Cognition and Emotion

ISSN: 0269-9931 (Print) 1464-0600 (Online) Journal homepage: https://www.tandfonline.com/loi/pcem20

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Peter J. Reschke, Eric A. Walle & Daniel Dukes

To cite this article: Peter J. Reschke, Eric A. Walle & Daniel Dukes (2020): Did you mean to do that? Infants use emotional communication to infer and re-enact others' intended actions, Cognition and Emotion, DOI: 10.1080/02699931.2020.1745760

To link to this article: https://doi.org/10.1080/02699931.2020.1745760

Published online: 26 Mar 2020.

COGNITION AND EMOTION
https://doi.org/10.1080/02699931.2020.1745760

Routledge
Taylor & Francis Group

BRIEF ARTICLE

Did you mean to do that? Infants use emotional communication to infer and re-enact others' intended actions

Peter J. Reschke [a,b], Eric A. Walle[b] and Daniel Dukes[c]*

[a]School of Family Life, Brigham Young University, Provo, UT, USA; [b]Psychological Sciences, University of California, Merced, CA, USA; [c]Swiss Centre for Affective Sciences, University of Geneva, Geneva, Switzerland

ABSTRACT

Infants readily re-enact others' intended actions during the second year of life. However, the role of emotion in appreciating others' intentions and how this understanding develops in infancy remains unstudied. In the present study, 15- and 18-month-old infants observed an experimenter repeatedly attempt but fail to produce a target action on an object and express either frustration or neutral affect after each attempt. Analyses of infants' responses revealed that 18-month-old infants, but not 15-month-olds, produced more target actions in the frustration condition than the neutral condition. These results suggest that infants use emotional communication to disambiguate and re-enact others' intended actions and that this ability develops in the second year of life.

ARTICLE HISTORY
Received 15 May 2019
Revised 16 March 2020
Accepted 17 March 2020

KEYWORDS
Imitation; intentionality; emotion; social cognition; infancy

Appreciating others' motivational states is an essential component in the development of psychological reasoning and allows the perceiver to make predictions regarding other agents' actions (Baillargeon et al., 2016). A related, yet often separately studied, skill is the development of emotion understanding, which is rooted in perceiving how an individual's goals relate to their environment (Reschke et al., 2017). Emotional communication provides the observer with insight to interpret and appraise other individuals' prior, present, and future mental states and behaviours. For example, communicating emotion when engaging in goal-directed behaviours, such as trying to open a door (Warneken & Tomasello, 2006), alerts observers to the agent's goal (open the door), whether the goal is being accomplished or hindered (e.g. frustration = hindered), and what actions might be required to complete the goal (e.g. assistance may be needed to open the door). A growing body of research indicates that emotion understanding and understanding others' intentions are developmentally interconnected (see Reschke et al., 2017 for a review). However, while research has demonstrated that infants can re-enact others' intended actions (Meltzoff, 1995), it remains to be studied how emotion signals may facilitate this behaviour by helping to disambiguate failed actions. The present study examined the role of emotional communication in infants' appreciation of and response to others' failed actions.

Infants' ability to appreciate and imitate others' intended actions develops markedly during the first two years of life. Infants readily imitate others' object-directed actions by 6 months (Barr et al., 1996) and visually discriminate complete and incomplete actions by 10 months of age (Brandone et al., 2014; Hamlin et al., 2009). However, the ability to imitate the inferred, but unseen, goal-directed action rather than the observed failed action does not develop until the second year of life. In a classic study by Meltzoff (1995), 18-month-old infants observed an experimenter display a neutral facial expression while attempting but failing to produce a target action on a novel object (e.g. trying but failing to activate a buzzer with a baton). Despite only observing the experimenter's failed attempts, infants

CONTACT Peter J. Reschke peter_reschke@byu.edu
*Present address: Institute of Special Education, University of Fribourg, Fribourg, Switzerland.

inferred and imitated the unobserved, intended actions (e.g. activating the buzzer using the baton) at a frequency equal to infants who had observed the experimenter successfully model the target actions. Other studies using this behavioural re-enactment paradigm have shown that this ability is present by at least 15 months of age (Bellagamba & Tomasello, 1999; Bellagamba et al., 2006; Johnson et al., 2001), though even 12-month-old infants may demonstrate such ability if simpler objects and actions are provided (Nielsen, 2009). Though informative, these studies have missed an important aspect of inferring others' intended goals, namely infants' emotion understanding.

