A fine-grained understanding of emotions: Young children match within-valence emotional expressions to their causes

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Abstract

Previous research suggests that the ability to make fine-grained distinctions among emotions emerges gradually over development. However, such studies have looked primarily at children's first-person responses to emotional expressions or at whether children can match emotion labels to emotional expressions. Relatively little work has looked at children's ability to link emotional responses to their probable causes. Here we ask two, three, and four year-old children and adults to identify the causes of vocal expressions. Because we were interested in the ability to make nuanced distinctions, we looked within a single valence and asked whether children could distinguish expressions elicited by exciting, delicious, adorable, funny, and sympathetic events. Our results suggest both an early emerging ability to distinguish within-valence emotions and rapid development; by four, children's performance mirrored that of the adults. This suggests that very early in development, children have a rich representation of emotions that allows them to link distinct positively valenced emotional expressions to their probable causes.

Keywords: emotion understanding; causal reasoning; vocal expressions; toddlers; preschoolers

Introduction

"I recognize terror as the finest emotion and so I will try to terrorize the reader. But if I find that I cannot terrify, I will try to horrify, and if I find that I cannot horrify, I'll go for the gross-out. I'm not proud." -- Stephen King

"airy, amused, animated, beatific, blissful, blithe, bright, brisk, buoyant, cheerful, cheery, comfortable, contented …"
-- The beginning of a list of words for happiness, from:
//www.derose.net/steve/resources/emotionwords/ewords.html

Human beings have a sophisticated understanding of emotions. Sufficiently sophisticated that English-speaking adults in our culture can appreciate the distinction between terror, horror, and disgust, and, more salubriously, the distinction between feeling airy, amused, and animated. To the degree that we make these distinctions, we represent not only the meaning of these emotion words, but also the expressions and vocalizations that might accompany them, and the causes and contexts that might elicit them.

However, relatively little is known about the development of this rich understanding of emotion. Studies in infancy have focused primarily on babies' distinct responses to positive and negative emotions. Thus for instance infants have an augmented startle response when a sudden noise is paired with an angry (versus neutral) face and a reduced startle when it is paired with a happy face (Balaban, 1995). Similarly social referencing studies show that infants will approach novel toys and visual cliffs if their caregiver displays a positive, encouraging expression but withdraw if their caregiver displays a frightened, negative expression (e.g. Klinnert, 1984; Kinnert, Emde, Butterfield, & Campos, 1986; Mumme & Fernald, 2003; Mumme, Fernald, & Herrera, 1996; Sorce, Emde, Campos, & Klinnert, 1985). More recent work has shown that infants expect an agent who has succeeded at its goal to express a positive emotion rather than a negative emotion (Skerry & Spelke 2014). By 18-months, children will use a recipient's emotional responses to food (i.e. happy or disgusted) to offer the food she likes (Repacholi & Gopnik, 1997). These suggest that infants distinguish positively and negatively valenced emotion and that these representations are structurally connected with their representations of goals and desires in ways that allow them both to use emotions to inform their own actions, and to use others' actions to predict their emotions.

Other studies have attempted to tease apart infants' responses to more subtle distinctions, including within-valence emotions. However, the evidence for fine-grained distinctions among emotions early in development is relatively weak. Although some work on social referencing suggests that infants are slightly more likely to cross the visual cliff given if the parent displays a sad face than a fearful or angry one (Sorce, Emde, Campos, & Killnert, 1985), this difference could be explained by the arousal values of these emotions; sadness may be lower in arousal than fear or anger, and thus its deterrent effect may be weaker. Other studies have shown (in looking time studies and in coding infants' own responses to the stimuli) that infants can discriminate facial expressions including anger, fear, and sadness (e.g., Haviland & Lelwica, 1987; Serrano, Iglesias, & Loeches, 1992). Similar distinctions have been shown for positive facial expressions (e.g., pure happiness and happiness mixed with surprise; Ludemann, 1991). Studies have also shown that infants can distinguish congruent and incongruent pairings of emotional faces and voices, and by 7-months, can discriminate emotions in either modality (e.g. Flom & Bahrick, 2007; Grossman, Striano, & Friederici, 2006; Walker-Andrews, 1986). Neural measures have also found for instance that infants generate different EEG responses to angry and fearful faces (Hoehel & Striano, 2008). However, although these methods speak to infants' ability to distinguish cues to different emotions, they fall short of telling us whether infants discriminate emotions as such.

