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RESEARCH ARTICLE

Social interaction targets enhance 13-month-old infants' associative learning

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Abstract

Infants are attentive to third-party interactions, but the underlying mechanisms of this preference remain understudied. This study examined whether 13-month-old infants ($N = 32$) selectively learn cue–target associations guiding them to videos depicting a social interaction scene. In a visual learning task, two geometrical shapes were repeatedly paired with two kinds of target videos: two adults interacting with one another (social interaction) or the same adults acting individually (non-interactive control). Infants performed faster saccadic latencies and more predictive gaze shifts toward the cued target region during social interaction trials. These findings suggest that social interaction targets can serve as primary reinforcers in an associative learning task, supporting the view that infants find it intrinsically valuable to observe others' interactions.

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1 | INTRODUCTION

Social interactions provide an essential source of learning opportunities for infants, through both active participation as well as observation of others' interactions (Paradise & Rogoff, 2009; Tomasello, 2016). To maximize such learning opportunities, infants are equipped with capacities and mechanisms that navigate them to social interactions (e.g., Reid & Striano, 2007).

Infants preferentially attend to communicative signals from birth. Newborns look longer at faces with opened than closed eyes (Batki et al., 2000), show enhanced neural processing of direct over averted gaze (Farroni et al., 2002), and orient toward infant-directed over adult-directed speech (Cooper & Aslin, 1990). In the second half of the first year of life, infants are also attentive to social interactions between *others*. Six-month-olds perform more saccadic gaze shifts in accordance with the reciprocal flow of a conversation when they see two people facing each other as opposed to people standing back-to-back while talking (Augusti et al., 2010), 9-month-olds look longer at face-to-face interactions when simultaneously presented with two people standing back-to-back (Handl et al., 2013; see also Beier & Spelke, 2012), 12-month-olds look longer at social over non-social turn-taking events (Bakker et al., 2011), and 14-month-olds look longer at biological motion of face-to-face interactions as compared to horizontally mirrored point-light displays (Galazka et al., 2014). Together, these findings suggest that, toward the end of the first year of life, typically developing infants are not only attentive to signals of direct interaction opportunities, but also to situations in which they can observe social interactions between others.

The emerging preference for others' social interactions is highly adaptive as it ultimately guides infants to potential observational learning opportunities. In their everyday life, however, infants' social attention and behavior are driven by proximal causes (Tamir & Hughes, 2018). One possible proximal driver of infants' preference for social interactions is the incentive value of social interactions (Anderson, 2016). Studies on active social engagement support the idea that direct social interactions are intrinsically valuable to typically developing infants. In the second half of the first year of life, infants show signs of seeking and liking social engagement (Striano & Bertin, 2005; Striano & Rochat, 1999; Venezia, Messinger, Thorp, & Mundy, 2004; Venezia Parlade et al., 2009). It remains unclear whether it is also intrinsically rewarding for infants to observe *others'* interactions. One way to examine this possibility is through reinforcement learning (Berridge et al., 2009). If it is rewarding for infants to observe third-party interactions, they should (based on reward learning) learn the association between an arbitrary shape cue and a target video more effectively if the target shows a social interaction as compared to a non-interactive control scene (Berridge & Robinson, 2003; Tamir & Hughes, 2018; Vernetti et al., 2017). Previous research has shown that targets with high social-emotional value can enhance infants' associative learning and motivate behavior to acquire the valued stimulus. For example, when seeing a non-social cue (arbitrary shape) repeatedly preceding a target video showing the face of their mother, 7-month-old infants show faster decreasing saccadic latencies to the target region across trials compared to a target video showing the face of a stranger (Tummeltshammer et al., 2018). To what extent third-party social interaction targets can serve as primary reinforcer remains unclear.

