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Emotion as information in early social learning

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Abstract

The majority of research on infants' and children's understanding of emotional expressions has focused on their abilities to use emotional expressions to infer how other people feel. However, an emerging body of work suggests that emotional expressions support rich, powerful inferences not just about emotional states but also about other unobserved states, such as hidden events in the physical world and mental states of other people (e.g., beliefs and desires). Here we argue that infants and children harness others' emotional expressions as a source of information for learning about the physical and social world broadly. This "emotion as information" framework integrates affective, developmental, and computational cognitive sciences, extending the scope of signals that count as "information" in early learning.

Keywords: social cognition, affective cognition, emotional expressions, theory of mind, Bayesian models

Humans are remarkable social learners. Starting early in life, human learners use observations of other people's gaze, speech, and goal-directed actions to guide their inference, exploration, and learning. Yet there is another source of social signal that is ubiquitous in young children's lives: emotional expressions. Despite much prior research on how children learn from others and how they understand others' emotions, these two literatures have remained rather separate, leaving open important questions about the role of emotional expressions in early social learning. In what follows, we briefly review these literatures—inferential social learning and emotion understanding—to provide the grounding for our hypothesis: Human learners use emotional expressions as information to infer unobservable aspects of the physical and social world. We then summarize recent empirical work that supports this hypothesis. We end by discussing open questions for future work as well as broader implications of our proposal.

1. Prior Work: Early Social Learning and Emotion Understanding

1.1 Inferential social learning: using others' behaviors as information about the world

Decades of research in cognitive science have revealed the constructive nature of the human mind (Marr, 1982). Even from sparse, underdetermined input, humans draw rich, powerful inferences to acquire abstract, structured knowledge. A body of work suggests that such inferential abilities also support how young children learn from others; given just a few utterances (e.g., “Look, it’s a *blicket!*”) or observations of goal-directed actions (e.g., pressing a button on a toy to play music), infants readily acquire meanings of new words (e.g., Woodward et al., 1994), generalize object properties (e.g., Gweon et al., 2010; see also Csibra & Shamsudheen, 2015), and even infer the cause of their own failures (Gweon & Schulz, 2011).

Such rich interpretation of others' behaviors is based on an intuitive, causal theory of how

these social signals are generated. To the extent that learners understand how an agent's perceptual access and mental states (e.g., beliefs, desires) give rise to the agent's speech, actions, and communicative behaviors, they can also go backward from behaviors to hidden states; in other words, by using others' behaviors as information, learners can infer hidden aspects of the world or the mental states that generated those behaviors (e.g., Goodman & Frank, 2016; Jara-Ettinger et al., 2016; Shafto et al., 2012). Collectively, this literature demonstrates how early social learning goes beyond imitation of others' behaviors. Instead, young children interpret the meaning of others' behaviors to draw rich inferences and learn about how the world works (i.e., inferential social learning; Gweon, 2021). One ubiquitous source of social information has been missing from this picture, however: emotional expressions (see Fig. 1a).

1.2 Early understanding of other people's emotions

A large body of literature on early emotion understanding has focused on how children understand emotional expressions as indicators of how other people feel. These studies have investigated how young children discriminate, categorize, or label emotional expressions (for review, see Ruba & Pollak, 2020; Widen, 2013). For instance, even 5-month-old infants can discriminate positive expressions from negative expressions, and by 7 months of age, infants readily map positive and negative facial expressions to positive and negative vocal expressions, respectively. Although such work focuses on children's abilities to use emotional expressions to understand the underlying emotion per se, the possibility that children use emotional expressions as information about the physical and social world—an idea we call “emotion as information”—has received relatively less attention.

Prior work on early social referencing (e.g., de Rosnay et al., 2006; Moses et al., 2001;

Repacholi & Meltzoff, 2007; Sorce et al., 1985; Vaish et al., 2008; for review, see Clément & Dukes, 2017; Walle et al., 2017) suggests that even infants use emotional expressions to guide their actions under conditions of uncertainty. That is, in ambiguous contexts (e.g., visual cliffs, novel toys), 1-year-old infants refer to another person's emotional expression to decide whether to approach or avoid the situation; they are more likely to avoid the ambiguous situation when they observe a negative emotional expression than when they observe a neutral or positive emotional expression. These behaviors are consistent with the idea that emotional expressions provide information for learning and raise important questions about the underlying representations and inferential processes. For instance, how fine-grained are infants' early representations of emotions (beyond positive vs. negative)? How flexibly can infants use another person's emotional expressions to guide their own inferences (beyond approach vs. avoid in ambiguous situations)? And how do their abilities to use emotion as information develop with their growing capacities for reasoning about the contents of other minds (i.e., theory of mind)?

