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Young children's developing ability to integrate gestural and emotional cues

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ABSTRACT

In three studies, children aged 22 to 46 months (N = 180) needed to integrate pointing gestures or gaze cues with positive and negative facial expressions to succeed in an object-choice task. Finding a toy required children to either choose (positive expression) or avoid (negative expression) the indicated target. Study 1 showed that 22-month-olds are better at integrating a positive facial expression with a pointing gesture compared with a negative facial expression with a pointing gesture. Study 2 tracked the integration of negative expressions and pointing across development, finding an unexpected, U-shaped trajectory with group-level success only at 46 months. Study 3 showed that already 34-month-olds succeeded when pointing was replaced with communicative gaze. These findings suggest that at the end of the second year of life, children are generally able to integrate emotional displays and communicative cues such as gestures and ostensive gaze to reevaluate and contextualize utterances. In addition, pointing gestures appear to be understood by young children as a call to act on a referenced object. Findings illustrate that communicative cues should be studied in conjunction with emotional displays to draw an ecologically valid picture of communicative development.

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Introduction

Human communication is inherently multimodal and requires the integration of different types of cues. Nonverbal cues such as gestures and facial expressions play an important role in children's prelinguistic communication as well as language learning (Bohn & Frank, 2019; Colonnesi, Stams, Kosten, & Noom, 2010; Tomasello, 2003, 2008). Much like words in spoken language, gestures and emotional displays can be combined in productive ways and modify each other's meaning systematically. If you ask your friend for advice on what kind of dish to order and she replies by pointing to the plate in front of her while smiling, you might feel encouraged to get the same. You would probably arrive at a different conclusion if the same pointing gesture was accompanied by a disgusted facial expression. Young children encounter such combinations of deictic reference with negative valence not only when inquiring about others' preferences but also on a daily basis in the form of prohibitory and safety rules (Dunn & Munn, 1987; Kopp, 1982; Smetana, Kochanska, & Chuang, 2000). Here, we studied the integration of referential and emotional cues during the early preschool years.

Emotion Understanding During the First Years of Life

Already at 4 months of age, infants discriminate discrete emotions such as happy, angry, and sad (Flom & Bahrick, 2007; Montague & Walker-Andrews, 2001). At 12 months of age, children begin to understand the referential dimension of emotional displays and use emotional expressions to gain information about ambiguous events or objects (Sorce, Emde, Campos, & Klinnert, 1985). For example, 12-month-olds, but not 8-month-olds, expect an actor who emotes positively to one of two objects to reach for this object subsequently (Phillips, Wellman, & Spelke, 2002). In a visual cliff scenario, Sorce et al. (1985) found that 12-month-olds would halt at the cliff when the mother showed a fearful expression but would cross when she expressed interest or joy. In addition, 12- to 18-month-old children adapt their behavior toward a novel toy in line with an adult's positive or negative vocalizations when gazing at a toy (Moses, Baldwin, Rosicky, & Tidball, 2001; see also Klinnert, 1984). When a stranger enters a room, 15-month-old children look at their mother and adjust their reaction according to whether the mother's facial expression is positive or ignoring (Feiring, Lewis, & Starr, 1984). In a particularly comprehensive study, Walle, Reschke, Camras, and Campos (2017) showed that 16-, 19-, and 24-month-olds react differently toward objects that were referred to with emotional displays of hi joy, sadness, fear, anger, or disgust by the experimenter. Although all age groups were generally more likely to approach an object that was highlighted with joy as opposed to disgust or anger, it is remarkable that 30% to 50% of children in all age groups went on to explore the negatively marked stimuli (Walle et al., 2017; see also Walle, Reschke, Main, & Shannon, 2020).

Directing and Following Attention During Infancy and Toddlerhood

At the same time they start to understand referential emotions, children also begin to understand other referential cues. From 10 months of age onward, pointing gestures directionally influence infants' attention (Gredebäck, Melinder, & Daum, 2010). On average, infants spontaneously start using pointing gestures to communicate with adults about 2 months later (Matthews, Behne, Lieven, & Tomasello, 2012). Production of pointing goes hand in hand with comprehension (Behne, Liszkowski, Carpenter, & Tomasello, 2012). Around the same age, children differentiate between intentionally produced pointing gestures and points that arise as a byproduct of other actions, suggesting that infants differentiate between the signal itself and the speaker's intentions behind it (Aureli, Perucchini, & Genco, 2009; Behne, Carpenter, & Tomasello, 2005). Esteve-Gibert, Prieto, and Liszkowski (2017) showed that 12-month-old infants integrate different social cues when interpreting others' pointing gestures. When an adult pointed to an object with the index finger and vocalized excitedly (as if wanting to share interest), infants simply attended to the object. When the adult used a palm-up whole-hand pointing gesture and vocalized short syllables (as if requesting), infants attended to the object but also offered it to the adult.

Gaze cues are equivalently powerful in directing children's attention. Beginning in the first year of life, infants follow gaze to a target in the presence (Senju & Csibra, 2008; Senju, Csibra & Johnson, 2008) and absence (Gredebäck, Astor, & Fawcett, 2018) of ostensive cues and even in the absence of a salient congruent head turn (Tomasello, Hare, Lehmann, & Call, 2007). At the end of the second year of life, children are able to use both pointing and gaze with and without a head turn to find a hidden toy in an object-choice task (Itakura & Tanaka, 1998).

