Children's intuitions about the structure of mental life

Kara Weisman
(kweisman@stanford.edu)
Department of Psychology
Stanford University

Carol S. Dweck
(dweck@stanford.edu)
Department of Psychology
Stanford University

Ellen M. Markman
(markman@stanford.edu)
Department of Psychology
Stanford University

Abstract

We investigated children's understanding of mental life by analyzing attributions of perceptual, cognitive, affective, and other capacities. 200 children (7-9y) and 200 adults evaluated the mental capacities of beetles or robots. By assessing which capacities traveled together when participants disagreed about these controversial "edge cases," we reconstructed the latent structure underlying mental capacity judgments from the bottom up—a novel approach to elucidating conceptual structure among children. For both children and adults, factor analyses revealed a distinction between *social-emotional*, *physiological*, and *perceptual-cognitive* capacities, hinting at three fundamental ways of explaining and predicting others' actions: as social partners, biological creatures, and goal-directed agents (each involving related forms of both "experience" and "agency"; Gray et al., 2007). Relative to adults, children attributed greater social-emotional capacities to beetles and robots, suggesting that intuitive ontologies of mental life could be critical for making sense of children's developing understanding of the social world.

Keywords: mind perception; sentience; animate–inanimate distinction; cognitive development.

Introduction

Questions about the nature of mental life extend back to antiquity, but it is only recently that cognitive scientists have begun to explore lay people's conceptions of the mind.

One particularly exciting approach was pioneered by Gray, Gray, and Wegner (2007) in their work on mind perception. From participants' responses to simple questions about the mental capacities of various characters (e.g., "Which is more capable of experiencing joy: a frog or an infant?"), Gray et al. extracted a conceptual space characterized by two dimensions: "experience," the extent to which a character is capable of hunger, fear, pride, and other inner experiences; and "agency," the extent to which a character is capable of self-control, morality, memory, and other capacities central to acting in the world.

This bottom-up approach has tremendous potential in elucidating the kinds of deep conceptual structures that are difficult for participants to report on directly (and for experimenters to anticipate a priori). Rather than imposing theory-driven categories onto participants' responses, Gray et al. (2007) let the data speak for themselves.

However, Gray et al.'s (2007) study focused participants' attention on the similarities and differences *between characters*, thus illuminating the dimensions along which social beings are thought to differ from each other—an important part of social reasoning, but not equivalent to intuitions about the structure of mental life itself.

Inspired by their approach, we recently conducted a series of studies designed to assess intuitive ontologies of mental life directly (Weisman, Dweck, & Markman, 2016). We focused participants' attention on the connections and divisions *between different aspects of mental life* by asking them to evaluate a wide variety of mental capacities for a single character (e.g., a robot or a beetle). By analyzing patterns of attributions across participants, we uncovered a 3-part conceptual structure that emerged reliably across several studies: Physiological sensations and self-initiated behaviors hung together to form a suite of capacities related to the body; social-emotional experiences and moral agency formed a suite of capacities related to the "soul"; and perceptual-cognitive abilities and goal pursuit formed a suite of capacities related to the mind. Interestingly, each of these three factors encompassed aspects of *both* "experience" and "agency." Instead of the broad distinction that seems to characterize adults' understanding of social beings (Gray et al., 2007), adults' understanding of the structure of mental life itself seems to hinge on distinctions among *varieties* of experience and agency, and *connections* among related kinds of experience and agency.

Intuitions about mental life are at the core of many of the oldest and richest lines of research in developmental psychology, including animism (Piaget, 1929), lay biology and psychology (Carey, 1985), and theory of mind (Wellman & Woolley, 1990). But most of this work has relied on a priori distinctions between perception, desires, emotions, intentions, beliefs, knowledge, etc. (Flavell, 1999), leaving the actual conceptual structure underlying children's reasoning and behavior unknown; to our knowledge, there have been no attempts to map out the ontology of mental life from the ground up with children. This may be due in part to the challenges of implementing bottom-up approaches, which generally require hundreds of participants to answer dozens of questions—not the typical design for studies with young children. On the other hand, studies like Gray et al. (2007) and Weisman et al. (2016) are built on the premise that these complex conceptual structures can be uncovered from participants' answers to relatively simple questions, suggesting that this approach might lend itself to adaptation for younger participants.