Re-enacting others' intended actions is likely connected to emotion understanding in at least two ways. First, although studies using the behavioural re-enactment procedure explicitly omit overt expressions of emotion (e.g. Bellagamba et al., 2006), their inclusion of persistent, varied actions may convey relational significance signalling goal frustration (Reschke et al., 2017). Thus, the absence of emotional expressions in the face and voice does not preclude the perception of emotion through other channels. Second, imitation studies explicitly manipulating motivational states ("accidental", "intentional", "joking") do so primarily by systematically varying emotionally-relevant cues, such as vocal prosody (e.g. Sakkalou & Gattis, 2012), facial expression (e.g. Király, 2009), and combinations of emotion cues (e.g. Repacholi, 2009). For example, infants are more likely to imitate an observed "wrong action" (e.g. putting boots on their hands) when the experimenter demonstrated that action jokingly (Hoicka & Gattis, 2008). While these studies have examined how emotions influence infants' imitation of observed actions, no study to our knowledge has examined infants' use of explicit emotional communication to re-enact unobserved, intended actions. This line of inquiry is significant because re-enacting others' intended actions requires the infant to represent the motivational state of a social partner, whereas imitating observed actions does not necessitate cognitive representation (Meltzoff, 1995). If a connection between emotion and goal understanding exists, it stands to reason that emotions may facilitate infants' ability to infer others' motivational states, such as when they fail to complete an intended action. In short, emotions may help infants accurately represent the unseen action, and thus increase imitation of that action.

The present study

This study employed a modified behavioural re-enactment procedure to examine the influence of emotional cues on 15- and 18-month-old infants responding to an agent's failed actions. Infants observed an experimenter attempt but fail three times to complete target actions involving five unique objects. Novel to the present study, infants viewed an experimenter who expressed *either* frustration or maintained a neutral facial expression after each failed attempt. Previous research has shown that infants at these ages can complete the behavioural re-enactment procedure (Bellagamba et al., 2006; Johnson et al., 2001; Olineck & Poulin-Dubois, 2009) and regulate their behaviour toward objects based on an experimenter's emotional cues (Repacholi, 2009). Infants' production of the target action (i.e. the unobserved action) and latency to imitate were coded. It was hypothesised that 15-month-old infants and 18-month-old infants would produce target actions more often in the frustration condition than the neutral condition. Expectations regarding infants' latency to imitate were largely exploratory, and thus no formal predictions were made. Below we report how we determined our sample size, data exclusions, manipulations, and measures in the study.

Method

Participants

The final sample included twenty 18-month-old infants ($M_{age} = 18.01$ months, $SD = 0.52$, Range: 17.15–18.76 months, 9 females) and twenty 15-month-old infants ($M_{age} = 14.79$, $SD = 0.53$, Range: 14.09–15.80 months, 8 females). Two additional 18-month-old infants and two additional 15-month-old infants were tested but excluded because of fussiness ($n = 2$) or missing more than 3 of 5 trials ($n = 2$; see manipulation check section). Four 18-month-olds and four 15-month-olds included in the final sample provided data for only four of five trials and one 15-month old only provided data for three of five trials. The sample was ethnically and socioeconomically diverse. Nineteen participants were of Hispanic ethnicity, 16 were Caucasian, 1 was African American, 2 selected "Other", and 2 did not provide racial information. Median family income was $50,000 (range: less than $25,000 to more than $150,000 per year) and median caregiver education level was a college

degree (range: high school diploma to graduate degree).

Previous studies using the behavioural reenactment procedure have used a repeated-measures design (5 trials) with 10 infants per condition (Bellagamba & Tomasello, 1999; Meltzoff, 1995) and reported large effect sizes (Cohen's f range: .52–1.15). A power analysis using the same design and sample size with this range of effect sizes suggested that our study would have sufficient power ($1-\beta = .81$ to .99, $\alpha = .05$, two tailed).

