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Emotion as information in early social learning

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3332 words, 41 references, 5 Recommended readings

(Requirements: 2802 + 600 = 3402 words, 41 references)

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Abstract

The majority of research on children's understanding of emotional expressions has focused on infants and children's ability to use emotional expressions to learn about emotion per se: how other people feel about events in the world. However, an emerging body of work suggests that emotional expressions support rich, powerful inferences not just about emotional states but about other unobserved aspects of others' minds and the world. Here we argue that infants and children harness others' emotional expressions as a source of information for learning 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 others’ 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 motivate our hypothesis: Human learners use others’ emotional expressions as information to infer unobservable aspects of the physical and social world. We then introduce 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, under-determined 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 blinket!”) 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, Markman, & Fitzsimmons, 1994), generalize object properties (e.g., Gweon, Tenenbaum, & Schulz, 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 others' perceptual access and mental states (e.g., beliefs, desires) give rise to their speech, actions, and communicative behaviors (see Fig. 1a), they can also go backwards from behaviors to hidden states; in other words, by using others' behaviors as information, learners can infer hidden aspects of the world or others' mental states that generated those behaviors (e.g., Shafto, Goodman, & Frank, 2012; Goodman & Frank, 2016; Jara-Ettinger, Gweon, Schulz, & Tenenbaum, 2016). Collectively, this literature demonstrates how early social learning goes beyond imitation of others' behaviors. Instead, young children interpret the meaning of social signals based on their intuitive theory of how these signals are generated, and use them to guide their inferences, exploration, and learning (i.e., inferential social learning, Gweon, in press). One ubiquitous source of social information has been missing from this picture, however: emotional expressions.

1.2. Early understanding of others' emotions

A large body of literature on early emotion understanding has focused on how children understand emotional expressions as indicators of how others feel. These studies have investigated how infants and children discriminate, categorize, recognize, or label emotional expressions (see Ruba & Repacholi, 2019; Widen, 2013 for review). For instance, even 5-month-old infants can discriminate positive expressions from negative expressions, and by 7 months, infants readily map positive and negative facial expressions to positive and negative vocal expressions, respectively. While 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 world---an idea we call “emotion as information”---received relatively less attention.

Prior work on early social referencing (e.g., Sorce, Emde, Campos, & Klinnert, 1985; Moses, Baldwin, Rosicky, & Tidball, 2001; de Rosnay, Cooper, Tsigaras, Murray, 2006; Repacholi & Meltzoff, 2007; Vaish, Grossman & Woodward, 2008; see Walle, Reschke, & Knothe, 2017 and Clément & Dukes, 2017 for review) suggests that even infants use emotional expressions to guide their actions under uncertainty. That is, in ambiguous contexts (e.g., visual cliffs, novel toys), one-year-old infants refer to others’ emotional expressions to decide when to approach or avoid; 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 others’ emotional expressions to guide their own inferences (beyond approach vs. avoid)? And how do their abilities to use emotion as information develop with their growing capacities for reasoning about the contents of others’ 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, with increasing sophistication throughout childhood (e.g., Asaba, Ong, & Gweon, 2019; Lagattuta, Wellman, & Flavell, 1997; Pons,

Harris, & de Rosnay, 2004; Doan, Friedman, & Denison, 2020). These studies, however, have primarily focused on how children infer how others might feel based on information about others' perception of external events and their internal mental states (i.e., *forward inferences*; see Fig. 1b, straight arrows). Our main proposal concerns inferences in the other direction (i.e., *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 focused on how children learn from others' speech and action, whereas prior work on early emotion understanding focused on how children reason about how others feel. While 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 others' 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).