Thus, in the current study we developed a bottom-up approach for uncovering children's intuitions about the structure of mental life. We believe these intuitions are critical for making sense of children's social and moral reasoning about the people, animals, and other social partners in their lives.

Study

We based our experimental paradigm on our previous work with adults, in which participants evaluated a target character on 40 mental capacities using a 7-point scale from *not at all capable* to *highly capable*. Pilot testing suggested two necessary modifications for children: rewording some of the mental capacity items, and using a 3-point response scale (*no*, *kinda*, *yes*). Although a 3-point scale is not optimal for factor analyses, it allowed children to move fast enough through the study to answer all 40 questions, and maintaining this within-subjects design was our top priority for the planned factor analysis.

As in our previous work, we focused on judgments of the mental capacities of two "edge cases" in social reasoning: a beetle and a robot. Because beetles are animals and robots are artifacts, this pair provides insight into the role of biological life in attributions of mental life—an issue of particular interest from a developmental perspective, given the long history of work on the development of the animate–inanimate distinction and its relation to folk psychology. Most critically for our bottom-up approach to uncovering intuitive ontological structures, the "mental lives" of these entities are *controversial*: People differ in their assessments of the mental capacities of beetles and robots (Weisman et al., 2016). This allowed us to address the following question: When children disagree about the mental capacities of some entity, which capacities "go together"?

Pilot testing suggested that children as young as 7y found the paradigm easy and enjoyable, and work on the development of lay biology and psychology has suggested that these concepts may continue to develop well into middle childhood (e.g., Carey, 1985; Hatano & Inagaki, 1997; Piaget, 1929; cf. S. Gelman & Opfer, 2002). Thus, we targeted 7- to 9-y-old children for our child sample.

We also recruited a group of adults to validate our child-friendly paradigm, i.e., to evaluate whether it replicated our earlier work with adults (Weisman et al., 2016).

Methods

Participants. 400 people participated in this study.

Children (n=200) participated at one of several Bay Area museums or at their younger sibling's preschool (median study duration: 5.18min). Children ranged in age from 7.0-10.0y (median: 8.3y). An additional 12 children participated but were excluded for being outside the target age range (n=7), being of unknown age (n=4), or being shown a target character other than a beetle or a robot (n=1).

Adults (n=200) participated via MTurk. Adult participants had gained approval for ≥95% of previous work on MTurk; had verified accounts based in the US; and indicated that they were ≥18y old. Adults were paid $0.30 (median duration: 2.48min). Repeat participation was prevented.

Materials and procedure. Participants were randomly assigned to evaluate one of two target characters: a beetle, accompanied by a photograph of a black beetle on a leaf (n=98 adults, 104 children), or a robot, accompanied by a photograph of a humanoid robot (Sony Qrio; n=102 adults, 96 children). The picture and label (*a beetle* or *a robot*) were present throughout the survey.

Instructions focused on the idea that we wanted to know what participants thought "[beetles/robots] can do and can not do." Participants rated the target character on 40 mental capacities, presented in a random order for each participant. On each trial, participants responded *no*, *kinda*, or *yes* to the question "Do you think a [beetle/robot] can…?"

The 40 mental capacities were designed to be as close as possible to those in our previous studies (Weisman et al., 2016) while being comprehensible to children in early elementary school. This set of items included physiological sensations related to biological needs (e.g., *get hungry*); emotional experiences (e.g., *feel happy*); perceptual abilities (e.g., *hear sounds*); cognitive abilities (e.g., *remember things*); capacities related to autonomy or agency (e.g., *decide what to do*); social abilities (e.g., *feel guilty*); and several additional items (e.g., *be aware of itself*). Each of these a priori categories included at least five items of varying valence, complexity, and phrasing (see Table 1).

We also prepared a short definition for each item, so as to be consistent in our responses to participants if they asked for clarification. Children were encouraged at the beginning of the study to ask questions if they did not know what a word meant, in which case they given these definitions; adults were told that they could access these definitions by hovering over the text. Pilot testing suggested that 7 items required clarification for most children, so these items were always accompanied by their definitions from the beginning of the trial (for both children and adults), as follows: *have a personality, like when someone is shy and somebody else is silly*; *have beliefs, like when you think something is true*; *feel pleasure, like when something feels really good*; *have desires, like when you really want something*; *have self-control, like when you stop yourself from doing something you shouldn't do*; *have goals, like when you're trying hard to do something or make something happen*; and *feel sick, like when you feel like you might throw up*.