In the current study, we investigated the incentive value of third-party social interactions in an associative visual learning paradigm. Infants saw one of two different non-social cues (circle or triangle) presented in the center of a screen, repeatedly paired with one of two target videos appearing left or right of the cue (target regions). One video showed two adults turning toward one another and engaging in a social interaction (touching hands, leaning toward one another). In contrast, the other video showed the same two adults performing identical movements as in the social interaction video while standing back-to-back (non-interactive control). To assess infants' learning performance, we measured their saccadic latencies from the central cue to the correct target region across trials and explored the occurrence of anticipatory gaze shifts (see also Reuter et al., 2018; Wang et al., 2012). Based on previous research, we expected that associative learning would be reflected in a decrease in saccadic latencies across trials. We hypothesized that if social interaction targets increase infants' learning performance in the visual learning task, infants' saccadic latencies should decrease relatively faster in the social interaction condition than in the non-interactive condition (interaction effect of condition and trial). To examine whether infants transferred the value from the social interaction target to the social interaction-predictive cue, we compared their proportional looking times at the cue before and after the visual learning task (preferential-looking task), and coded their first-touch behavior while presented with touchable plush versions of the cue shapes (manual forced-choice task). We assumed that if infants successfully learned the associative meaning of the cue shapes, and if they preferred the social interaction target, they should choose the social interaction-predictive cue in both tasks. We tested infants between 13 and 14.5 months of age. Even though infants have been found to learn statistical regularities among central cues and peripheral targets at a younger age (e.g., Wu & Kirkham, 2010), we decided to test older infants based on piloting and because our paradigm was relatively complex compared to these studies.

2 | METHODS

We pre-registered the hypotheses, methods, procedures, and the data analysis plan on AsPredicted (https://aspredicted.org/zt975.pdf). As mentioned in the pre-registration, we assessed infants' gaze-following abilities in addition to our main research question to explore possible relations to their performance in the visual learning task. As there was no relation between infants' performance in gaze following and visual learning, we report the procedure, analyses, and results in the Supporting Information.

2.1 | Participants

Thirty-two infants between 13 months, 0 days, and 14 months, 15 days were included in the final sample of the study ($n = 16$ female; $M = 416.8$ days, $SD = 15.4$ days). Data from six additional infants were excluded due to calibration error ($n = 3$) or because the infant did not complete the study ($n = 3$). We excluded 5 of the 32 infants from the manual forced-choice task because they did not look at both shapes before making a choice ($n = 1$), did not touch a shape within 2 min ($n = 3$), or because they touched both shapes at the same time ($n = 1$). All participants were born full-term. They were recruited from the database of the Uppsala Child and Baby Lab at Uppsala University and came from Uppsala (Sweden) or surrounding areas, an urban, industrialized context. We did not collect individual data regarding the participants' socioeconomic background, but families in this database typically come from mixed, mainly mid to high socioeconomic backgrounds, with the parents having a university degree. The present study was conducted according to guidelines laid down in the Declaration of Helsinki, with written informed consent obtained from both caregivers for each infant before any assessment or data collection. All procedures involving human subjects in this study were approved by the Uppsala Local Ethical Review Board at Uppsala University.

2.2 | Procedure

The testing took place at the Uppsala Child and Baby Lab (Uppsala University) between October and November 2018. Each testing session started with a 10-min eye-tracking phase, including the visual learning and preferential-looking task (Video 1 shows the gaze replay of one exemplary infant participating in both tasks of the eye-tracking phase). During the tasks, the infants sat in front of a screen on their parent's lap. We used a 23″ monitor with 96 dpi and 1920 × 1080 screen resolution with an integrated Tobii TX300 eye tracker (Tobii Technology). We used a five-point calibration procedure to calibrate the eye tracker to the participant's eyes. The experiment was run by using E-Prime (version 3.0; Psychology Software Tools) and E-Prime Extension for Tobii (version 3.1), interfacing with the Tobii eye-tracking hard- and software (Tobii Studio version 3.4.8.1348) via TET and Clearview PackageCalls. We used E-Prime for randomization and counterbalancing. Data were recorded separately for the left and the right eyes at a sampling frequency of 120 Hz. Following the eye-tracking phase, we conducted the manual forced-choice task. The procedure is described in the Supporting Information. All manual choice sessions were video recorded.