Integrating Referential and Negative Emotional Cues

Specific challenges arise when directional cues are combined with salient negative emotional displays, that is, when children need to avoid an item that is referred to in a negative way. Recovering the meaning of a communicative act involving a referential gesture and a negative facial expression in an object-choice situation requires some kind of disjunctive reasoning; when faced with two mutually exclusive options (e.g., $P \vee Q$), where one of which is negated ($\neg P$), preference should be given to the unmarked alternative ($\rightarrow Q$). The listener needs to reason that the location that is being communicated about is not the location that contains the desired object and that, therefore, it must be in the other location instead. Children solve basic versions of disjunctive reasoning tasks from 22 months of age onward (Austin, Theakston, Lieven, & Tomasello 2014; Hill, Collier-Baker, & Suddendorf, 2012; Mody & Carey, 2016, Moll, Koring, Carpenter, & Tomasello, 2006).[1] However, there is evidence suggesting that even younger children can integrate negative displays in an object-choice scenario. Repacholi (1998) presented 14- and 18-month-old children with an object-choice task in which an actor picked up two boxes in quick succession and emoted positively toward the content of one box and negatively toward the content of the other box. Infants preferred to touch and search the positively indicated box in all conditions. However, the operationalization with two cues limits the interpretation of participants' responses. To solve the task, children would not necessarily need to understand the negative cue but could have simply relied on the positive cue alone. To really test young children's ability to use a negative referential cue, it is necessary to show that they systematically avoid one of two objects when only one of them is referred to negatively.

Challenges of not Following a Pointing Gesture

Avoiding an object that is highlighted via communicative cues poses an additional challenge for young children. Although in most cases it is perfectly fine to focus exclusively on an item that was explicitly referred to in an interaction, children here need to step back and integrate additional information such as the negative display and the alternative option. Studies on epistemic vigilance using an object-choice paradigm also require children to refrain from following communicative cues by evaluating contextual evidence such as that the sender is not being truthful or has competing motives. Therein, they have very similar task demands. These studies show that even when other information tells them not to, preschoolers have a very strong tendency to follow testimony (Jaswal, Croft, Setia, & Cole, 2010, Mascaro & Sperber, 2009)—and pointing gestures in particular (Couillard & Woodward, 1999; Grassmann & Tomasello, 2010; Palmquist & Jaswal, 2012; Palmquist, Kondrad, & Norris, 2018; Stengelin, Grüneisen, & Tomasello, 2018). Vanderbilt, Liu, and Hayman (2011) found that 3- and 4-year-olds were equally willing to accept advice from helpers and hinderers who consistently provided correct and incorrect advice, respectively. Pointing gestures not only trump other types of reference but also are particularly hard to ignore for young children. For example, 3-year-olds were more likely to hand over an object that an experimenter highlighted via pointing when she looked and pointed at two different objects simultaneously (Lee, Eskrit, Symons, & Muir, 1998). The most striking findings are provided by studies on deceptive pointing, with 3- and 4-year-olds consistently failing to reject the advice of an overtly misleading informant (Couillard & Woodward, 1999; Heyman, Sritanyaratana & Vanderbilt, 2013).

[1] Recent evidence suggests that even 12-month-olds can compute logical inferences of this sort (Cesana-Arlotti et al., 2018); however, a more parsimonious object tracking account might suffice to explain the findings (Jasbi et al., 2019).

One reason why children have such a hard time with rejecting deceptive or misleading advice could be limitations in their executive functioning (Couillard & Woodward, 1999; Palmquist & Jaswal, 2012; Palmquist et al., 2018). Overcoming the prepotent response of taking the indicated option is then most likely in cases where responses to cues are highly entrained such as the pointing gesture (Heyman et al., 2013; Palmquist, Burns, & Jaswal, 2012; Palmquist & Jaswal, 2012; Palmquist et al., 2018). Pointing is positively connotated because it serves primarily to direct attention toward entities that are interesting and relevant in everyday interactions.

Another possible explanation is that children generally assume that acts of intentional communication are truthful (i.e., truthful communicator bias). Evidence for this explanation is provided by studies showing that children are better able to reject a cue when its presentation (e.g., a flashing light as an indicator) is dissociated from an interlocutor (Heyman et al., 2013, Study 5). If the communicative intent, however, was the only factor influencing children's performance, children should perform equally well with different types of cues such as pointing and gaze in the studies below.

Outline and Motivation for the Current Studies

In the studies presented here, we investigated the development of children's ability to use referential and emotional cues when making inferences about a speaker's intended meaning. Specifically, we tested how children respond to combinations of pointing gestures or gaze with salient positive or negative facial expressions. In an object-choice task with two hiding places, we established as common ground that one of two hiding places was baited with a desired toy and that children's interlocutor was both knowledgeable and willing to help the children. After hiding the desired object (a marble) under one of two boxes outside the view of the children, the experimenter indicated one of the locations accompanied by either a positive or negative facial expression. To succeed in the case of a positive expression, children can simply follow the gesture and retrieve the marble. In the negative condition, however, the experimenter effectively conveys not to take the one that she pointed at and that the marble is in the other hiding place. This requires children to (a) understand the emotional display, (b) follow the referential cue, (c) reason by exclusion that the target must be in the other hiding place, and (d) inhibit the prepotent response of taking the indicated option. Study 1 contrasted the integration of positive and negative facial expressions with pointing gestures in 22-month-olds in a between-participants design. Following up on the results of Study 1, Study 2 traced the development of children's ability to integrate negative expressions with pointing gestures in a cross-sectional design with 28-, 34-, 40-, and 46-month-olds. Study 3 investigated the integration of a different kind of referential cue (peeking under the box) with negative facial expressions in 22-, 28-, and 34-month-olds. Considering the difficulties that young children have in avoiding an object that was pointed to in an object-choice task, participants should be able to avoid a target at an earlier age when referenced with a negative connotation via gaze rather than pointing.