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3 **2.1 Computational framework**
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5 Our proposal builds on recent advances in computational cognitive science that formalize
6 emotion reasoning as one of the core aspects of human social intelligence (Ong, Zaki, &
7 Goodman, 2019; Saxe & Houlihan, 2017; Wu, Baker, Tenenbaum, & Schulz, 2018). The key
8 idea of these computational models is that the intuitive theories that humans use to reason about
9 and learn from others incorporate not only how external events and internal mental states give
10 rise to speech and actions (e.g., Goodman & Frank, 2016; Jara-Ettinger et al., 2016; Shafto et al.,
11 2012) but also emotional expressions. These models can successfully capture how adults use
12 events in the world and others’ mental states to predict others’ emotional responses (*forward*
13 *inferences*) and, in the reverse direction, how we might recover hidden events and mental states
14 from observed emotional expressions (*inverse inferences*; Ong et al., 2019; Wu et al., 2018).
15 This recent computational work provides a formal framework for studying emotion as input to
16 children's inferences. Note that while these ideas are related to appraisal theory – a *scientific*
17 *theory* of how emotion is generated from cognitive evaluations of events (see Moors, Ellsworth,
18 Scherer, & Frijda, 2013 for review), our proposal concerns how learners’ *intuitive theory* of how
19 emotion is generated allows them to draw rich inferences from others’ emotional expressions.
20 Below, we review the latest empirical work that supports our hypothesis.
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43 **2.2 Emotion as information about the external world**
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45 Even one-year-old infants can use others’ emotional expressions to infer their probable eliciting
46 causes (Wu, Muentener, & Schulz, 2017). When infants heard a vocalization (e.g., “Whoa!”
47 versus “Aww!”) while two items were presented side by side on a screen (e.g., a toy on the left
48 and a cute baby on the right), infants preferentially looked at the item that had likely elicited the
49 vocalization, suggesting an ability to connect emotional expressions to their probable causes (see
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Fig. 2a). This form of emotion understanding is remarkably fine-grained; beyond distinguishing a few basic emotions or contrasts across valence, infants can differentiate a range of positive emotional expressions (including those elicited by funny, exciting, adorable, sympathetic, and delicious stimuli) and identify the probable causes that generated them.

Infants' inferences reflect their expectations of an eliciting cause rather than a probabilistic matching of the vocalization and the external event. 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 toy car) than when it was congruent (e.g., an adorable stuffed animal; see Fig. 2b), suggesting they posited the presence of another hidden object that is more consistent with the perceived expression.

Infants and children can also interpret the same emotional expression differently depending on others' mental states and the broader context. When an adult expresses surprise/excitement about a toy, it is usually about the toy itself. However, when the adult is already familiar with the object, even infants interpret the expression as directed towards something else (e.g., another toy or a specific part of the toy; Moll, Koring, Carpenter, & Tomasello, 2006). By preschool years, children jointly consider others' emotional expressions (e.g., surprise vs. happiness) and their prior knowledge to infer the presence of a hidden causal function of a toy and modulate their 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 others’ evaluation of those events. Prior work has found that even very young children consider others’ emotional expressions as indicators of their desires. When an experimenter makes a negative expression towards goldfish crackers and a positive expression towards broccoli, 18-month-olds infer what food the person wants, even if it conflicts with what they themselves want (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., positive expressions mean like, negative expressions mean dislike). For instance, given a change in the valence of someone’s facial expression before and after she sees an outcome, five-year-olds can infer that she 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 see Sally come back looking angry, they infer that Sally must have seen Anne move her toy and would search in the toy’s actual location; when children see Sally come back looking happy, they infer that she had not seen the transfer and would look for her toy in its previous location (Wu, Haque, & Schulz, 2018).

By age seven, children can use the fact that people sometimes feign emotional expressions to recover not only the mental states of the person displaying the emotion but also of the person observing it. Suppose, at a basketball game, the Bears beat the Lions; a fan displayed a sad expression in front of a player, but displayed a happy expression behind his back. Children can use the contrasting expressions to infer that the fan rooted for the Bears and the player

played for the Lions. That is, children can use masked emotional expressions to make mental state inferences not only about the person emoting but about their 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 others' internal qualities such as competence (Asaba, Wu, Carrillo, & Gweon, 2020; Brey & Shutts, 2018; Weiner, Graham, Stern, & Lawson, 1982). When two students both succeeded at a task but a teacher showed surprise to one student and no surprise to the other, children (six to nine year-olds) inferred that the student who elicited the teacher's surprise is less competent than the other student (Asaba, Wu, Carrillo, & Gweon, 2020). This finding suggests that children 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 the external world, emotional expressions also 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 that investigates the role of emotional signals as information for learning. Below we discuss a few questions we find exciting.

3.1 Is there a role of *emotionese* in learning?

In many cultures, adults modify their speech and actions when they interact with infants. They use simple, slow, and dynamic speech (i.e., "motherese") and make expansive, repetitive movements when demonstrating objects ("motionese"). These modifications facilitate infants' understanding

of language and goal-directed actions (Golinkoff, Can, Soderstrom, & Hirsh-Pasek, 2015; Brand, Baldwin, & Ashburn, 2002). Is there also “*emotionese*” where adults exaggerate (or even feign) their emotional expressions when interacting with infants? Future work could characterize how infant-directed emotional expressions differ from adult-directed or involuntary emotional responses, and whether infants learn better from “*emotionese*.”

