have accounted for all the skills involved in ToM or understanding expertise. For instance, working memory may also be an important component of children's understanding of expertise, as children must maintain information about both experts in order to compare them.

Although CA predicted children's performance on components of the expert knowledge task, CA did not account for all of the variance in children's performance. In fact, the predictive power of CA was strongest for near items, only marginally significant for middle items, and non-significant for underlying principles items. Thus, categorization appears to be most essential for inferring what an expert knows when the topics in question are more closely related to the expert's topic of expertise. Categorization is, however, less central to connecting more distant topics that share common underlying principles. Perhaps including measures that tap into *how* children reason about expertise, such as asking them to provide explanations for their choice of expert, would be a better predictor of individual differences in these items. More generally, although the current model accounts for a significant proportion of the variance in children's performance, identifying other factors that underlie individual differences in children's ability to infer what an expert knows remains a task for future research.

Nevertheless, the current findings suggest that any potential framework for explaining children's judgments about information sources must acknowledge the contribution of non-social reasoning skills on ostensibly social inferences and intuitions.

Despite recent advances in research on the development of social cognition and non-social cognitive skills, little work has examined how these different types of skills may synergize to allow children to generate sophisticated judgments. Most studies of the division of cognitive labor are exploratory, and focused on understanding how children represent different kinds of information and informants. This kind of work is necessary and it is valuable to the mission of understanding how children represent knowledge in the world around them, but this is perhaps the first investigation designed to explore how more general social and cognitive competencies related to children's understanding of the division of cognitive labor. Beyond explaining developmental differences in children's ability to infer what experts are likely to know, the results presented here demonstrate how non-social competencies can influence decisions that, at face value, may appear to be strictly social judgments. Hence, in order to fully understand how children learn to navigate the social and informational worlds, it is essential to consider the entire range of component skills that may be involved.

Acknowledgments

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