Other findings suggest that infants understand the link between others' goal-directed actions and their emotional expressions. For instance, when agents successfully achieve their goals, 10-month-olds expect them to display a positive rather than negative expression (Skerry & Spelke, 2014). By early preschool years, children begin to use both external events and others' mental states to predict their emotional responses, and children's sophistication in making such predictions increases throughout development (e.g., Asaba et al., 2019; Doan et al., 2020; Lagattuta et al., 1997; Pons et al., 2004). Whereas previous studies have focused primarily on such *forward inferences* (see Fig. 1b, straight arrows), our main proposal concerns inferences in the other direction, that is, *inverse inferences* (see Fig. 1b, curved arrows): Can infants and children also use others' emotional expressions to recover hidden events and unobservable mental states

that gave rise to those expressions?

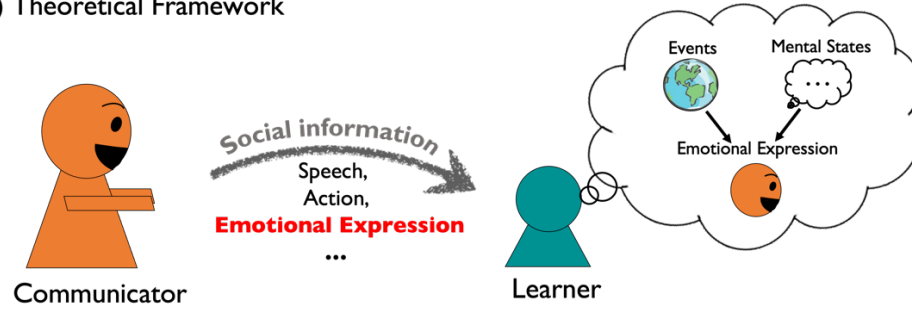
1.3 Summary

In sum, existing literature on early social learning has focused on how children learn from others' speech and action, whereas prior work on early emotion understanding has focused on how children reason about how other people feel. Although infants' ability to engage in social referencing is consistent with our proposal, this literature has remained relatively separate from research on children's inferential abilities in other domains. Therefore, there are important open questions about how children draw inferences from others' emotional expressions and how these inferences guide exploration and learning throughout early childhood.

2. Emotion as Information: Learning From Emotional Expressions

Our key claim is that humans, starting early in life, consider others' emotional expressions as information (note that we use "emotional expressions" to refer to the facial, vocal, and bodily features that are commonly associated with emotions). We contend that, just as children use others' speech and actions to infer unobservable aspects of the world, they also use others' emotional expressions to learn about the physical and social world, beyond the emotional content itself (Fig. 1).

(a) Theoretical Framework



(b) Inverse inferences that learners can make by using emotion as information

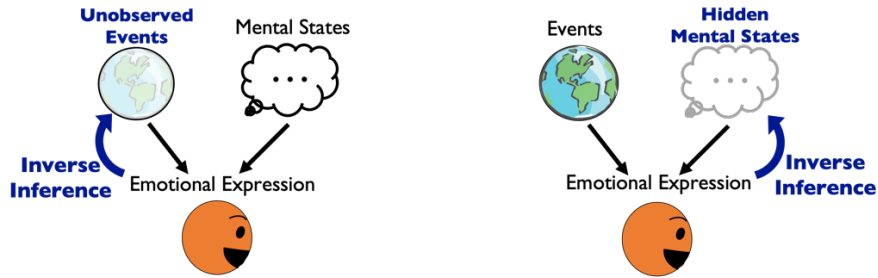


Fig. 1. The emotion-as-information framework. We propose that the repertoire of social information that supports early learning includes not only speech and actions but also emotional expressions (a). Learners represent these social signals as generated by both events in the physical world and others' internal mental states (as illustrated by the graphical causal model inside the thought bubble). As illustrated in (b), children can not only use external events and others' mental states to predict how others would feel (i.e., forward inferences, straight arrows), but can also use others' emotional expressions as information to recover unobserved events (left) and hidden mental states of other people (right; i.e., inverse inferences, curved arrows).