2.3 | Stimuli and design

2.3.1 | Visual learning task

Every participant saw a total number of 24 gaze-contingent trials (12 per condition). On each trial, one of two non-social cues (blue triangle or green circle) appeared between two white frames in the center of a black screen. Once the infant fixated on the cue for 150 ms, a "ping" sound appeared, and the cue remained on screen for another 300 ms before it disappeared (Video 2 shows four exemplary trials with sound). After a 600 ms delay, one of two different target stimuli appeared within one of the two white frames (4000 ms): a video depicting a social interaction scene or a non-interactive control scene. The social interaction video showed two women facing forward before they turned toward one another and engaged in a social interaction (leaning toward one another or touching hands). The control video showed the same two women turning away from one another, performing the identical movements as in the social interaction video while standing back-to-back. The rule of target appearance (right or left of the cue) remained consistent for both videos throughout the experiment. The videos were framed in the color of the corresponding cue shape to highlight the associative relation between cue and target. If the infant did not fixate on the cue within 2 s, it disappeared before returning for another 2 s. If the infant did not look at the cue during this second 2-s-interval, no target video was displayed, and the next trial began (see also Tummeltshammer et al., 2014). The timing of the learning task is illustrated in Figure 1 and explained in detail in Table S1. Infants were presented with a 4-s kaleidoscope video every four trials to maintain their attention (see also Reuter et al., 2018). We counterbalanced the location of the social interaction target (right or left from the central cue), the shape cueing the social interaction target (triangle or circle), and the order of the first two trials (social interaction first or non-interactive control first) across participants. The order of the remaining trials was pseudo-randomized, with the same cue never appearing more than two times in a row. Each video covered an approximate area of 13.1° width × 8.7° height (at a screen distance of 60 cm). The cue covered an area of 5° × 5°. The distance between the center of the cue and the outer edge of the target AOIs was 6.7°.

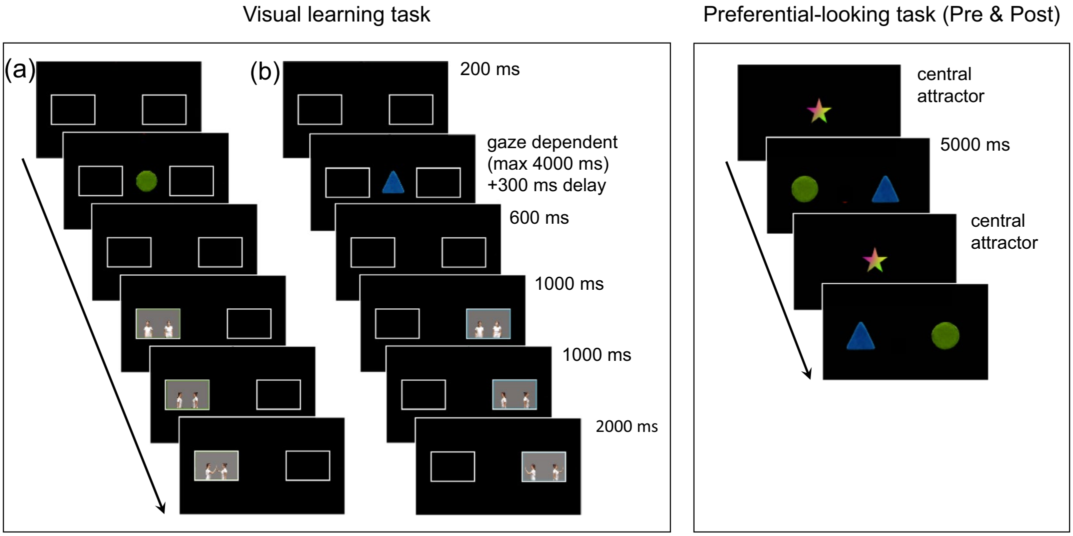

FIGURE 1 Exemplary sequence and timing of the visual learning task and the preferential-looking task (presented pre- and post-learning). The visual learning task shows two exemplary trials with (a) the circle cueing the social interaction video on the left side and (b) the triangle cueing the non-interactive control video on the right side (touching hands interaction). The target onset was at 900 ms after the infant had fixated the cue (300 ms delay plus 600 ms gap)

2.3.2 | Preferential-looking task

Before and after the visual learning task, we assessed infants' visual preference by presenting the cue shapes side-by-side on the screen (see Figure 1). The shapes were shown in both possible left-right arrangements during two successive trials (at 5 s each). The position of the shapes on the first trial was counterbalanced across participants.

2.3.3 | Manual forced-choice task

In addition to the screen-based preferential-looking task, we assessed infants' manual choice preference for touchable plush versions of the cue shapes, by coding their first-touch behavior when presented with both shapes at the same time (see Supporting Information for procedural details). The left-right positioning of the shapes on the choice board was counterbalanced across participants.