Data preparation. We scored responses of *no* as 0, *kinda* as 0.5, and *yes* as 1. We dropped trials with response times that were faster than a preset criterion of 250ms (n=3 child trials, 97 adult trials) and retained participants regardless of skipped trials (n=55 child trials, 1 adult trial). Overall, only 1% of adult trials and 1% of child trials were missing data.

Analysis plan. Our primary goal was to determine which mental capacities go together: e.g., if a participant indicated that a character was capable of hunger, what other capacities did she endorse? To do this, we used exploratory factor analyses (EFA) to reveal the covariance structure underlying participants' responses, collapsing across characters and using Pearson correlations to find minimum residual solutions. We first examined maximal (13-factor) unrotated solutions to determine how many factors to extract, using the following preset retention criteria: Each factor must have an eigenvalue >1.0; individually account for >5% of the total variance; and be the "dominant" factor (the factor with the highest factor loading) for ≥1 mental capacity item. We focus our interpretation on varimax-rotated solutions, extracting the number of factors that met these criteria. (Using polychoric correlations and/or oblimin rotation yielded similar latent structures.)

Results and Discussion

We first assess the validity of our child-friendly paradigm relative to our previous work with adults by examining an EFA of adults' responses. We then address our primary question—*children's* intuitions about the structure of mental life—via EFA of children's responses. Finally, we analyze differences in factor scores between children and adults.

EFA: Adults. EFA revealed 3 factors that met our criteria.

After rotation, the first factor corresponded primarily to physiological sensations related to biological needs. It was the dominant factor for such items as *get hungry*, *do math* (negative loading), *feel pain*, *feel scared*, and *feel tired*. Factor 1 accounted for 25% of the variance in the rotated maximal solution.

The second factor corresponded primarily to capacities for self- and other-relevant emotions. It was the dominant factor for such items as *feel joy*, *feel proud*, *feel sad*, *feel happy*, and *feel love*. Factor 2 accounted for 21% of the variance in the rotated maximal solution.

Finally, the third factor corresponded primarily to perceptual-cognitive abilities to detect and use information about the environment. It was the dominant factor for such items as *recognize somebody else*, *figure out how to do things*, *remember things*, *sense whether something is close by or far away*, and *communicate with somebody else*. Factor 3 accounted for 10% of the variance in the rotated maximal solution. (See Table 1 for all factor loadings.)

In sum, as in our original studies (Weisman et al., 2016), a three-factor structure emerged from adults' mental capacity attributions, characterized by a distinction between physiological, social-emotional, and perceptual-cognitive abilities. This suggests that our child-friendly paradigm was valid: Using reworded items and a 3-point response scale elicited the same intuitive ontology of mental life, among adults, as revealed by our "adult-friendly" paradigm.

EFA: Children. Again, 3 factors met our retention criteria.

After rotation, the first factor corresponded primarily to social-emotional abilities. It was the dominant factor for such items as *feel proud*, *feel happy*, *feel joy*, *get hurt feelings*, and *feel sad*. Factor 1 accounted for 25% of the variance in the rotated maximal solution.

The second factor corresponded primarily to physiological sensations. It was the dominant factor for such items as *get hungry*, *feel pain*, *do math* (negative loading), *smell things*, and *feel scared*. Factor 2 accounted for 18% of the variance in the rotated maximal solution.

The third factor corresponded primarily to perceptual-cognitive abilities. It was the dominant factor for such items as *be aware of itself*, *figure out how to do things*, *be aware of things*, *sense whether something is close by or far away*, and *sense temperatures*. Factor 3 accounted for 7% of the variance in the rotated maximal solution.

In sum, like adults, children's mental capacity attributions were dominated by a 3-way distinction between social-emotional, physiological, and perceptual-cognitive abilities.

Note that a number of additional or alternative latent factors could have emerged from this analysis. For example, children might have distinguished primarily between internal experience and external action (Gray et al., 2007), or they might have demonstrated finer-grained groupings of mental capacities based on phrasing, rote knowledge, etc. Instead, the latent conceptual structure underlying children's responses appears to be very similar to that of adults.

Children vs. adults. To formally compare responses from children and adults, we considered the full, combined dataset and examined factor scores by age group.