2.1 Computational framework

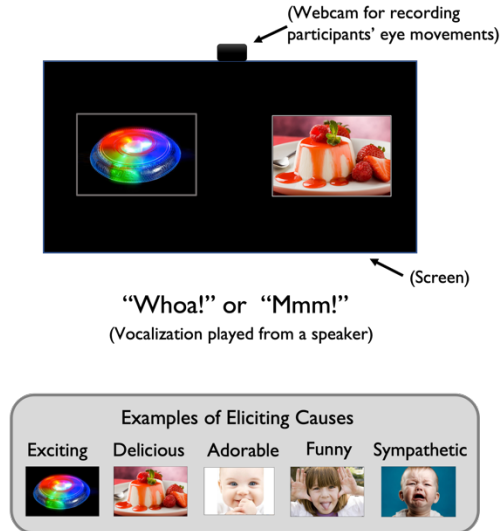
Our proposal builds on recent advances in computational cognitive science that formalize emotion reasoning as one of the core aspects of human social intelligence (Ong et al., 2019; Saxe & Houlihan, 2017; Wu, Baker, et al., 2018). The key idea of these computational models is that the intuitive theories that humans use to reason about and learn from others incorporate how external events and internal mental states give rise not only to speech and actions (e.g., Goodman & Frank, 2016; Jara-Ettinger et al., 2016; Shafto et al., 2012), but also to emotional expressions. These models can successfully capture how adults use external events and others' mental states to predict

others' emotional responses and, in the reverse direction, how adults might recover hidden events and mental states from observed emotional expressions (Ong et al., 2019; Wu, Baker, et al., 2018). This recent computational work provides a formal framework for studying emotion as input to children's inferences. Note that although these ideas are related to appraisal theory—a *scientific theory* of how emotion is generated from cognitive evaluations of events (see Moors et al., 2013, for review)—our proposal concerns how learners' *intuitive theory* of how emotion is generated allows them to draw rich inferences from emotional expressions. In the following subsections, we review the latest empirical work that supports our hypothesis.

2.2 Emotion as information about external events

Recent work suggests that even 1-year-old infants can use others' emotional expressions to infer the causes that likely elicited them (Wu et al., 2017). In three experiments, infants heard a vocalization (e.g., “Whoa!” or “Mmm!”) while two items were presented side by side on a screen (e.g., an exciting toy on the left and a delicious dessert on the right; see Fig. 2a). The infants preferentially looked at the item that had likely elicited the vocalization. These experiments show that beyond distinguishing a few basic emotions or contrasts in valence, infants can differentiate a range of positive emotional vocalizations (including those elicited by funny, exciting, adorable, sympathetic, and delicious stimuli) and identify the probable causes that generated them. These results suggest that infants have a remarkably fine-grained understanding of various emotional expressions, even those with the same valence, and readily connect these expressions to their probable causes.

(a) Mapping vocalizations onto eliciting causes



(b) Using vocalizations to infer hidden causes

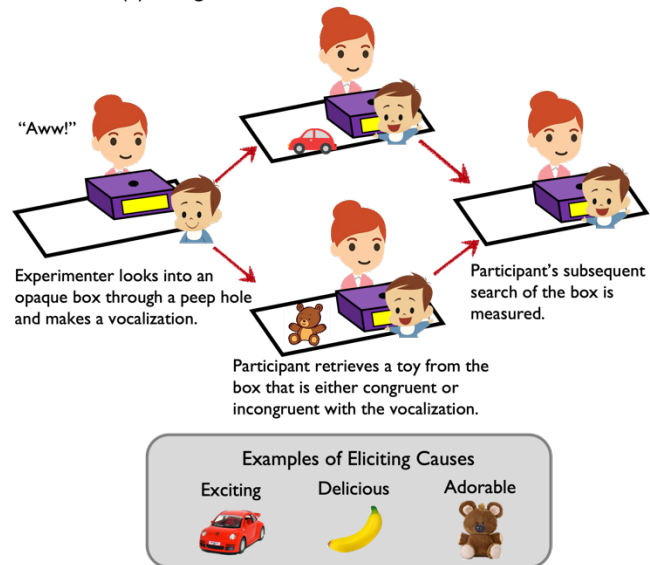


Fig. 2. Illustration of the procedures in Wu et al. (2017). This study investigated 1-year-old infants' use of emotional vocalizations to make inferences about external events in the physical world. In Experiments 1 through 3 (a), infants saw two pictures side by side on a screen and heard an emotional vocalization. The research question was whether infants would prefer to look at the likely cause of the vocalization—for example, whether they would look at the exciting toy when hearing "Whoa!" and look at the delicious dessert when hearing "Mmm!" Five positive emotional vocalizations that are elicited by exciting, delicious, adorable, funny, and sympathetic stimuli were used. In Experiments 4 and 5 (b), an experimenter looked into a box and made an emotional vocalization (e.g., "Aww!"). These experiments tested whether infants would search longer for an additional toy if the first toy they retrieved was incongruent with the vocalization (e.g., a shiny, exciting toy car) than if it was congruent (e.g., an adorable stuffed animal). Three vocalizations elicited by exciting, delicious, and adorable objects were used.