Stronger evidence that infants have rich internal representations of emotions comes from studies of infants' and toddlers' production of emotion (see Camras, Malatesta, & Izard, 1991; Malatesta, Culver, Tesman, & Shepard, 1989 for reviews). However, infants' and toddlers' ability to generate rich emotional responses in ways that adults interpret as contextually appropriate may be distinct from their ability to understand the kinds of events that elicit different emotions.

Even studies in older children suggest a relatively protracted development of emotion understanding. When asked to label prototypical facial expressions with basic emotion labels (i.e. happiness, sadness, fear, anger, surprise, disgust; Ekman, 1992), two-year-olds generally use no labels; over the next four years, children gradually add the six basic emotion labels to their vocabulary (see Widen, 2013 for a review). This slow and gradual development has also been found cross-culturally (Kayyal, Widen, & Russell, 2012). Other studies have found that children fail to understand the relationship between beliefs and emotion even well beyond the age at which children explicitly understand false beliefs. For instance, children who are capable of recognizing that Little Red Riding Hood falsely believes her grandmother (rather than a wolf) is in the bed, nonetheless inaccurately infer that Red Riding Hood is scared (Bradmetz & Schneider, 1999). Findings like these have led researchers to propose that early in childhood, children begin with a very coarse model of emotion (distinguishing only valence and arousal) and only gradually infer a more elaborate, differentiated understanding (Widen & Russell, 2008a; 2008b).

However the evidence for the relatively slow development of children's fine-grained distinctions in emotions comes primarily from verbal tasks where children are asked to match the meaning of words with emotional faces or stories, or draw inferences that depend on relatively advanced language facilities. In many domains of social cognition, children have evinced sophisticated abilities much earlier when tasks have depended less on verbal input. Given recent evidence suggesting that in infancy and early childhood, children evaluate prosocial and antisocial actions, understand fair and unfair distributions of resources, collaborate on joint goals, evaluate agents' competence and incompetence, and expect members of social groups to behave alike (e.g., Geraci & Surian, 2011; Hamlin, Wynn, & Bloom, 2007; 2011; Hamlin, Ullman, Goodman, Tenenbaum, & Baker, 2013; Jara-Ettinger, Tenenbaum, & Schulz, in press; Powell & Spelke, 2013; Sloane, Baillargeon, & Premack, 2012; Warneken, Lohse, Mellis, & Tomasello, 2011), it would be surprising if young children genuinely had no ability to make any nuanced distinction within emotional valences.

How can we evaluate children's sensitivity to fine-grained distinctions among emotions? Asking children to discriminate emotional expressions (as in many infancy studies) is revealing about infants' ability to distinguish emotions but not about their ability to understand them. However, asking children to connect emotion words to emotional expressions or emotional stories (as in many studies with preschoolers) may tax children's verbal competence and underestimate their actual comprehension. Here we introduce a new paradigm for assessing children's representations of emotions in early childhood. The paradigm draws on the intuition that there are probabilistic causal relationships between particular events and particular emotional responses. Spoiled food generates a disgust reaction; harm directed at an innocent victim generates anger; precarious heights generate fear. By the same token, fireworks generate excitement; cute babies generate affection; and breathtaking landscapes generate awe. The causal relationships are only true in probability; there may be variability in individuals' responses. However, given abundant research suggesting that very young children are sensitive to evidence for causal relationships in other domains (see Gopnik & Wellman, 2012; Schulz, 2012 for review) it seems possible that children would also have learned causal relationships between specific kinds of events and specific emotional responses. Here we ask whether very young children can connect emotional expressions to their probable causes. We hypothesize that given a non-verbal assessment of their emotion understanding, even young children will make nuanced within-valence discriminations much more accurately than previous research would suggest.

We presented the generative candidate causes of the emotions pictorially; to avoid confusion, we therefore elected to have the emotional responses be vocal expressions rather than facial expressions. We anticipated that children would have no difficulty registering the different vocalizations since studies suggest that children are proficient at distinguishing emotional cues in vocal expressions (Flom & Bahrick, 2007; Grossman, Striano, & Friederici, 2006; Sauter, Panattoni, & Happe, 2013; Walker-Andrews, 1986).