EFA using the combined dataset revealed three factors that met our retention criteria. Unsurprisingly, these three factors were very similar to those revealed for adults and children analyzed independently: They corresponded to social-emotional abilities, physiological sensations, and perceptual-cognitive abilities (see Table 1).

The purpose of this combined EFA was to examine differences in adults' and children's evaluations of beetles and robots within this 3-part structure. To do so, we derived factor scores (via the ten Berge method) using the rotated 3-factor solution. This yielded 3 scores for each participant, corresponding, in principle, to holistic judgments of the social-emotional, physiological, and perceptual-cognitive abilities of the target character the participant evaluated. (Note that each of these 3 scores takes into account factor loadings for all 40 mental capacities, as listed in Table 1.)

This allowed us to examine the effects of age group (*adult*, *child*), character (*beetle*, *robot*), and factor (*social-emotional*, *physiological*, *perceptual-cognitive*) on these scores via mixed effects linear regression. See Table 2 for the results of a maximal model and Fig. 1 for mean scores.

Collapsing across age groups and domains (physiological, social-emotional, and perceptual-cognitive), factor scores suggest that participants generally attributed fewer mental capacities to the robot than the beetle (b=-0.25). However, this appears to be entirely due to the huge discrepancy between characters in the physiological domain; the difference between characters was reduced to nothing in the social-emotional domain (b=0.26), and reversed in the perceptual-cognitive domain (b=0.39). Collapsing across entities (beetle, robot), children tended to attribute more mental capacities adults (b=0.19), but this was driven primarily by the social-emotional domain (b=0.46), and was reversed in the perceptual-cognitive domain (b=-0.30).

Scores in the physiological and perceptual-cognitive domains were very similar for children and adults: Both

Table 1: Factor loadings from exploratory factor analyses for adults alone (*n*=200), children alone (*n*=200), and the combined dataset. Loadings are from 3-factor varimax-rotated minimum residual solutions. Items are grouped according to their dominant factor (the factor with the strongest factor loading) in the combined analysis; loadings >0.60 or <-0.60 are in bold. Items marked with an asterisk were accompanied by a brief definition (see main text).