Other experiments in the same study (Wu et al., 2017) demonstrated that infants' inferences reflect their expectations of an eliciting cause rather than a probabilistic matching of the vocalization and the external event (see Fig. 2b). When someone looked into a box and made a vocalization (e.g., "Aww!"), infants spent more time searching for an additional object when the content of the box was incongruent with the expression (e.g., a shiny, exciting toy car) than when it was congruent (e.g., an adorable stuffed animal). Such selective searching behavior suggests that infants in the incongruent condition posited the presence of another hidden object that was more consistent with the perceived expression.

Infants and children can also interpret the same emotional expression differently depending

on the mental state of the person expressing emotion and the broader context. An adult's expression of surprise or excitement about a toy is usually about the toy itself. However, when the adult is already familiar with the object, even infants interpret the expression as directed toward something else (e.g., another toy or a specific part of the toy; Moll et al., 2006). By preschool years, children jointly consider another person's emotional expression (e.g., surprise vs. happiness) and prior knowledge to infer the presence of a hidden causal function of a toy and modulate their own exploration accordingly (Wu & Gweon, 2021). Other work suggests that children even use others' emotional reactions to different states of a toy (e.g., getting broken or fixed) to infer who owns the toy (Pesowski & Friedman, 2016). Collectively, these results reveal early-emerging abilities to reason and learn about the external world by using emotional expressions as a source of information.

2.3 Emotion as information about internal mental states

At least by the second year of life, children understand that emotional expressions are only probabilistically related to external events in the world; emotional expressions also depend on evaluation of those events. For instance, even very young children consider other people's emotional expressions as indicators of their desires; when an experimenter made a negative expression toward crackers and a positive expression toward broccoli, 18-month-olds inferred what food the person wanted, even if it conflicted with what they themselves wanted (Repacholi & Gopnik, 1997).

More recent work suggests that these abilities reflect more than simple mappings between the valence of emotional expressions and desires (e.g., a positive expression indicates something is liked, a negative expression indicates something is disliked). For instance, given a change in the

valence of someone's facial expression before and after seeing an outcome, 5-year-olds can infer that the person had a false belief prior to knowing the outcome (Wu & Schulz, 2018). In a modified version of the classic false-belief task (in which Anne moved Sally's toy during Sally's absence), when children saw Sally come back looking angry, they inferred that Sally must have seen Anne move her toy and would search in the toy's actual location; when children saw Sally come back looking happy, they inferred that she had not seen the transfer and would look for her toy in its previous location (Wu, Haque, & Schulz, 2021).

By age 7, children can use the fact that people sometimes feign emotional expressions to recover not only the mental state of a person displaying an emotion but also the mental state of another person observing it. For example, children saw an illustrated story in which, after the Bears beat the Lions in a basketball game, a fan displayed a sad expression in front of a player, but displayed a happy expression behind his back. Children used the contrasting expressions to infer that the fan rooted for the Bears and the player played for the Lions. Thus, children can use masked emotional expressions to make mental-state inferences not only about the person emoting but also about the person's intended audience, whose expressions were not observed at all (Wu & Schulz, 2020).

Children's abilities to infer mental states from emotional expressions also support their learning about other individuals' internal qualities, such as competence (Asaba et al., 2020; Brey & Shutts, 2018; Weiner et al., 1982). In one recent study (Asaba et al., 2020), 6- to 9-year-old children saw an illustrated story in which two students succeeded at a task and a teacher displayed surprise toward just one of the two students. Even though the students were equally successful, the children inferred that the student who elicited the teacher's surprise was less competent than the other student. This finding suggests that they understood the teacher's surprise as reflecting her

prior belief that the student would not succeed.

Taken together, these studies show that in addition to signaling information about external events in the physical world, emotional expressions provide an important entrée into other minds. Children's ability to use emotional expressions to infer abstract qualities such as competence further highlights the importance of raising adults' awareness about what their emotional expressions might communicate to young children.

3. Open Questions

The work reviewed thus far lays the foundation for an emerging topic for research on the role of emotional signals as information for learning. In this section, we discuss a few questions we find exciting.

3.1 Is there *emotionese*, and does it play a role in learning?

In many cultures, adults modify their speech and actions when they interact with infants. They use simple, slow, and dynamic speech when talking to infants (i.e., *motherese*) and make expansive, repetitive movements when demonstrating object properties to infants (i.e., *motionese*). These modifications facilitate infants' understanding of language and goal-directed actions (Brand et al., 2002; Golinkoff et al., 2015). Is there also *emotionese*—that is, exaggerated, or even feigned, emotional expressions adults use when interacting with infants? Future work could characterize how infant-directed emotional expressions differ from adult-directed or involuntary emotional responses, and whether *emotionese* facilitates infants' learning.