For the eliciting causes we chose five kinds of scenes. These were chosen arbitrarily, constrained by three criteria: a) all scenes had to elicit positively valenced emotions (to avoid distressing the children); b) each kind of scene should elicit what an adult would perceive as an emotional response distinct from that elicited by any of the other four kinds, c) the eliciting scenes had to be easy to portray and easy for young children to recognize. From these criteria we developed stimuli corresponding to funny, exciting, adorable, sympathetic, and delicious events. (See Figure 1.)

To ensure that the stimuli did indeed elicit natural and distinctive emotional vocalizations, we asked two female adults to look at each scene and respond as spontaneously as possible, out loud, but without any words. (See Methods.) Their vocalizations were recorded. We then paired each vocal expression with two candidate causes (only one of which was actually used to elicit the vocalization) and looked at whether children (ages two to four) and adults could link the vocalization with the eliciting cause of the emotion. We predicted that, contradictory to previous research, even young children could discriminate within-valence emotional expressions and identify their causes.

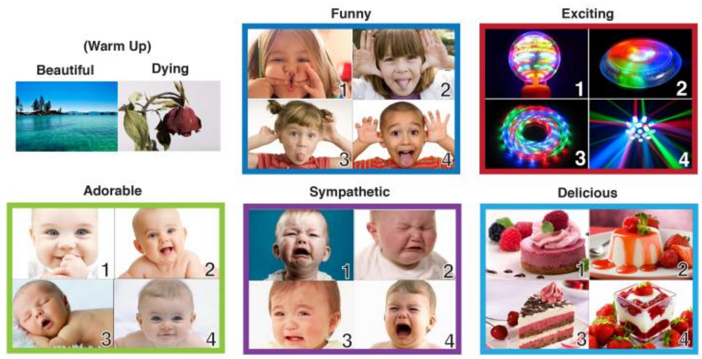

Figure 1 Eliciting cause stimuli. See text for details.

Methods

Participants

Forty-eight children (mean age: 3.4, range: 2.0-4.9 years) were recruited at a children's museum: 16 were two-year-olds (mean age: 2.5, range: 2.0-2.9); 16 were three-year-olds (mean age: 3.4, range: 3.0-3.9); and 16 were four-years-olds (mean age: 4.5, range: 4.1-4.9). Although most of the children were White and middle class, a range of ethnicities and socioeconomic backgrounds reflecting the diversity of the local population were represented. An additional eight children were recruited but not included in the final sample due to: (1) location biases (i.e. pointing to the left (or right) pictures throughout the experiment; *n*=5); (2) refusal to point (*n*=2); (3) getting distracted (i.e. playing with the keyboard; *n*=1).

Fifty-eight adult participants were recruited on Amazon Mechanical Turk (MTurk), a marketplace for online workers. A range of ethnicities and socioeconomic backgrounds reflecting the diversity of the marketplace were represented. Each MTurk worker received $0.2 for participating in this study.

Materials

Eliciting cause stimuli For each of the five kinds of candidate causes we chose four pictures to create a full stimulus set. For funny stimuli we chose children making silly faces; for exciting stimuli we chose light-up toys; for adorable stimuli we chose cute babies; for sympathetic stimuli we chose crying babies, and for delicious stimuli we chose desserts. All pictures were found online in Google Image and cropped to the same image size. See Figure 1. As noted, our primary selection criteria were that the stimuli be easily recognizable by children and likely to generate distinct positively valenced emotional responses in adults,. Additionally however, to ensure that any observed effect was relatively general, we wanted to include both objects and people. We also wanted to ensure that any responses to agents could not be explained as mimicry or emotional contagion. The inclusion of crying babies was thus particularly interesting because it would require children to map a negative eliciting cause to a positive comforting response. To the degree that children can do this, it would suggest that children do not merely process the valence of salient stimuli, but represent emotions within a causal framework where they can link emotional responses to probable causes, even across valence boundaries. Two pictures that did not belong to any of the five target categories (and that differed in valence from each other) were used for a Warm-Up Trial: a picture of a beautiful beach and a picture of a dying flower. See Figure 1.