Item	Social-emotional			Physiological			Perceptual-cog.		
Do you think a [target] can…?	Ad.	Ch.	ALL	Ad.	Ch.	ALL	Ad.	Ch.	ALL
feel proud	**0.81**	**0.78**	**0.86**	0.13	-0.03	0.03	0.08	-0.02	-0.05
feel happy	**0.77**	**0.76**	**0.83**	0.33	0.07	0.18	0.05	0.04	0.02
feel joy	**0.81**	**0.75**	**0.82**	0.30	0.12	0.18	0.02	-0.04	-0.03
feel sad	**0.80**	**0.66**	**0.77**	0.26	0.27	0.23	0.04	0.02	0.00
get hurt feelings	**0.70**	**0.66**	**0.77**	0.21	0.19	0.16	0.04	0.10	0.00
feel love	**0.76**	**0.63**	**0.74**	0.26	0.11	0.16	0.14	0.00	0.03
feel guilty	**0.69**	0.59	**0.71**	0.14	0.06	0.07	0.06	0.06	0.00
get angry	0.51	0.50	**0.67**	0.38	0.31	0.30	0.15	0.05	0.04
*have beliefs**	0.51	0.53	**0.65**	-0.03	-0.04	-0.04	0.33	0.22	0.18
feel embarrassed	**0.60**	0.57	**0.65**	0.09	0.04	0.05	0.03	-0.06	-0.06
*have a personality**	0.50	0.51	**0.64**	-0.05	-0.06	-0.06	0.26	0.30	0.20
*feel pleasure**	0.47	**0.62**	**0.64**	0.55	0.09	0.30	0.08	0.02	0.04
feel calm	0.43	0.48	**0.60**	0.53	0.22	0.36	0.16	0.12	0.11
have thoughts	0.36	0.46	0.55	0.24	0.24	0.22	0.37	0.32	0.30
know what's nice and what's mean	0.42	0.47	0.54	-0.20	-0.18	-0.19	0.34	0.20	0.22
*have desires**	0.36	0.43	0.53	0.53	0.33	0.39	0.19	0.03	0.09
understand how somebody else is feeling	0.42	0.40	0.51	-0.09	-0.31	-0.21	0.31	0.28	0.24
*have self-control**	0.42	0.26	0.47	0.00	0.02	0.00	0.34	0.28	0.25
*have goals**	0.21	0.37	0.42	0.16	-0.17	-0.01	0.42	0.22	0.29
get hungry	0.04	0.12	0.14	**0.94**	**0.87**	**0.90**	-0.08	-0.07	-0.04
do math	0.05	0.14	0.05	**-0.83**	**-0.71**	**-0.79**	0.36	0.34	0.31
feel pain	0.17	0.21	0.26	**0.82**	**0.79**	**0.79**	0.06	0.01	0.06
smell things	0.01	-0.10	-0.08	**0.67**	**0.64**	**0.64**	0.21	0.11	0.22
feel scared	0.32	0.39	0.46	**0.75**	0.53	**0.62**	0.13	0.06	0.10
*feel sick**	0.29	0.16	0.21	**0.66**	0.51	0.58	0.14	-0.06	0.09
feel tired	0.24	0.27	0.41	**0.72**	0.46	0.58	0.22	-0.01	0.10
feel safe	0.28	0.42	0.47	**0.71**	0.33	0.50	0.23	0.31	0.25
figure out how to do things	0.16	0.12	0.18	0.00	-0.04	-0.04	0.59	0.49	0.55
be aware of things	0.06	0.17	0.08	0.32	0.20	0.23	0.50	0.49	0.50
sense whether something is close by or far away	-0.03	0.02	-0.16	0.10	0.01	0.00	0.57	0.44	0.49
remember things	0.19	0.10	0.16	-0.33	-0.40	-0.39	0.57	0.39	0.47
sense temperatures	0.00	-0.12	-0.26	0.19	-0.13	-0.03	0.51	0.42	0.46
make choices	0.14	0.28	0.23	0.08	0.18	0.09	0.57	0.36	0.46
recognize somebody else	0.21	0.18	0.14	-0.45	-0.16	-0.34	**0.61**	0.32	0.46
decide what to do	0.09	0.31	0.20	0.09	0.28	0.14	0.48	0.40	0.45
be aware of itself	0.21	0.11	0.31	0.23	0.06	0.14	0.41	0.52	0.42
hear sounds	0.01	-0.18	-0.11	0.13	0.01	0.05	0.50	0.33	0.42
see things	-0.03	-0.13	0.03	0.24	-0.05	0.11	0.55	0.23	0.40
communicate with somebody else	0.14	0.08	0.17	-0.32	-0.18	-0.26	0.57	0.24	0.40
make plans	0.28	0.32	0.33	-0.31	-0.18	-0.27	0.46	0.41	0.40
% variance explained …3-factor solution:	37%	50%	53%	37%	30%	28%	26%	20%	19%
…maximal (13-factor) solution:	21%	25%	37%	25%	18%	20%	10%	7%	8%

Table 2: Results of a mixed effects linear regression of factor scores on target character, factor, and age group, with random intercepts by participant. Categorical predictors were effect-coded and compared to the grand mean (GM). "Significant" predictors (|*t*|>2) are in bold.

Predictor	*b*	*se*	*t*
(Intercept)	-0.01	0.02	-0.25
character (robot vs. GM)	**-0.25**	**0.02**	**-10.00**
factor 1 (vs. GM)	0.00	0.03	-0.06
factor 3 (vs. GM)	0.01	0.03	0.41
age group (children vs. GM)	**0.19**	**0.02**	**7.65**
character * factor 1	**0.26**	**0.03**	**8.64**
character * factor 3	**0.39**	**0.03**	**13.00**
character * age group	0.05	0.02	1.87
factor 1 * age group	**0.46**	**0.03**	**15.10**
factor 3 * age group	**-0.30**	**0.03**	**-9.88**
character * factor 1 * age group	0.00	0.03	0.12
character * factor 3 * age group	-0.04	0.03	-1.35

children and adults marked a clear difference between the robot and the beetle in the physiological domain (Fig. 1, center), in line with the animate–inanimate distinction[1]; and both age groups credited the robot with slightly greater perceptual-cognitive skills than the beetle (right). In contrast, in the social-emotional domain (left) both the beetle and the robot received rather low scores among adults, but very *high* scores among children. See Fig. 2 for raw counts of *no*, *kinda*, and *yes* responses for all items, grouped by character, age group, and dominant factor.