3.2 How does communicative intent influence learning from emotional expressions?

Social learning is particularly powerful in communicative contexts. Given ostensive cues that signal the communicative, pedagogical intent of a demonstrator (e.g., “Hi, [baby’s name]! Look!”), infants generalize demonstrated object functions or labels to other objects of the same kind (e.g., Csibra & Shamsudheen, 2015; Gweon et al., 2010). Some evidence suggests that generalization also occurs with emotional expressions; when an adult displays a valenced emotional response to an object in a communicative context (e.g., a disgusted response to a novel object), infants interpret the expression as conveying generalizable knowledge about the object and expect other people to show the same response to the object (for review, see Gergely & Kiraly, 2019). Although these studies show how infants generalize one person’s object-directed emotional expression to other people, open questions remain about how they generalize the expression to other objects. For instance, when someone makes a sad face at a broken toy truck, would infants show category-based generalization (i.e., expect the person to express sadness toward other toy trucks regardless of their brokenness), as they do when they observe object-directed demonstrations or labels? Or would they show feature-based generalization (i.e., expect sad expressions toward other broken objects regardless of category)? Although our emotion-as-information framework and existing evidence suggest that emotional expressions and other social signals are interpreted in similar ways, it remains an important question for future research to determine how emotional expressions might differ from other social signals in supporting fast, powerful inductive learning in communicative contexts.

3.3 Is there cross-cultural variability in the use of emotion as information?

A long-standing theoretical debate concerns the universality of human emotional expressions (for review, see Barrett et al., 2019; Cowen et al., 2019). Studying how emotional states are inferred

from expressions across cultures is a challenging research endeavor both conceptually and methodologically, and we do not address it here. Yet the question of cross-cultural variability is still important: Do the kinds of inferences we have described—inferences from emotional expressions to both internal and external states—rely on shared mechanisms of social inference, or are they instead more idiosyncratic, cultural routines? For instance, although the evidence for emotion as information has primarily come from children in industrialized, Westernized societies (where deliberate, exaggerated displays of emotions are relatively common), do young children in other societies, especially those where people may be habitually less expressive (Tsai, 2017), also treat emotional expressions as a rich source of information for learning? Appropriate cross-cultural adaptation of some of the paradigms described here could shed light on the relative consistency of emotion-based inference across cultures, providing evidence about the extent to which inferential social cognition consists of a set of core abilities shared across distinct human cultures (Gergely & Csibra, 2003; Gweon, 2021; Jara-Ettinger et al., 2016).

3.4 How do learners integrate emotion information with different, perhaps conflicting, sources of information?

We have proposed that, in addition to speech and actions, emotional expressions are a source of information for learning. In the real world, however, these different types of social information are embedded in a coherent stream of events. How do young learners integrate them, especially when they conflict with each other? Suppose, for instance, that a parent says to a child, “These carrots taste great!” while inadvertently frowning after taking a bite; how might the child resolve the incongruence? Can the child infer how the carrots actually taste and what the communicative goal of the parent is (i.e., trying to persuade the child to eat carrots)? Despite abundant work

investigating children's inferences from different sources of social information separately (e.g., Goodman & Frank, 2016; Gweon, 2021; Jara-Ettinger et al., 2016; Shafto et al., 2012), it remains an important task for researchers to provide a more unified model of early social learning that integrates these various sources of information.

4. Broader Implications

This emotion-as-information view has implications for a number of domains. First, it can advance the general public's awareness of what children can learn from emotional expressions and the potential of using emotional expressions (strategically) to support early learning. Second, although some disorders, such as autism, are associated with impairments in emotion recognition (see Bayet & Nelson, 2019, for review), their downstream consequences on learning and reasoning are still poorly understood. We hope to inspire more research on this topic in atypical development. Finally, this view sets new directions for artificial intelligence. Although there has been much progress in developing artificial intelligence systems that can categorize or recognize emotional expressions, these systems can be even more powerful if they can learn from emotional expressions as humans do.

5. Conclusion

We have argued here that emotional expressions are a powerful source of information. Although human inferences surely extend beyond the observable data, there may nonetheless be more observable data than previously considered. Human learners have access not only to the world they see and the behavior and testimony of other people, but also to the ways others react to the world. These emotional reactions, as demonstrated by this article, may speak louder than initially thought.

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