Emotional Vocalization stimuli The set of twenty test pictures and the two warm-up pictures were combined and presented in random order to two female adults. The adults were told that they could not use words, but that they should look at each picture and vocalize their response. They recorded their responses individually in a private room. We selected one vocal response for each picture, using half the vocalizations from one adult and half from the other. This resulted in 20 test audio clips corresponding to the 20 test pictures and 2 warm-up clips corresponding to the 2 warm-up pictures (see http://web.mit.edu/yangwu/www/VocRes/). Each vocal response was cropped to a two-second audio clip.

Stimulus Presentation Both the pictures and the vocal responses were presented using Matlab and PsychToolbox on a 15-inch laptop. A doll (height: 37 cm) and a white cylinder-shaped speaker (diameter: 10 cm; height: 17 cm) were also used. The speaker was connected to the laptop and the doll was placed on the speaker so that when a vocal response was played, it looked like the doll made the sound.

Each child saw one warm-up trial and 20 test trials. In each test trial, a Matlab script was used to a) randomly select two of the five categories; b) randomly choose one picture from each of the two selected categories, and c) randomly choose the vocal expression elicited by one of the two pictures. The script also specified that each picture would be presented in exactly two test trials: once as the target and once as the distractor and each vocal expression would be played on only a single test trial.

On each trial, the two pictures (13 cm × 9 cm) were presented in both sides of the screen. The timing of the presentation of the pictures and vocal expression was triggered by pressing a button on the keyboard.

The presentation for adults used the same materials but a slightly different script due to the technical constraints of running online experiments with full picture-sound randomization. There was no warm-up trial for adults and adults had 10 test trials rather than 20. For the test-trials we randomly sampled two pictures from each of the five categories and used these to generate a randomly ordered set of 10 picture pairs. Half the adults were given the vocal expression corresponding to one picture in each pair in the set; the other half of the adults were shown the same set of pictures but given the vocal expression corresponding to the other picture in each pair.

Procedure

Children were tested individually in a private room at the children's museum. The laptop used for presenting the stimuli was placed on a table. The laptop screen was about 40 cm from the child. The speaker was put in front of the laptop, 8 cm from the child.

The experimenter first introduced the doll to the child: "Hi, this is Sally! Today we'll play a game with Sally!" The experimenter then placed the doll on the speaker, facing the laptop screen.

Warm-up Trial The experimenter presented one picture on the left side of the screen and said: "This is a picture of a beautiful beach. When Sally looks at it, she makes this sound." The experimenter surreptitiously pushed a button on the keyboard and the sound actually recorded by the actor on viewing the scene came from the speaker, where Sally sat, so that it seemed that Sally produced the sound. The experimenter then made the left picture disappear, and presented a picture on the right side of the screen. The experimenter said: "This is another picture. It's a dying flower. When Sally looks at it, she makes this sound." The experimenter activated the other sound. The first sound was a positive "Ooh!"; the second, a negative "Ohh." (See Audio File: Ooh & Ohh.) The experimenter then displayed both pictures and introduced the game: "In this game I will show you two pictures. Sally will look at one of them and make a sound. We will need to guess which picture Sally is looking at. OK? I'll play the game first!" The experimenter played the positive sound again, pointed to the picture of the beach, and said: "When Sally makes this sound, I think she is looking at the picture of a beautiful beach." Then she played the sad sound, pointed to the dying flower, and said: "When Sally makes this sound, I think she is looking at this dying flower." During the entire warm-up phase, if the child looked puzzled, got distracted, or asked to repeat any part of the trial (e.g. to play the sound again), we repeated the part of the presentation that the child may have missed, in order to make sure that the child understood the procedure. Lastly, the experimenter said: "Now it's your turn to play the game!" and started the test trials.

Test Trial On each test trial, the experimenter pushed a button on the keyboard to trigger the presentation of two pictures and said: "Here are two new pictures, and Sally makes this sound." Then she pushed a button on the keyboard to trigger the vocalization. (The timing was controlled by the experimenter but the choice of stimuli was controlled by the Matlab script; see Stimulus Presentation.) She asked the child: "Which picture do you think Sally is looking at?" If the child made no response, the experimenter played the sound again and said, "Do you think Sally is looking at this picture [pointing to the left picture] or this picture [pointing to the right picture]? Do you want to point?" If the child still made no response after a subsequent prompt, the experimenter skipped that trial and moved on to the next trial. If the child skipped three trials successively, or asked to stop, we terminated the experiment. On average, two year-olds completed 15.1 trials; three-year-olds completed 18.4 trials and four-year-olds completed 19.0 trials. The three groups differed significantly in the number of trials completed (F(2)=3.898, p=.027). Two-year-olds completed fewer trials than four-year-olds (Tukey's HSD tests, p=.033); two-year-olds and three-year-olds did not differ from each other (p=.085); three-year-olds and four-year-olds did not differ from each other (p=.908). The percentage of correct responses for each child was computed only for the completed trials. The entire experiment took less than three minutes.