In sum, we see only minor differences between children and adults in their attributions of physiological and perceptual-cognitive abilities to beetles and robots—but a major difference in the social-emotional domain: Relative to adults, children tended to credit both beetles and robots with much greater social-emotional abilities.

General Discussion

A bottom-up approach designed to shed light on children's intuitions about the ontology of mental life revealed an adult-like conceptual structure in place among 7- to 9-y-old children. Patterns of mental capacity attributions revealed a shared fundamental distinction between *social-emotional*, *physiological*, and *perceptual-cognitive* abilities. To our knowledge, this is the first bottom-up exploration of children's intuitions about the structure of mental life.

In a close parallel to adults (Weisman et al., 2016), the distinction that loomed the largest in children's responses

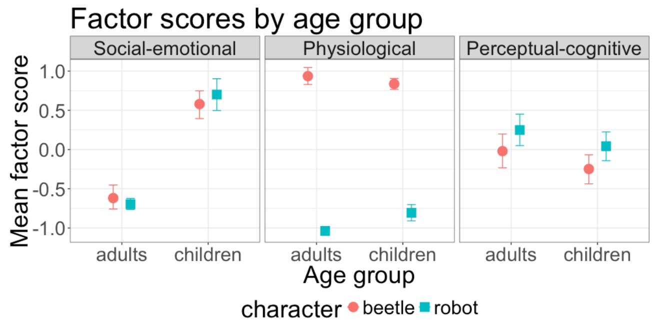

Fig. 1: Mean factor scores for the beetle and the robot for each of the three factors (social-emotional, physiological, perceptual-cognitive), among adults (*n*=200) and children (*n*=200). Error bars are non-parametric bootstrap 95% CIs.

was not between experience and agency (Gray et al., 2007), but between three *varieties* of experience: emotional, physiological, and perceptual. Echoing this previous work, different aspects of agency were distributed across these factors: The social-emotional factor included several items related to moral agency (e.g., *understand how somebody else is feeling*, *know what's nice and what's mean*), while items related to goal pursuit tended to pattern with perceptual-cognitive abilities (*decide what to do*, *make plans*).[2] For both children and adults, connections *between* related varieties of experience and agency seemed to play a particularly important role in intuitive ontologies of mental life—perhaps because they allow us to explain and predict others' actions in several fundamental domains (interactions among social partners, the bodily needs of animals, and the goal-directed actions of agents).

Although the conceptual structure underlying children's mental capacity attributions was quite similar to that of adults', there was one striking difference in their evaluation of entities within that structure: Children were far more generous in their assessment of the social-emotional abilities of both beetles and robots. The specificity of this age difference—which emerged dramatically in one domain, but not others—suggests that this is unlikely to be due either to a general tendency toward "mentalizing" these characters (or a simple "yes" bias). But its extension to *both* beetles and robots raises many questions. With regard to robots, children growing up in the 21st century might be converging on a new understanding of technological "beings" as inanimate objects with some degree of social-emotional life (see Kahn, Gary, & Shen, 2013)—but this kind of historical conceptual change would *not* predict the high rates of social-emotional attributions to *beetles* that we observed. Our findings are perhaps more consistent with a general openness to untraditional social partners that extends into middle childhood (but not adulthood)—or with a difference in construals of what it means to feel proud, happy, guilty,

[1] Compared to adults, children credited robots with slightly greater physiological capabilities. This is particularly obvious in examining modal responses for items like *feel safe* (adults: *no*, *n*=82; children: *yes*, *n*=40), *feel tired* (adults: *no*, *n*=88; children: *no*, *n*=38, *yes*, *n*=36), and *feel scared* (both age groups: *no*, *n*=93 adults, 50 children), which each have emotional and cognitive connotations in addition to their relevance for biological life.

[2] Note, however, that *have goals* loaded more strongly on the social-emotional factor, and two potentially "moral" items (*have self-control*; *communicate with somebody else*), loaded equally on the social-emotional and perceptual-cognitive factors.