The set of studies presented here complements and goes beyond several lines of work investigating children's ability to integrate contextual and multimodal information when making pragmatic inferences. First of all, it investigated a broader age range than most studies (Couillard & Woodward, 1999; Heyman et al., 2013) and followed the development of group-level performance from the end of the second year to the end of the fourth year of life in 6-month intervals. Other than previous work requiring children to avoid a negatively indicated option (Repacholi, 1998), we did not provide children with a positive and negative cue in the same trial because this would make the pragmatic inference obsolete. To evaluate the special status of the pointing gesture for children's performance, we replaced pointing with communicative gaze. As such, the current work complements earlier work that replaced pointing with placing a marker (Couillard & Woodward, 1999) or arrow (Jaswal et al., 2010).

Furthermore, in many studies using combinations of emotional and directional information, it is unclear whether children understand emotional expression as a message in and of itself or simply see it as a reaction toward the target object. Following Grice (1957), we might view emotional reactions per se as having natural meaning; that is, they are a logical consequence of a matter at hand (e.g., a person's emotional state) and thereby provide information about it. In Studies 1 and 2 below, we presented emotional cues as a non-natural meaning that was explicitly and intentionally produced for the recipient and not foremost as a reaction toward an object. In previous studies, the

experimenter either directly touched (Repacholi, 1998) or looked at (Moses et al., 2001) the referent while emoting. The emotional expression might have been interpreted as an involuntarily produced reaction to the stimulus. Children might have just exploited the adult's reaction to adjust their own behavior. Currently, it is unclear whether children can use valence information if the emotional expression is intentionally produced *for* them. Here, we studied this by looking at children's ability to integrate information provided by a pointing gesture and emotional facial expressions in succession. Whereas pointing was used to indicate the referent, the emotional expression was produced afterward while looking at the recipient instead of the referent in Studies 1 and 2. Hence, it was an intentional communicative act and less likely to be interpreted as an involuntary reaction.

Study 1

Method

Participants

All children who were tested in the studies reported here came from a medium-sized middle European city. They were recruited via a database of participants for child development studies for which their parents had voluntarily signed up. Appointments were made on the basis of parents' and children's availability. All studies described below were reviewed and approved by an internal ethics committee at the Max-Planck-Institute for Evolutionary Anthropology.

We invited 20 children in each condition and age group. In Study 1, 20 22-month-olds participated in the positive pointing condition (M_{age} = 22.03 months, *SD* = 1.12, range = 20.32–23.83; 10 boys). Another group of 20 22-month-olds was tested in the negative pointing condition (M_{age} = 22.50 mo nths, *SD* = 1.08, range = 20.51–23.80; 10 boys). We tested 22-month-olds as the youngest age group because prior work suggested that they can make a basic disjunctive inference at this age (Austin et al., 2014). An additional 6 children (positive condition: $n = 2$; negative condition: $n = 4$) were tested but not included in the analysis due to parental interference ($n = 1$) or because they were fussy and did not complete the procedure ($n = 5$). Sample size for each group was preplanned and based on earlier studies using a similar setup (Behne et al., 2005).

Procedure and Setup

On arrival in the laboratory, children were invited to play with a female experimenter (E; the same person in all studies) in a playroom for 15 to 20 min until the children felt comfortable in giving and taking toys with her. During this phase, parents completed consent forms and were instructed not to influence their children's behavior at the test.

Next, children and parents were led into the testing room, and children were invited to play a hiding game that set the context for the test trials. E first presented them with a marble and a small piece of tissue. Children learned that a marble could be fed into a papier-mâché elephant to make a chime play. The piece of tissue had no relevance in the context of the game. Next, E presented two identical small boxes serving as hiding places. E presented the marble and the piece of tissue, put them side by side, and covered them with the boxes. Children received the prompt "Where is the marble?" and could then retrieve the marble from under the box to feed the toy elephant. The hiding game was repeated for three trials in total. The warm-up procedure was designed to ensure that children knew that the marble would be hidden under one of the two boxes, whereas the other box would be baited with the tissue. Furthermore, the three trials showed that children felt comfortable in lifting the boxes, were motivated to search for the marble, and preferred to find the marble over the piece of tissue.

For the actual *test setup,* the child was invited to sit or stand facing E at a distance of approximately 120 cm. A small table in front of E served as a tray for the hiding game. The table was approximately 120 cm wide and 30 cm high. The boxes for the hiding game were placed in the corners of the table such that the child could reach them conveniently on walking over but could not lift both boxes at once when making a choice. A visual occluder of 100 × 80 cm was placed in front of the table to block visual access to the table during the baiting of the boxes. The soft felt surface of the table ensured that children could not hear where the marble was placed. To keep the child alert and mark the beginning

of a new trial, E used a new pair of identical boxes in different colors for every trial. For an illustration of the setup, see Fig. 1.

In each *test trial,* E placed a pair of boxes for the hiding game on the table. Boxes were upside down such that the child could see that they were empty. E then placed a piece of tissue in the middle of the table, got the child's attention, and presented a marble. Once the child was attentive, E placed the occluder in front of the table to block visual access to the hiding event. E continued by taking the marble and tissue in both hands in the middle of the table. Next, she covered each item with a box and then moved both boxes simultaneously to the opposite ends of the table.

For the *pointing event,* E removed the occluder and called the child's name to get his or her attention. Depending on the condition, E first made a positive or negative facial expression while looking at the child. Then she returned to a neutral facial expression and both pointed and looked at one of the boxes. Next, E retained the point, looked at the child again, and repeated the emotional expression. In case the child was inattentive, the pointing procedure was repeated such that the child had seen the emotional expression at least twice in each trial. Throughout the trial, the emotional expression was distinctly and only displayed while E was looking at the child. Although we cannot know conclusively how participants construed the situation at hand, the repetition and temporal displacement singled out the emotional content as a statement in a very ostensive and salient way that made the interpretation as a spontaneous reaction to the target unlikely. Thereby, the emotional expression was not presented as an immediate reaction to the target itself but rather meant to serve a deliberately communicative function. Note that when replacing the pointing gesture with peeking under the box in Study 3, the timing of the procedure was adjusted. Because gaze was the main means of establishing reference in Study 3, the emotional expression was presented while looking at the target.