2.4 | Coding and data analysis

The following pre-processing and analysis of the data was planned in the pre-registration. All additional analyses are explicitly labeled as exploratory. We used the Tobii Velocity-Threshold Identification (I-VT) fixation classification filter to define fixations and saccades. Data for both the left and the right eyes of each participant were averaged. When one eye could not be measured, we used the data from the other eye. Blinks and saccades were excluded for all measures of looking times. All areas of interest (AOIs) were defined as 1° visual angle larger than the maximal dimensions of the stimulus (Gredebäck et al., 2009). We used R software environment (RStudio version 1.2.1335) for setting AOIs, as well as for pre-processing and analyzing the data. All general linear mixed models (GLMMs) were conducted using R package "lme4" (Bates et al., 2020). All R scripts and the eye-tracking raw data are openly accessible on the Open Science Framework (https://osf.io/4a9b6/).

2.4.1 | Visual learning task

We defined three areas of interest: one square-shaped AOI covering the central cue area and two rectangular-shaped AOIs covering the target regions. We assessed the saccadic latencies toward the cued region for each trial and participant. Saccadic latency was defined as the time difference between the first fixation arriving within the cue AOI and the first fixation arriving within the correct target AOI. As pre-registered, we excluded a trial from the analysis if (a) the infant did not look at the cue during 4 s, (b) the infant's gaze did not arrive in the correct AOI until video offset, (c) the saccadic latency was longer than 2000 ms (assuming that the infant had looked away from the screen after looking at the cue), or (d) the saccadic latency deviated more than ±3 *SD* from the individual mean saccadic latency within conditions. After excluding trials due to these criteria, all participants contributed at least 8 valid social interaction trials ($M = 11.03$, $SD = 1.20$) and eight control trials ($M = 11.03$, $SD = 1.12$) to the final dataset. To compare the change in saccadic latency to the cued target region between conditions, we conducted a GLMM (Gaussian error distribution) for saccadic latency, including the interaction between trial (24 trials) and condition (social interaction, non-interactive control) as a fixed effect. As random effects, we included subject as an intercept, as well as random slopes for trial on subject, condition, and the interaction between trial and condition. *p*-Values for the individual fixed effects were based on likelihood ratio tests comparing the full models with respective reduced models using the *drop1*-function in R with an alpha-level of .05.

We ran four analyses in addition to the pre-registered plan. First, following visual inspection of the average latency data, we explored condition differences in infants' saccadic latencies on the first trial. Second, we repeated our main analysis for saccadic latency over a subset of data including the first six trials only, to account for the possibility that infants had habituated to the target videos throughout the second half of the task (see analysis of looking times in section "Additional Analysis and Results" in the Supporting Information). Third, we compared the number of anticipatory gaze shifts between conditions. We assumed that if infants selectively learned about the appearance of the social interaction target video based on the associative meaning of the corresponding cue shape, they should show more anticipatory gaze shifts in the social as compared to the non-social condition. We defined a gaze shift as anticipatory when it was initiated before target onset. To account for the processing lag of the infant oculomotor system (Gredebäck et al., 2009), we expanded the actual time of target onset (900 ms after the infant had fixated the cue) by 1-year-olds' reactive saccade latency (300 ms in 1-year-olds; Reznick et al., 2000; see also Canfield et al., 1997). The resulting threshold of 1200 ms was used to compute the number of trials for each infant during which they had performed a predictive gaze shift (latencies <1200 ms), and the number of trials during which they had performed a reactive gaze shift (latencies >1200 ms). To compare the number of anticipatory eye movements to the cued target region between conditions, we conducted a GLMM for predictive and reactive gaze shifts (binomial error structure), including condition as fixed effect, subject as random intercept, as well as a random slope of trial on subject. Fourth, we explored infants' first look pattern to rule out that infants sought the social interaction target *region* rather than learning and responding to the meaning of the cue. We assumed that if infants preferred the social interaction target *region*, they should always look at this region first, independent of the meaning of the cue. For the analysis, we calculated the mean proportional number of first looks to the correct target region by dividing the number of first looks to the cued target AOI by the total number of first looks to both AOIs.

2.4.2 | Preferential-looking task

To assess infants' looking preferences, we calculated the proportional looking time at the social interaction cue by dividing the duration of fixations on the social interaction cue shape by the total duration of fixations on both shapes. The resulting proportion scores were averaged over both 5-s trials. We compared pre- and post-responses to the shape by using a paired *t*-test and ran two one-sample *t*-tests against .50 to determine whether the relative looking time to the social interaction shape differed from chance level before and after the learning task. We explored the post-test shape preferences further by comparing the mean proportional looking times between infants who showed enhanced learning in the social interaction condition and less enhanced learners. We divided the sample based on a median split of a latency difference score. The score was calculated for each individual by subtracting the mean saccadic latencies during control trials from latencies during social interaction trials (Tummeltshammer et al., 2018). In the Supporting Information, we report the pre-registered exploratory analysis based on a median split of a difference score from each individual's learning function beta-coefficients. We decided to use the mean difference score since the descriptive pattern of infants' saccadic latencies suggested a non-linear learning curve.