Stimuli

Test objects

The test stimuli consisted of five novel objects built based on descriptions from prior studies using the behavioural re-enactment procedure (Meltzoff, 1995; Yott & Poulin-Dubois, 2012; see Figure 1).

Emotional expressions

A female experimenter presented each stimulus and expressed frustration or maintained a neutral expression for approximately 2 s following each failed action. For the frustration expression, the experimenter first clicked her tongue, displayed a frustrated facial expression (i.e. a "scowl" featuring separated lips with lowered corners, raised cheeks, wrinkled brow, and slightly squinted eyes), and then produced an audible exhalation. For the neutral expression, the experimenter's cheeks, eyebrows, and eyes remained neutral and she did not vocalise.

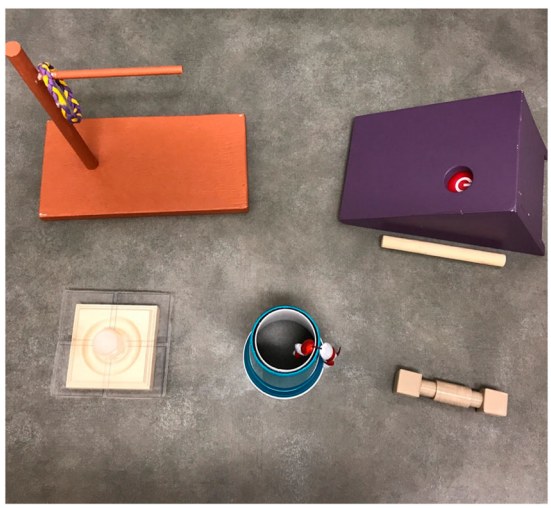

Figure 1. Images and Descriptions of Stimuli and Target and Observed Actions.

Note: It was discovered during data collection that the dumbbell was unintentionally too difficult to separate for infants. In order to maintain consistency in the experiment, the dumbbell was not corrected, and the original dumbbell coding scheme (Meltzoff, 1995) was modified to include infants' clear attempts to separate the dumbbell. This coding scheme is similar to that described in Meltzoff et al. (1999), in which the dumbbell had been purposefully glued together to prevent infants from separating it. Results including or excluding the dumbbell from the analyses reveal identical patterns and significance of results.

Procedure

All procedures were approved by the Institutional Review Board of the University of California, Merced. The caregiver and child were welcomed to a comfortably furnished room with toys. A researcher described all procedures to the caregiver, who provided consent and completed a demographic questionnaire. During this time the infant played with a second researcher (the experimenter). Next, the caregiver and infant were brought to a testing room and directed to sit at a table with the infant on the caregiver's lap. The experimenter sat directly across the table from the infant. The caregiver was instructed to remain neutral throughout the experiment. The experimenter introduced four warm-up toys (one plastic phone and three multicolored balls) separately to prime the infant to relinquish objects upon request and reduce potential distress during the test trials. After this brief period (approximately 1–2 min), the experimenter put away the warm-up toys and proceeded with the test trials.

Infants were randomly assigned to either the frustration condition or neutral condition. Object order was counterbalanced within each group. One video camera situated behind the experimenter captured infants' behavioural responses and a second video camera placed behind the infant and caregiver recorded the experimenter's actions and emotional expressions. A webcam placed on the edge of the table provided a live video feed of the interaction for an out-of-sight timekeeper, who communicated the end of each test trial to the experimenter by making a light tapping sound.

Test trials

There were five test trials, each consisting of a demonstration phase and a response phase.

Demonstration phase. The experimenter introduced one of the five test stimuli and attempted but failed three times to produce a target action on each object. The "failed" actions were taken from the "demonstration (intention)" condition in Study 1 of Meltzoff (1995; for

descriptions, see Figure 1). Novel to the current study, the experimenter expressed either frustration or neutral affect for approximately 2 s after each failed attempt. If necessary, the experimenter addressed infants directly prior to each action by saying the child's name or using the following phrases: "See what I have", or "Look over here". Following the third demonstration, the experimenter placed the stimulus in front of the infant and said, "It's your turn".