The *decision phase* was initiated by E prompting the child to make a choice, saying "Where is the marble?" After this prompt, E did not use any gestures or facial expressions. The child could walk to the table to open one of the two boxes. If the child found the marble, the child could feed the elephant. In case the child lifted the box with the tissue, E turned over the box with the marble and handed it to the child. If the child did not make a choice, E repeated the pointing event once. If the child still did not make a choice, E ended the trial by lifting both boxes and also handing the marble to the child. The child could feed the elephant in each case. Rewarding participants nondifferentially kept them engaged and counteracted demand effects that could have resulted from the games' payoff structure.

In Study 1, we employed two experimental conditions: a *positive condition* and a *negative condition.* In the positive condition, E showed a positive (happy, friendly, and interested) expression on her face, accompanied by a matching vocalization ("Ahh"), and pointed to the box where the marble was hidden. This condition corresponded to a standard object-choice task. In the negative condition, E displayed a negative emotional expression (aversive, disgusted, and suspicious) before pointing, again accompanied by a matching vocalization ("Eww"). In this condition, E always pointed to the box with the tissue (i.e., the irrelevant box). To find the marble and succeed in the hiding game, children needed to avoid the box that E was pointing at.

Following findings indicating that emotion expressions are much more variable than suggested by basic emotion approaches and thus are likely to be driven by specific appraisals (Scherer, Dieckmann, Unfried, Ellgring, & Mortillaro, 2019; Scherer & Ellgring, 2007), E used compositions of facial action units to indicate positive and negative feelings, respectively. The positive facial expression involved action units (AUs) that are generally seen as pleasant (Scherer & Ellgring, 2007): AU 1 (inner brow raiser) and AU 2 (outer brow raiser), AU 12 (lip corner puller) together with AU 25 (lips part), and AU 26 (jaw drop, open mouth), indicating a happily surprised face. The negative expression was disgust-like and involved AUs that are related to unpleasantness (Scherer & Ellgring, 2007): AU 4 (brow lowerer), AU 6 (cheek raiser), AU 7 (lid tightener), AU 9 (nose wrinkler), AU 10 (upper lip raiser), AU 16 (lower lip depressor), and also AU 25 (lips part). For photographs of the facial expressions, see Fig. 2.

Notably, whereas the experimenter in the procedure employed by Repacholi (1998) provided a positive and negative cue in each trial, E in our setup always pointed to one of the two boxes only. Children were tested in either the positive or negative condition. Hence, each child only saw E either point positively to the location containing the marble or point negatively to the box baited with the piece of tissue. The direction of the point and the location of the two items were pseudorandomized,

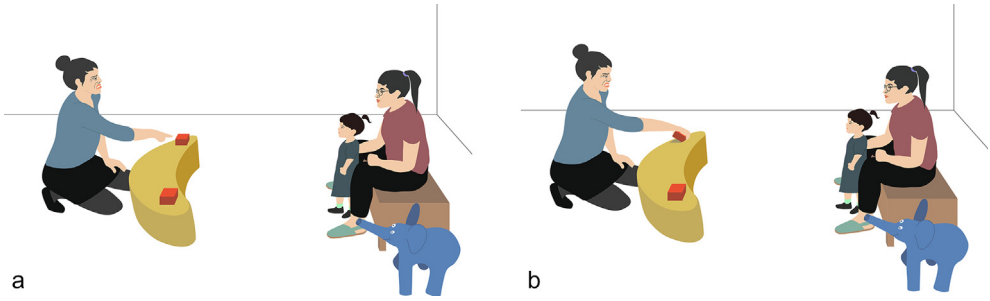

Fig. 1. Schematic drawing of the setup. The left panel (A) shows how the experimenter indicated a location by pointing in Studies 1 and 2. The right panel (B) shows indicating by peeking in Study 3. Children made a choice by approaching and touching one of the boxes.

Fig. 2. Examples of the positive (A) and negative (B) facial expressions made by the experimenter. The experimenter was the same person in all studies. Detailed Facial Action Coding System (FACS) coding of these expressions can be found in the main text.

with E never pointing to the same box more than twice in a row. Children were tested for eight consecutive trials.

Results and Discussion

In all studies, we coded as choice the container that children touched first (left or right from E) and whether this was the correct container (i.e., with the marble). For each group in each study, a second coder recoded 25% of trials. The lower bound of agreement between coders across studies was 92.5% (κ = .85).

Table 1 and Fig. 3 give an overview of the performance within each group compared with a performance expected by chance (50% correct). For this analysis, we aggregated the data across trials for each child within each age group and ran two-tailed one-sample *t* tests. On a group level, performance did not differ from chance in the negative condition but did so in the positive condition. A closer look at the distribution of the data in Fig. 3 shows that participants varied substantially in their performance in the negative condition. Some children performed above chance on an individual level, suggesting that success in the task was not entirely beyond children's ability at this age (see Table 1).

To directly compare performance in the two conditions, we fit a generalized linear mixed model to the trial-by-trial data with condition and trial as predictors. All models were fit in R (R Core Team, 2017) using the *lme4* package (Bates, Mächler, Bolker, & Walker, 2015). All models included random intercepts for participants and random slopes for trials. The *p* values for predictors are based on likelihood ratio tests obtained through single-term deletions (Dobson & Barnett, 2008). Data and analysis code associated with the study can be found in the online repository https://github.com/manuelbohn/emopoint.