2.4.3 | Manual forced-choice task

We assessed infants' choice behavior by coding which of the two shapes they touched first. A valid choice required that the infant had looked at both shapes and at the experimenter before or immediately preceding the touch. Moreover, choices were coded as invalid if the infant touched both shapes at the same time. We conducted a binomial test to determine the participant's choice. A second, naive coder coded a random 25% of the manual choice sessions (Cohen's kappa = 1).

3 | RESULTS

3.1 | Visual learning task

Infants' learning between the two conditions did not change over time, $\chi^2(1) = .87$, $p = .35$, estimate = 18.42, *SE* = 20.07. Instead and overall, infants looked faster to the location of the social target videos (*M* = 1107.35 ms, *SD* = 331.68) compared to the non-interactive control videos (*M* = 1284.79 ms, *SD* = 198.04; $\chi^2(1) = 9.53$, $p = .002$, estimate = −172.18, *SE* = 52.50; see Figure 2). We did not find a main effect of trial, $\chi^2(1) = .08$, $p = .78$, estimate = 2.35, *SE* = 8.48.

Exploratory analyses revealed that the main effect of condition was not present on the first trial, $\chi^2(1) = 3.47$, $p = .06$, estimate = −97.94, *SE* = 51.88. Moreover, in a subset including data from the first six trials only, the interaction between condition and trial revealed a significant effect on infants' saccadic latency ($\chi^2(1) = 4.65$, $p = .03$, estimate = −89.72, *SE* = 41.58). Overall, infants performed more predictive eye movements during social interaction trials (mean proportion = 0.45, *SD* = 0.35) compared to control trials (mean proportion =0.18, *SD* = 0.20; $\chi^2(1) = 8.78$, $p =.003$, estimate = 1.90, *SE* = 0.62). In addition, exploratory analyses of infants' first looks indicated that infants learned the association between cue shape and target video rather than seeking the target region. Two one-sample t-tests revealed that the proportional number of first looks at the correct target region was greater than chance in both conditions (social interaction condition: *M* = 0.72, *SD* = 0.32; $t(31) = 3.90$, $p = <.001$, $d = 0.69$; control condition: *M* = 0.72, *SD* = 0.31; $t(31) = 4.14$, $p = <.001$, $d = 0.73$), with

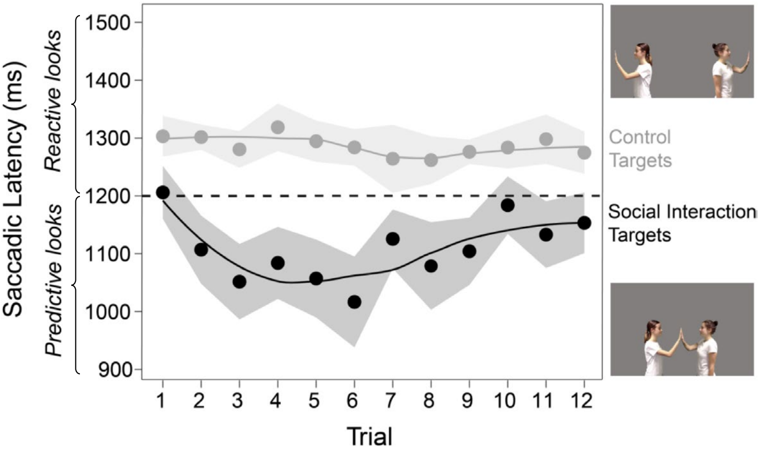

FIGURE 2 Change in saccadic latencies over social interaction trials and non-interactive control trials. The dots represent the means overall individuals for each trial, the shaded areas the standard errors. The smooth curves loess fits to the data of the plot. The dashed line at 1200 ms represents the threshold for prediction, calculated by expanding the timepoint of target onset (900 ms after the infant had fixated the cue) by 1-year-olds' reactive saccade latency (300 ms). Values below this threshold (<1200 ms) correspond to gaze shifts initiated before target onset, values above this threshold (>1200 ms) to gaze shifts initiated after target onset

no difference between conditions (paired t-test, $t(31) = -0.02$, $p = .98$, $d = 0.006$). Table S2 shows the total number of first looks at the two target regions for both conditions.