Response phase. Each response phase began when the experimenter released the object or the infant touched the object, whichever occurred first. Each response phase concluded when 20 s had elapsed, the infant spontaneously returned the object to the experimenter, or the infant dropped the stimulus to the floor, whichever occurred first. The experimenter looked between the infant and the centre of the table and maintained a neutral expression during the response phase.

Coding

Infant target actions

Two researchers blind to experimental condition independently coded whether infants produced the target action for each stimulus in each response phase. Successful target actions were coded as "1" and non-production of target actions coded as "0" (see Figure 1 for descriptions). Interrater reliability was excellent (Cohen's $\kappa = .95$).

Latency to imitate

A researcher independently viewed trials in which each infant produced the target action ($n_{trials} = 93$) and coded latency to imitate, defined as the first video frame of an infant-produced target action. A second coder viewed 20% of trials. Intercoder agreement was excellent (Pearson $r = .98$, $M_{difference} = .075$ s).

Manipulation check

A researcher independently viewed all demonstration trials to classify the emotional expressions displayed by the experimenter (1 = neutral, 2 = frustration, 3 = unclear). Codes were compared to the assigned conditions to verify that the experimenter displayed the assigned emotion. For two infants, the experimenter displayed an incorrect emotion for three of the five objects. These infants were not retained in the sample. For four other infants, the experimenter displayed an incorrect emotion during one of the five trials. The four valid trials for these infants were retained in the sample. A second coder viewed the emotional expressions of 24% of the retained infants. Intercoder agreement was nearly perfect (agreement = 98%).

Results

Re-enactment of target actions

Infants' production of the target actions was examined using a repeated-measures Generalised Linear mixed model specified with a binomial distribution, a logit link, and an unstructured covariance matrix with age group and emotion as between-subjects factors, and an Emotion × Age Group interaction. Object was also included in the model to control for differences in object difficulty. The model used Restricted maximum likelihood (REML). The data that support the findings of this study are openly available in the Open Science Framework at http://doi.org/10.17605/OSF.IO/M2BU6.

Preliminary analyses including the effects of trial order and infant sex revealed equivalent patterns and significance of results. Thus, these variable were excluded from subsequent analyses.

There was a significant effect of emotion, $F(1, 181) = 4.39$, $p = .04$, $\eta_p^2 = .02$. However, the effect of age group was not significant, $F(1, 181) = 1.04$, $p = .31$, $\eta_p^2 = .005$, nor was the Age Group × Emotion interaction, $F(1, 185) = 2.45$, $p = .12$, $\eta_p^2 = .01$.

Pairwise comparisons of the effect of emotion revealed that infants re-enacted significantly more target actions in the frustration condition ($M = 0.60$, $SE = .07$) than the neutral condition ($M = 0.38$, $SE = .07$), $t(181) = 2.16$, $p = .03$, CI [0.02, 0.41] (see Figure 2). Planned comparisons of the non-significant Emotion × Age Group interaction demonstrated that 18-month-old infants re-enacted significantly more target actions in the frustration condition ($M = 0.71$, $SE = .09$) than the neutral condition ($M = 0.36$, $SE = .10$), $t(181) = 2.81$, $p = .01$, CI [0.11, 0.61]. However, 15-month-old infants' re-enactment of target actions in the frustration ($M = 0.46$, $SE = .10$) and neutral conditions ($M = 0.36$, $SE = .20$) did not differ significantly, $t(181) = .38$, $p = .70$, CI [−0.23, 0.33].