Children performed better in the positive condition than in the negative condition (β = −1.90, *SE* = 0.66, *p* = .003). Across conditions, performance tended to increase in later trials (β = 0.39, *SE* = 0.21, *p* = .050). The difference between the positive and negative conditions suggests that children paid attention to the emotional facial expression of E. If children had ignored the facial expression altogether and only followed the point, performance in the negative condition should have been below chance. Although this might have been the case for some individuals, it was not the dominant behavior in the group. Nevertheless, children performed much better when the emotional expression encouraged them to approach the indicated location. To succeed in the negative condition, children needed to inhibit approaching the indicated location, evaluating the facial expression. That is, children needed to exclude the alternative that E pointed to and approach the other one instead.

Previous studies on children's referential understanding of emotions (e.g., Repacholi, 1998) presented positive and negative emotions together, thereby omitting the need for excluding one alternative. However, based on these results alone, it remains unclear at what age children (at a group level) can infer the intentions behind referential communicative acts including negative emotions. In Study 2, therefore, we followed the developmental trajectory of children's performance in the negative condition using a cross-sectional design. We expected an increase in children's performance with age. We tested additional age groups in 6-month intervals until we found group-level performance to be above chance level. Given that children in our task succeeded in the positive condition at 22 months of age and that the literature reports that toddlers and preschoolers excel at following pointing gestures in object-choice tasks with adult and puppet partners (cf. Couillard & Woodward, 1999; Grassmann & Tomasello, 2010; Kachel, Moore, & Tomasello, 2018; O'Madagain, Kachel, & Strickland, 2019; Palmquist et al., 2012, 2018; Vanderbilt et al., 2011), we omitted running further age groups with positive facial expressions.

Study 2

Method

Participants

In Study 2, we tested four age groups with 20 children in each group. Following up on Study 1, we started with 28-month-olds (M_{age} = 28.86 months, *SD* = 0.99, range = 26.3–29.91 months; 10 boys) and progressed in intervals of 6 months to the next age groups: 34-month-olds (M_{age} = 34.88 months, *SD* = 0.63, range = 33.69–35.80; 10 boys), and 40-month-olds (M_{age} = 40.19 months, *SD* = 1.11, range = 38.17–41.98; 10 boys). The oldest age group was 46-month-olds (M_{age} = 46.90 months, *SD* = 0.88, range = 44.41–47.96; 10 boys). One additional 28-month-old child was tested but excluded from the analysis due to fussiness.

Procedure and Setup

The procedure and setup were identical to those of the negative condition in Study 1.

Table 1
Summary statistics for performance compared with chance (.50) within each group.

Study	Age (months)	Cue	FE	*M*	*SD*	*t*(19)	*p*	Cohen's *d*	Individuals performing		Trial 1
									<.50	>.50	
1	22	Point	Positive	.84	.24	6.46	<.001	1.45	0	11	19
	22		Negative	.61	.31	1.57	.133	0.35	1	3	11
2	28	Point	Negative	.49	.37	−0.12	.902	0.03	4	4	9
	34			.35	.27	−2.55	.020	0.57	3	0	5
	40			.48	.34	−0.26	.800	0.06	3	1	7
	46			.75	.32	3.47	.003	0.78	2	8	11
3	22	Peek	Negative	.64	.33	1.83	.083	0.41	2	5	10
	28			.63	.31	1.97	.064	0.44	1	3	11
	34			.88	.20	8.80	<.001	1.97	0	12	15

Note. FE, facial expression. Evaluation of group-level performance is based on two-tailed one-sample *t* tests. For this analysis, data for each child were averaged across trials. Individual performance was evaluated through two-tailed binomial tests with none or all trials correct, resulting in $p < .05$. Trial 1 reports the number of children who responded correctly in the first trial.

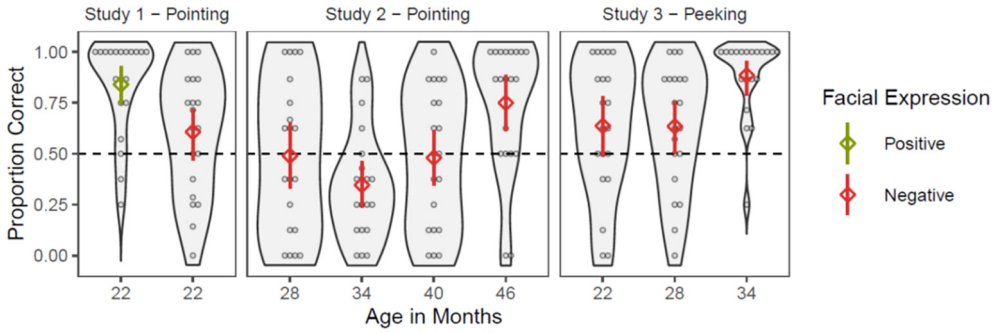

Fig. 3. Proportion of correct responses per age group and study. Diamonds show group means, and error bars represent 95% confidence intervals around the mean based on nonparametric bootstraps. The dotted line indicates performance expected by chance. Black circles show individual data averaged across trials, with the number of circles corresponding to the number of participants with that value. Smoothed density distributions are shown in gray.

Results and Discussion

Group-level summary statistics for Study 2 can be found in Table 1 and Fig. 3. The distribution of performance in each age group again showed great variability between participants. On a group level, performance was below chance at 34 months of age (with no children performing above chance) and above chance at 46 months of age. In contrast to our expectation, performance did not increase in a linear fashion with age. Visual inspection of Fig. 3 suggested a U-shaped development instead. We confirmed this visual impression statistically by fitting a model to all data from the negative condition. This model included all data from Study 2 and the negative condition from Study 1. For this analysis, we treated age as a continuous variable across groups. There was no linear effect for age ($\beta = 0.27$, $SE = 0.23$, $p = .235$). Adding a quadratic term for age to this model significantly improved the fit, $\chi^2(1) = 14.98$, $p < .001$. The estimate for the quadratic term was positive ($\beta = 1.00$, $SE = 0.25$), confirming the convex shape of the trajectory. Furthermore, performance increased in later trials ($\beta = 0.25$, $SE = 0.09$, $p = .007$). Fitting a model with age as categorical predictor and 34 months as reference group showed that performance at 34 months was worse compared with that at 46 months ($\beta = 1.76$, $SE = 0.66$, $p = .008$) and also trended to be below performance at 22 months ($\beta = 1.08$, $SE = 0.59$, $p = .069$).