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., Gweon, Tenenbaum, & Schulz, 2010; Csibra & Shamsudheen, 2015). Some evidence suggests that generalization also occurs with emotional expressions; when an adult displays a valenced emotional response to an object in communicative contexts (e.g., a disgusted response to a novel object), infants interpret the expression as conveying generalizable knowledge about the object and expect others to show the same response to the object (Gergely & Kiraly, 2019). While these studies show how infants generalize one person’s object-directed emotional expression to other *people*, we still do not know 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 agent to express sadness to other toy trucks regardless of their brokenness) as they do with object-directed demonstrations or labels? Or would they show feature-based generalization (i.e., expect sad expressions to other broken objects regardless of category)? Although our emotion-as-information framework and existing evidence suggest that emotional expressions are interpreted in similar ways as other social signals, it remains an important question

for future research to understand 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 (see Barrett, Adolphs, Marsella, Martinez, & Pollak, 2019; Cowen, Sauter, Tracy, & Keltner, 2019 for review). The issue of how emotional states are inferred from expressions across cultures is complex 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 describe – 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, while 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, in turn providing evidence about the extent to which inferential social cognition forms a set of core abilities shared across distinct human cultures (Gergely & Csibra, 2003; Jara-Ettinger et al., 2016; Gweon, in press).

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

So far we have discussed that besides speech and actions, emotional expressions are another 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, 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 they infer how the carrots actually taste and the communicative goal of the parent (i.e., trying to persuade them to eat carrots)? Despite abundant work investigating children’s inferences from different sources of social information separately (e.g., Goodman & Frank, 2016; Gweon, in press; Jara-Ettinger et al., 2016; Shafto et al., 2012), it remains an important task for future research 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, we expect to advance the general public's awareness of what children can learn from their emotional expressions, and the potential of using emotional expressions (strategically) to support early learning. Second, while 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 targets for artificial intelligence (AI). Beyond machines that can categorize or recognize emotional expressions, AI systems could be even more powerful if they can learn from emotional expressions like humans do.

5 Conclusion

We have argued here that emotional expressions are a powerful source of information. While human inferences surely extend beyond the observable data, there may nonetheless be more

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3 observable data than we have previously considered. Human learners have access not only to the
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5 world they see and the behavior and testimony of other people, but also to the ways others react
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7 to the world. These emotional reactions, as demonstrated by this article, may speak louder than
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9 many of us have ever realized.
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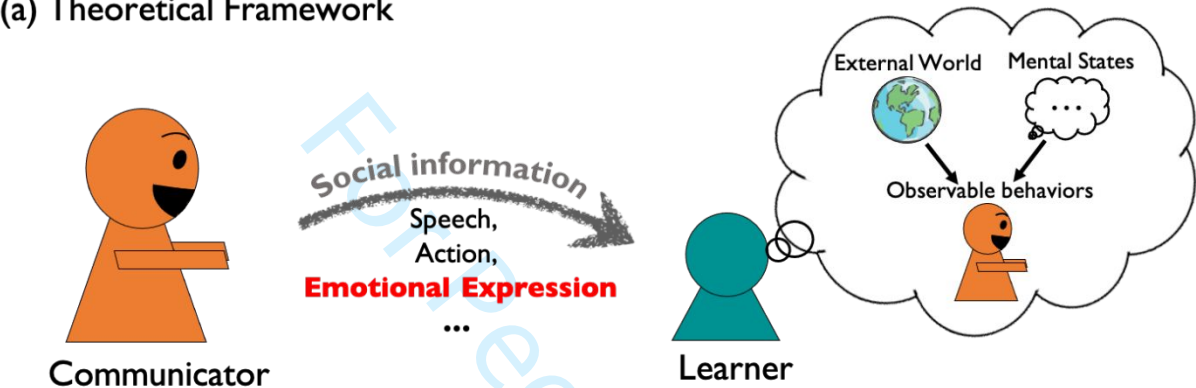
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Figure 1 (a) Theoretical framework. We propose that the repertoire of social information that supports early learning includes not only speech and actions but also emotional expressions. Learners represent these social signals as generated by both events in the external world and others' internal mental states (as illustrated by the graphical causal model inside the thought bubble). (b) Beyond studying how children use others' observation of the world and their mental states to predict how they would feel (i.e., forward inferences, straight arrows), we focus on how children use others' emotional expressions as information to recover others' observation of the world (left) and their mental states (right) that are otherwise unknown (i.e., inverse inferences, curved arrows).

(a) Theoretical Framework



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



Figure 2 One-year-old infants’ inferences about probable causes of emotional vocalizations suggest an early-emerging, sophisticated ability to use emotion as information about the external world (Wu et al., 2017). When infants heard an emotional vocalization (e.g., “Aww!”), they (a) preferred to look at a likely cause of the vocalization (i.e., an adorable baby rather than a light-up toy), and (b) searched longer for an additional toy if the first toy they retrieved was incongruent with the vocalization (e.g., a toy car).