The adult participants were tested online. Adults were told that the vocal expression in each trial was someone's response when looking at one of the pictures and their task was to guess which picture the person was looking at when she made the sound. Participants were also told that they could replay the sound as often as needed on each trial by clicking a button.

Results

Participants correctly matched the vocal expression to its causes significantly above chance in all age groups (two-year-olds: M=.60, SD=.142, 95% CI [.52, .67], t(15)=2.745, p=.015, d=.10; three-year-olds: M=.68, SD=.194, 95% CI [.57, .78], t(15)=3.637, p=.002, d=.18; four-year-olds: M=.90, SD=.055, 95% CI [.88, .93], t(15)=29.589, p<.001, d=.40; adults: M=.87, SD=.177, 95% CI [.82, .91], t(57)=15.704, p<.001, d=.37; One-Sample T Test, two-tailed). See Figure 2.

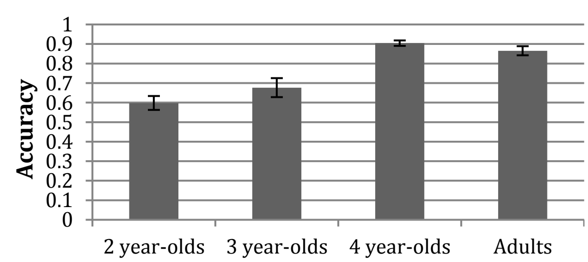

Figure 2 Response accuracy in each age group. Error bars indicate SEM.

A 4×5 mixed-design analysis of variance was conducted on participants' responses with the age group as the between-subjects factor and the emotion category as the within-subjects factor. Only the effect of age was significant (F(3,102)=15.794, p<.001, η_p^2=.32); there was no main effect of category (F(4, 408)=2.116, p=.078, η_p^2=.02) or interaction (F(12, 408)=1.025, p=.424, η_p^2=.03). The performance of two and three-year-olds did not differ from each other (Tukey's HSD tests, p=.525), but both age groups differed from four-year-olds and adults (all ps<.001).

Four-year-olds performance was comparable to adults (p=.831). See Figure 3.

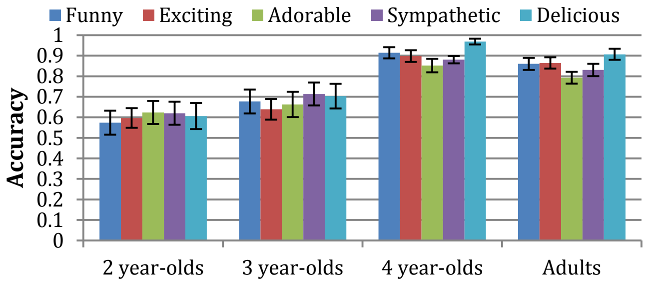

Figure 3 Response accuracy by category in each age group. Error bars indicate SEM.

The effect of age is apparent in looking at the performance of individual children: 12.5% of two-year-olds, 31.3% of three-year-olds, 100% of four-year-olds performed above chance. See Figure 4.

These results suggest that some sensitivity to relatively fine-grained distinctions among positive emotional expressions emerges as early as two and three. However, as evident in Figure 4, children also undergo rapid developmental change. By four, children achieve adult-like performance on this task. Overall, children's performance was not specific to any set or subset of these stimuli; children succeeded whether the eliciting causes were animate or inanimate, and succeeded even when they had to map a stimulus expressing negative emotion to a positive response.