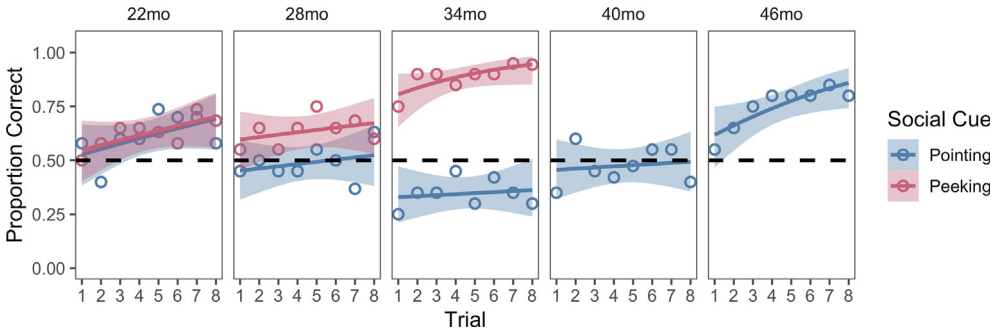

Fig. 4. Proportion correct choices by age group and trial for conditions with negative facial expressions. Regression lines show smoothed conditional means with 95% confidence intervals. Here, 40- and 46-month-olds were not tested in peeking because performance was above chance at 34 months of age. mo, months.

The pattern of results observed in the negative conditions suggests that children (at a group level) do not succeed in integrating negative emotional expressions with pointing gestures until 46 months of age. Furthermore, the tendency to act on the indicated object or location becomes stronger, apparently leading 36-month-olds to ignore the facial expression altogether. Fig. 4 shows that performance in this age group remained below chance across all trials, suggesting that the behavior is relatively robust against experience.

One explanation for the U-shaped development is that pointing gestures do more than index a referent. They also create a tendency to act on the pointed to location/object, suggesting an affirmative connotation, namely a call to act on the object. This "secondary meaning" of pointing gestures is less pronounced in younger children and increases with experience (approximated by age in our study), leading older children to ignore additional cues to a speaker's intention when the gesture is used in a way that differs from the usual way. From 34 months of age onward, children get better at inhibiting their initial response tendency, making room for integration with the facial expression. This interpretation is supported by the trial-by-trial performance of the 46-month-olds. Performance in Trial 1 is around chance, with a steep increase in the following trials, suggesting an initial tendency (at least in some children) to ignore the facial expression and follow the pointing gesture. It might be argued that children were also drawn to the negatively highlighted object because the negative emotional expression might have made it more interesting (cf. Walle et al., 2017). However, when children are presented with both negative and positive emotional displays to different targets, they have a preference for the positively marked object (Repacholi, 1998).

To evaluate the hypothesis that the U-shaped developmental pattern might result from children becoming increasingly ready to follow pointing gestures regardless of contextual information, we ran a third study and replaced the referential gesture with gaze. Instead of pointing to the container and subsequently emoting toward children, E peeked under the container and displayed the emotional expression while looking at its content. If children's failure to avoid the negatively indicated option was due to the special role of the pointing gesture rather than their ability to make the pragmatic inference, replacing it with peeking under the box should lead to group-level success at an earlier age.

Study 3

Method

Participants

In Study 3, we tested children of three ages with 20 participants in each group. To complement Study 1, we started with 22-month-olds (M_{age} = 23.35 months, *SD* = 0.48, range = 22.35–24.00; 9 boys) and then went on to test 28-month-olds (M_{age} = 28.59 months, *SD* = 1.04, range = 26.36–29.75; 10 boys) and 34-month-olds (M_{age} = 35.35 months, *SD* = 0.45, range = 34.48–35.93; 11 boys). An

additional 5 children were tested but not included in the analysis (22-month-olds: n = 3; 34-month-olds: n = 2). These children were excluded due to restlessness (n = 3) or because they were too shy to make a choice (n = 2).

Procedure and Setup

The setup for Study 3 was identical to that described for Studies 1 and 2. However, the pointing gesture was replaced with an act of peeking under the boxes. Here, gaze was the main way of establishing reference. Therefore, the emotional expression was presented while looking at the target in order to make the procedure to clearly settle the referent and make the procedure more natural.

In the test trials of Study 3, E removed the occluder and called the child's name and engaged the child by making eye contact. Then, E looked at the incorrect box (i.e., the one baited with tissue), reached for it, and lifted it up slightly such that she could see its content but the child could not. On lifting the box, E started to make a negative facial expression (see Fig. 2). Then, E looked back at the child and removed her hands from the box. In contrast to the pointing events in Studies 1 and 2, the emotional expression was displayed only once and while looking at the target. However, E's behavior was still framed as a communicative act rather than a reaction toward the content of the box due to the attention-getter and the pragmatics of the hiding game. If the child was inattentive during the peeking event or did not make a choice, the peeking event was repeated.

Results and Discussion

Table 1 and Fig. 3 summarize performance per group in Study 3. Performance tended to be above chance already in the two younger age groups, again with substantial variability across participants and multiple individuals performing above chance in each group. At 34 months of age, the task appeared to be nearly trivial for the children, with more than half of the group being 100% correct (see Table 1). To evaluate the developmental trajectory, we fit a model with a linear predictor for age. This turned out to be positive and significant (β = 0.65, SE = 0.25, p = .009), corroborating the absence of a U-shaped trajectory. Performance further increased with trials (β = 0.78, SE = 0.26, p > .001). A change in inferential abilities as outlined above therefore is unlikely to explain the trajectory in Study 2.