Latency to imitate

Infants' latency to imitate was examined using a repeated-measures ANOVA with emotion and age as between-subjects factors and an Emotion × Age Group interaction. Given the exploratory nature of

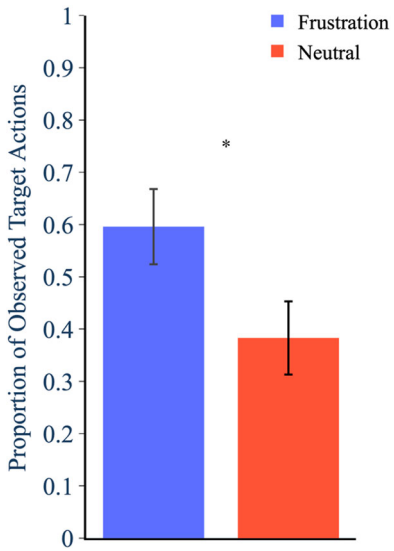

Figure 2. Estimated Marginal Mean proportions of 18- and 15-month-old infants' re-enacted target actions by emotion condition. Error bars represent +/−1 SE. Note: The maximum proportion is 1.0, which would correspond to infants re-enacting the target actions on all trials. '*' = $p < .05$.

these analyses, significant omnibus tests were followed with Bonferroni-corrected post hoc comparisons ($\alpha = .0125$).

There was no main effect of emotion, $F(1, 66) = 1.87$, $p = .18$, $\eta_p^2 = .03$, nor a main effect of age, $F(1, 66) = .01$, $p = .91$, $\eta_p^2 = .0002$. However, there was a significant Emotion × Age Group interaction, $F(1, 66) = 7.16$, $p = .01$, $\eta_p^2 = .10$. Specifically, younger infants initiated target actions significantly later in response to frustration ($M = 7.01$ s) than to neutral affect ($M = 3.58$ s), $t(79) = 2.64$, $p = .01$, CI [3.34, 202.56]. However, older infants' latency to respond in the frustration ($M = 4.64$ s) and neutral (5.75 s) conditions did not differ significantly, $t(45) = -1.02$, $p = .32$, CI [−51.96, 118.62]. Additionally, latencies to respond for younger and older infants did not differ significantly in the frustration condition, $t(61) = 2.06$, $p = .04$, CI [−17.60, 159.69], and neutral condition, $t(68) = 1.74$, $p = .087$, CI [−31.01, 161.46].

Comparison to baseline

Lastly, infants' mean imitation rates were compared to a baseline rate of 0.20 using one-tailed binomial tests to determine whether infants re-enacted target actions at levels greater than expected had infants not have observed any demonstrated actions (see baseline condition in Meltzoff, 1995). Imitation rates were significantly higher than expected by chance for the 15-month-olds in the frustration ($p < .001$) and neutral ($p < .001$) conditions, as well as for 18-month-olds in the frustration ($p < .001$) and neutral ($p < .001$) conditions.

Discussion

This study demonstrates that emotional communication influences infants' re-enactment of unobserved intended actions. Specifically, whereas all infants re-enacted more intended target actions in response to a frustrated experimenter than a neutral experimenter, this ability appears to be heightened for 18-month-olds in comparison to 15-month-olds. Additionally, while 18-month-olds responded with equal latencies in both conditions, 15-month-old infants were significantly slower to produce the target actions in the frustration condition than the neutral condition. Taken together, these results suggest that the experimenter's emotional communication facilitated intention disambiguation for older, but not younger, infants.

To our knowledge, this is the first study to document the emergence of infants' ability to use emotion to help disambiguate others' intentional states. The results also suggest that infants' ability to re-enact unobserved actions may develop prior to their ability to integrate emotion into this process. Fifteen-month-old infants' failure to incorporate emotion may be due to a still-emerging ability to simultaneously attribute and process the experimenter's mental states to regulate their behaviour (see Repacholi et al., 2014). Alternatively, 15-month-old infants may simply be less proficient at appreciating others' emotional communication (Walle, Reschke, Camras, et al., 2017). Indeed, infants' appreciation of others' intentions and emotions may initially emerge as separate skills that become more coordinated later in development, not unlike the development of other social cognitive skills, such as goal understanding and emotion attributions (see Reschke et al., 2017).