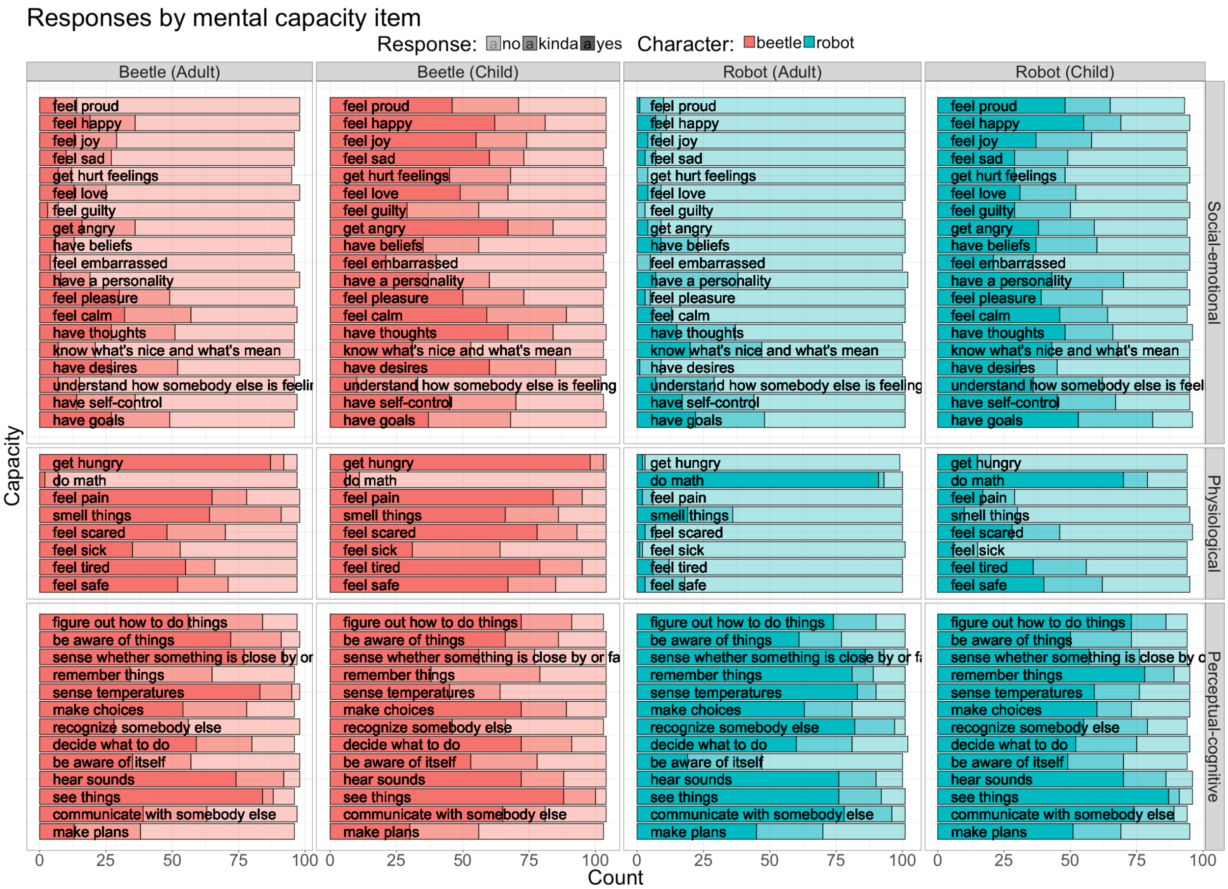

Fig. 2: Raw counts of responses to each item, by character (beetle, robot), age group (children, adults), and dominant factor (social-emotional, physiological, perceptual-cognitive), listed in descending order of absolute factor loading (see Table 1). Opacity indicates responses of *yes* (dark), *kinda* (medium), or *no* (light).

etc. To what kinds of entities would children of this age *deny* social-emotional abilities, and how do they draw this line? What aspects of attributing pride, happiness, or guilt might change between 7-9y and adulthood?

Our findings point to the importance of distinguishing between different aspects of mental life in building theories of how social cognitive reasoning might evolve—both over the lifespan and across history and cultures. The current studies offer the major advantage of making these distinctions on the basis of children's own conceptual structure, rather than a priori categories generated by experimenters—an approach that could prove particularly powerful in making sense of children's beliefs about and behaviors toward the many kinds of human, animal, and technological "beings" in the modern social world.

Acknowledgments

This material is based upon work supported by the NSF GRFP under Grant No. DGE-114747, and by a William R. & Sara Hart Kimball Stanford Graduate Fellowship. Thanks to the Tech Museum of Innovation, Palo Alto Junior Museum & Zoo, Bay Area Discovery Museum, Bing Nursery School, research assistants, and families.

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