Comparing the results from Studies 2 and 3 showed a separation of inferential and integrative abilities in the task at hand. At 34 months of age, children selected the correct container below chance when the negative facial expression needed to be integrated with a preceding point, but their performance was above chance when the same expression was displayed while looking at the target. In both cases, children needed to exclude the indicated container in favor of the alternative. No such pattern should have been observed if children would generally struggle with avoiding the highlighted container. It seems that pointing gestures, presumably due to how they are used in everyday life, do more than just indicate objects for children. They have an additional "secondary meaning," encouraging children to approach or act on the indicated object.

General Discussion

In this set of studies, we investigated children's ability to integrate facial expressions and pointing gestures. Our goal was to determine at what age children would be able to integrate a referential cue with a negative facial expression in order to avoid a referenced target in an object-choice task. Study 1 found that 22-month-olds are better at recovering the speaker's intended meaning when the pointing gesture is accompanied by a positive facial expression as opposed to a negative facial expression. Study 2 followed the developmental trajectory of the ability to integrate negative expressions and pointing in 28-, 34-, 40-, and 46-month-olds, finding a U-shaped developmental pattern with group-level success only in the oldest age group. Study 3 showed that already at 34 months of age children are generally able to combine a referential cue with an emotional display. Here, pointing was replaced with peeking under the box, and the emotional expression was displayed while looking at the target. Together, these results suggest that toward the end of the second year of life, children

become able to integrate referential and emotional cues. However, pointing gestures are a special case given that they appear to carry an affirmative meaning and do more than just indicate a referent (cf. Couillard & Woodward, 1999); they are a call to action for young children.

The results from Study 1 mirror findings from work using verbal prompts (Grigoroglou, Chan, & Ganea, 2019), in which younger 2-year-olds performed better with affirmative sentences as opposed to negative sentences in a search task. In contrast to Grigoroglou and colleagues (2019), we did not find that performance with negative prompts steadily increased over the second year of life, with 22- to 40-month-olds struggling to integrate a pointing gesture and a negative facial expression. Performance even decreased from 22 to 34 months of age. How can we explain this U-shaped developmental trajectory? We suspect that two staggered developmental processes are at work here. On the one hand, children experience communicative acts in general, and pointing gestures in particular, to be used mainly in veridical and affirmative ways, that is, to provide true information or to encourage engagement with a referent (Heyman et al., 2013; Jaswal et al., 2014; Palmquist et al., 2012; Palmquist & Jaswal, 2012). Following Karmiloff-Smith (1992), children might develop a procedural understanding of pointing in that seeing a point to an object triggers the dominant response of approaching or acting on the pointed to object. In addition, pointing gestures themselves might be construed as an attempt to touch a referent by young children during the first years of life (O'Madagain et al., 2019). Hence, the purely indexical function of pointing might not be immediately accessible, which would prevent children from integrating additional contextual information (cf. Karmiloff-Smith, 1992). In line with our results in Study 2, a number of studies suggest that this process culminates at 3 years of age. For example, children of that age follow a clearly ignorant pointer's gesture even if it directly conflicts with a reliable gesture from a knowledgeable communicator (Palmquist et al., 2012; Palmquist & Jaswal, 2012). Furthermore, 3-year-olds struggle to ignore pointing gestures to one of two containers even if these points are constantly misleading in several consecutive trials (Couillard & Woodward, 1999). This response seems to be less pronounced in younger children; for example, 2-year-olds differentiate between points from an adult compared with points from a peer (Kachel et al., 2018). However, at 4 years of age, children are able to avoid following pointing gestures in an object-choice task when an experimenter explicitly states that she is going to point where the target item is not hidden (Palmquist et al., 2018).

The results of Study 3 suggest that the dominant response in 3-year-olds is specific to pointing and does not generalize to an equivalent directional cue, namely gaze. When E peeked under the box, thereby highlighting it spatially, 3-year-olds considered the emotional expression and refrained from approaching the box. This is in line with work by Mascaro and Sperber (2019), who found that 3- and 4-year-olds were able to learn the rule that a marker (Study 1) or an arrow (Study 2) marked the location of an empty container in an object-choice task with a cooperative (i.e., nondeceptive) partner. They also concluded that reinterpreting a well-established signal such as pointing is particularly difficult for young children (Mascaro & Sperber, 2019). Findings also corroborate a developmental pattern observed in tasks on reasoning by exclusion. Although children succeed in using an explicit verbal expression (e.g., "It is not in this bucket"; "No!") to retrieve a toy from an alternative container at the end of the second year of life, they become able to interpret equivalent gestural cues only over the course of the third year of life (Austin et al., 2014; cf. Hill et al., 2012).

Replacing pointing with peeking under the box required an adjustment in timing of the procedure. In the pointing manipulation (Study 2), E displayed the emotional expression first while looking at the child and then pointed at the target with a neutral expression and still held the pointing gesture while looking back at the child to repeat the emotional expression. In the peeking manipulation (Study 3), the emotional expression was presented only once and while looking at the target. Because here E's gaze established the referent, it would have been misleading and unnatural to display the emotion while looking back at the child. However, this raises the concern that differences in children's behavior across studies could be due to differences in the timing rather than the nature of the referential cue. We believe that this is unlikely. First, children saw the emotional expression only once per trial in Study 3, which could have made the negative connotation of the referent less salient. Second, displaying the emotion while looking at the referent could have created the impression that the emotional expression was not an intentional message but rather a mere reaction to the referent. Both of these factors could have made children less likely to process the negative connotation and make the

pragmatic inference of avoiding the referent. However, group-level performance at 34 months of age increased from 35% (Study 2) to 88% (Study 3) despite this simplified and more conservative procedure. Study 3 showed that children of this age have the general ability to combine a referential cue with an emotional expression to avoid a referent in an object-choice task (this! + negative emotion → choose alternative). In line with studies showing children to succeed in avoiding a referenced item in an object-choice task when replacing pointing with a marker or an arrow (Couillard & Woodward, 1999; Jaswal et al., 2010), we believe that the changes in children's behavior across both studies are best explained by changing the referential cue.