More broadly, this study helps bridge research on infant social referencing and psychological reasoning. Social referencing research typically examines how infants reference a social partner's emotional expression to respond to ambiguous, tangible referents, such as toys (Repacholi, 2009), food (Repacholi & Gopnik, 1997), individuals (Boccia & Campos, 1989), or situations (Sorce et al., 1985). Our results indicate that 18-month-old infants can also reference an

adult's emotional expression to disambiguate an *intangible* referent, namely their motivational state. This process is noteworthy because it requires the infant to represent the others' mental state and appreciate their emotional communication, whereas social referencing regarding tangible objects does not necessarily require representation of mental states. This further highlights the developmental connectedness of social cognition and emotion understanding (Reschke et al., 2017).

Lastly, the results add to a body of research indicating that 15- and 18-month-old infants can infer and re-enact others' intended actions. Although the mean rates of imitation observed in the neutral condition (15-month-olds: 0.41; 18-month-olds: 0.41) were lower than analogous conditions reported by Meltzoff (i.e. 0.80; 1995) and others (e.g. 0.72, Bellagamba & Tomasello, 1999; 0.55, Yott & Poulin-Dubois, 2012), they were comparable to those from other labs using the behavioural re-enactment procedure (e.g. 0.37; Johnson et al., 2001). Furthermore, observed imitation rates were significantly greater than chance levels in all conditions.

Limitations and future directions

The findings suggest that 18-month-olds increased re-enactment of target actions when (negative) emotional information was provided. However, there are at least two alternative explanations to this interpretation. First, it is possible that the frustrated expression was more interesting to older infants, and thus increased their attention to the demonstrations. We feel that this explanation is less likely given that the 18-month-old infants in the frustration and neutral conditions produced target actions with equal latencies. Additional research using eye-tracking technology could explore how emotion influences infants' focus to different aspects of interpersonal contexts (e.g. object, hands/actions, social partner). Second, it is possible that infants imitated more in the frustration condition than the neutral condition due to additional auditory information absent in the neutral condition. An additional neutral condition matching the amount of sensory information (e.g. vocal cues) would help examine this possibility. Thus, although we favour an interpretation that qualitative differences in emotion led to differences in imitation, the results of the current study should nevertheless be interpreted with caution.

Additionally, the current findings could be expanded by investigating the effect of positive emotions on infants' re-enactment of others' intentional actions. For example, an experimenter expressing laughter or joy following a so-called "failed" action may elicit increased infant imitation of the observed action because that action was interpreted as intentional (see Meltzoff et al., 1999). Indeed, previous research has shown that 14- to 18-month-olds are twice as likely to imitate observed actions accompanied with positive emotion versus negative emotion (Carpenter et al., 1998), and 25- to 36-month-old infants are more likely to imitate ambiguous object-directed actions accompanied with laughter (e.g. brushing one's teeth with the wrong end of a toothbrush) as opposed to negative affect (Hoicka & Gattis, 2008).

More broadly, these results add to a growing literature suggesting that infants use others' emotional communication to better appreciate others' mental states (e.g. Carpenter et al., 1998; Repacholi et al., 2014; Repacholi & Gopnik, 1997). Additional research is needed to examine the impact of other emotionally-relevant cues on infants' understanding of intentions and emotions, including ostension (Repacholi, 2009). For example, ostensive emotional communication in conjunction with a novel object-directed action may communicate qualitatively distinct relational significance (e.g. "I don't want you to do what I just did") than non-ostensive cues (e.g. "I didn't intend to do that. I meant to do something else"). In both instances, the observing infant might respond by not imitating the observed action, but only in the latter instance would an infant be more likely to re-enact the unobserved, intended action. Furthermore, infants may differentially utilise ostensive emotional communication as a function of their emerging understanding of social referencing (Brugger et al., 2007; Walle, Reschke, Camras, et al., 2017; Walle, Reschke, & Knothe 2017) and goal understanding (Király, 2009). We look forward to studies systematically investigating the interrelations of these constructs.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

D.D.'s research was supported by the Swiss National Science Foundation (Early Postdoc grant P2NEP1_178584).

ORCID

Peter J. Reschke http://orcid.org/0000-0002-1711-8385

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