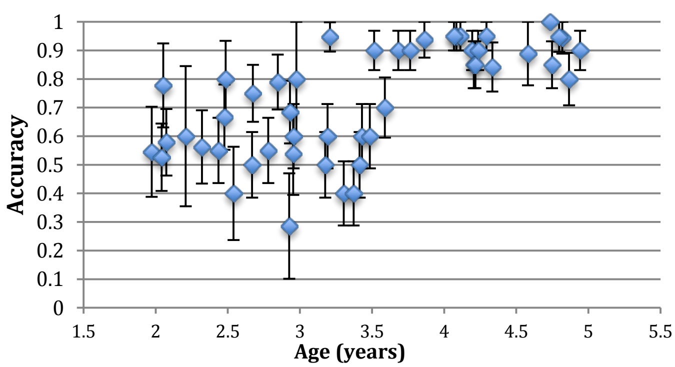

Figure 4 The response accuracy of each child as a function of age. Error bars indicate SEM.

Discussion

We found that children as young as two and three had an emerging ability to discriminate within-valence emotional expressions, and, at least in the context of a simple two-variable forced choice task, use these expressions to identify their probable causes. By four, children's performance on our task had already reached adult levels.

As noted, even infants discriminate emotional facial expressions (e.g. Serrano, Iglesias, & Loeches, 1992), match emotional facial and vocal expressions (e.g. Flom & Bahrick, 2007) and exhibit different behavioral responses to different emotional expressions (e.g. Klinnert, 1984). However, although these abilities might serve as bases for understanding emotions, the results themselves do not rule out low-level explanations for infants' performance. Infants might detect differences at the level of facial features, or learn behavioral responses to characteristic expressions without any understanding or representation of the underlying emotions. In our task, however, the underlying emotion is the only link between the vocal expressions and the elicitors. There are probabilistic causal relationships, but no surface cues that conjoin an exciting toy to an expression of delight or a crying baby to an expression of sympathy. Our finding that children not only distinguish relatively subtle gradations in emotions within valence but also map them onto probable causes is however, consistent with more recent research suggesting that even infants can match emotions appropriately to eliciting causes (i.e., anticipating positive responses for goal completion; Skerry & Spelke, 2014). Future research might look at whether the ability to draw more nuanced distinctions within valences emerges in younger toddlers and infants.

Future studies could also investigate the underlying mechanisms supporting this ability. One possibility is that children themselves experience an emotional response to the elicitors, simulate the emotional expression they would make, and compare this simulation with the vocal expression they hear in order to identify the appropriate mapping between the candidate cause and the vocalization. A second possibility is that children have observed others responding to similar cues in similar ways in the past and have learned stable associations between the events. We refer to causes rather than "associations" throughout because a wealth of research suggests that children readily infer causal relationships from data when they see evidence for plausible causal relationships (see Gopnik & Wellman, 2012, Schulz, 2012, and Tenenbaum, Kemp, Griffiths, & Goodman, 2011, for reviews); here however the point is only that children might originally learn the mappings from statistical input in their environment. A final possibility is that children have an abstract representation of the kinds of stimuli and events that elicit emotions and the kinds of emotional expressions linked to those emotions. For example, they might represent that humorous events generate amusement and amusement generates characteristic vocalizations. Given that studies in other domains (e.g., intuitive physics) suggest that mental simulation, statistical associations, and abstract causal theories mutually inform each other to support commonsense judgment (Battaglia, Hamrick, & Tenenbaum, 2013), these accounts may not be mutually exclusive. Critically however for our purposes, all of these accounts require children to draw relatively fine-grained distinctions between emotional responses. If children collapsed across different positive emotions, or responded only to the valence and arousal of emotional expressions, they could not reliably make nuanced mappings either for themselves or for others.

Finally, we realize that there may be some dispute about the degree to which we want to think of the response to any of these eliciting causes as an emotional response per se. We might say we feel "excited" on seeing the light-up toy or "amused" when we see the silly faces, but there is no simple emotion label that captures what we feel when we see a cute baby (endeared? affectionate?), a crying baby (sympathetic? tender?), or delicious food (delighted? anticipatory?). We believe this speaks more to the impoverished nature of our emotion labels than to the absence of emotional responses to our stimuli. Patently, people often have strong emotional responses both to babies (adorable or distressed) and to food. Although, as our opening quotations illustrate, there are myriad emotion words in English, the proliferation of emotion words is not a cross-cultural universal (e.g., Lutz, 1982) and the words that we have may fail to capture anything like the full richness of human emotional experience. However, the current results suggest that some of that richness can be captured non-verbally and may be accessible, even to very young children.

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