The development of a procedural understanding of pointing might explain the decline in performance in our study throughout the second year of life. On the other hand, children's executive functions in general, and inhibitory skills in particular, improve substantially during the fourth year of life. In tasks that require participants to inhibit a predominant response, such as the Day–Night task, 4-year-olds generally outperform 3-year-olds (see, e.g., Carlson & Moses, 2001; Garon, Bryson & Smith, 2008; Müller, Liebermann-Finestone, Carpendale, Hammond, & Bibok, 2012). In our studies, the improvement in performance from 34 to 46 months of age might reflect the increasing ability to inhibit the prepotent response and consider additional contextual information. This could go along with a process of children representationally redescribing pointing as a purely indexical communicative act on a more explicit level (Karmiloff-Smith, 1992). Explicit representations, as opposed to procedural representations, allow for an integration of information from different sources. Initially, children might still be tempted to follow the pointing gesture given that 46-month-olds' performance was at chance in Trial 1 (see Fig. 4). However, performance increased rapidly in subsequent trials, showing that children are able to eventually overcome this prepotent tendency. This hypothesis could be tested by correlating performance in our task with other measures of inhibitory skills. Following Yurovsky and Frank (2017), we may conclude that the integration of different social cues depends on a gradual development of domain-general abilities.

Comparing children's performance with true negative points and overtly deceptive points, Palmquist et al. (2018) found performance to be above chance for true negative points at 4 years of age, which is perfectly in line with our findings. The authors interpreted their finding to indicate that children's inability to neglect information from deceptive pointing (Couillard & Woodward, 1999; Heyman et al., 2013) stems from their expectation that pointers are truthful (i.e., truthful pointer bias) rather than from their expectation about the meaning of the gesture itself (i.e., point bias) (cf. Palmquist et al., 2018). Our studies can further qualify this finding by showing that 4-year-olds succeed in a nonverbal version of the same task and by showing that even younger children perform above chance when pointing is replaced by ostensively looking at the item to be avoided. We may conclude that although even 2-year-olds are generally able to avoid negatively referenced targets, they still struggle with overcoming a pointing bias at 3 years of age but go on to overcome a truthful pointer bias only after 4 years of age.

The interpretation offered here focused on children's mean performance in each age group. It is, however, worthwhile to look at the distribution of the data in each condition. In general, there is a lot of variability in each group and in all conditions. Except in the negative pointing condition at 34 months of age, some children perform above chance on an individual level (see also Table 1). This suggests that successful integration of negative facial expressions and pointing gestures is already possible at an earlier age. Palmquist et al. (2018) combined their task with different tests for children's inhibitory control and found that individual performance was correlated with higher-order inhibitory control as measured by a Dimensional Change Card Sort task but not with children's performance in a simpler Grass–Snow task. The finding underscores that not searching a location that was pointed at requires children to inhibit the prepotent response of following points.

To the extent that a correct response in our task requires the inversion of a positive message by combining it with a negative emotional cue, it has similar demands as tasks employed to investigate the onset of irony comprehension. In this line of work, the meaning of a positive utterance is usually inverted by a special tone of voice (Dews et al., 1996; Hancock, Dunham, & Purdy, 2000, Wilson, 2013) requiring the parallel processing of two communicative cues by the recipient (Pexman, 2008). Children are generally described to separate literal speaker meaning from intended speaker meaning only around 5 or 6 years of age (Hancock et al., 2000). Given that children succeeded in our setup at

46 months of age in the pointing condition and at 34 months of age in the peek condition, our work might inform this literature by highlighting that the late onset of irony comprehension is unlikely to be due to children's problems with cue integration per se (cf. Wilson, 2013).

Finally, our results highlight that children up into the preschool years are prone to understand reference expressed via pointing gestures as a call to act on an object regardless of a saliently negative emotional embedding. This has important consequences for pedagogical interactions on a day-to-day basis. Children's ability to integrate an act of reference with a negation or behavioral restriction is critical for their understanding of prohibitory and safety rules (e.g., "Don't touch that!"; "Please don't go there!"; "You can't eat this!"). Even toddlers encounter such restrictive directions regularly in everyday life (Dunn & Munn, 1987; Kopp, 1982; Smetana et al., 2000), making them a crucial context for the mastering of negation in general (Choi, 1988; Pea, 1980). However, any prohibitive statement also highlights its referent given that children's attention is drawn to objects that are negated in linguistic statements (Nordmeyer & Frank, 2014) and pointing gestures are construed as affirmative, which makes it very hard for children to comply with an adult's directions and inhibit their tendency to further approach what has been prohibited. Thus, safeguarding children effectively may require safety rules and behavioral constraints to be made redundantly explicit by combining referential acts with both emotional and linguistic cues and providing a rich contextualization through explanations and rephrasing of the intended meaning—up until the fourth year of life.

Taken together, our studies show that children enter communicative interactions with certain expectations about speakers. Based on their everyday experience, children expect others' communicative acts to be veridical and affirmative. In many cases, this is a useful strategy in that it provides a rapid interpretation of otherwise ambiguous communicative acts (Bohn & Köymen, 2018). In some cases, however, it keeps children from considering all the available information, which has important pedagogical implications. With the development of executive skills, children are able to eventually overcome their prepotent responses and reliably integrate different sources of information.

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