3.2 | Preferential-looking task

The mean proportional looking time at the social interaction shape did not differ from chance level—neither before (M =0.48, $SD = 0.14$; $t(30) = -0.65$; $p = .52$, $d = -0.12$), nor after the learning task ($M = 0.46$, $SD = 0.15$; $t(31) = -1.58$; $p = .12$, $d = -0.28$). There was no difference between pre- and post-test ($t(30) = 1.18$; $p = 0.25$, $d = 0.19$). The group comparison revealed that infants with enhanced performance in the learning task looked relatively longer at the social interaction shape ($M = 0.52$; $SD = 0.12$) compared to less enhanced learners (M =0.39; $SD = 0.17$, $t(27) = 2.33$; $p = .03$, d =0.82). However, the mean proportion score of the enhanced learners did not exceed chance level ($t(15) = 0.56$; $p = .58$, $d = 0.14$).

3.3 | Manual forced-choice task

Infants did not prefer one shape over the other. Thirteen out of 27 infants (48%) touched the social shape first ($p = 1$).

4 | DISCUSSION

Previous work showed that infants are attentive to third-party social interactions. The present study extends this finding by revealing that this bias goes beyond a preferential orienting in the here and now. In a visual learning task, we found that 13-month-old infants learned a cue–target association guiding them to videos showing two people engaging in social interactions. In contrast, we did not find such a learning effect for target videos displaying a non-interactive control scene. Our findings suggest an early emerging motivation in infants to recognize and seek out opportunities to observe others' social interactions.

Infants' learning of the interaction-predictive association was manifested in relatively faster latencies and more predictive gaze shifts in the social interaction (vs. control) condition. In contrast to our hypothesis (i.e., decreasing saccadic latencies across trials), we found no effect of trial in our overall data. However, based on additional analyses, the current data nevertheless indicate that selective learning took place in the social interaction condition. First, the main effect of condition on latency was not present on the first trial, suggesting that it emerged during the learning task. Moreover, the faster latencies to the social interaction target region could not be explained by a general seeking of the interaction target *region* across conditions, suggesting that infants learned to anticipate the social interaction target based on the associative meaning of the cue. Additional support for learning of the interaction-predictive cue–target association comes from our finding that infants showed more predictive gaze shifts toward the correct target region in the social interaction condition compared to the non-interactive control condition. Visual inspections of the average latencies (see Figure 2) revealed that infants discovered the cue–target contingency rapidly, as the latencies to the social interaction target region decreased within the first few trials (see also Wang et al., 2012). Furthermore, the pattern of results raises the possibility that infants had habituated to the target videos throughout the second half of the learning task (see Supporting Information for supporting analyses). Considering this possibility, we carried out our main analysis for the first half of the learning task, revealing support for the idea that infants' learning between the two conditions changed over time during the first six trials. In contrast to the social interaction condition, infants' latencies remained unchanged at a reactive level throughout the control trials. The suggested absence of learning in the non-interactive condition contrasts with previous findings that already 6-month-olds are sensitive to statistical regularities in the visual domain (Tummeltshammer et al., 2014; Wang et al., 2012). One possible explanation for the discrepancy is that infants' motivation to watch the social interaction scenes had a suppressing effect on their responsiveness toward the control target, as the non-interactive scene was less meaningful to them (e.g., regarding social salience, potential learning opportunities, or intrinsic value). Given the similarities between the videos in both conditions (e.g., presence of two adults, equal amount, and synchronicity of motion), the absence of learning in the control condition suggests rather that infants invested their resources selectively in favor of detecting and approaching the more meaningful interactive scenarios.

We did not find any looking preferences for the social interaction-predictive cue shape itself, neither before nor after the learning phase (*cf*. Tummeltshammer et al., 2014). Even though enhanced learners showed higher proportions of looking times to the social interaction cue than less enhanced learners, their mean proportional looking time did not exceed chance level. One possible methodological explanation for the absence of a looking preference is that we presented our cues one-by-one in the center of the screen during the learning trials, but simultaneously and side-by-side during the preferential-looking task (in contrast to studies presenting the cues at identical positions in both phases, e.g., Tummeltshammer et al., 2014). Given this novel arrangement, infants may have needed more time to express a preference in their looking behavior. Thus, it is possible that the social interaction-predictive cue had acquired value through reward learning, even if this was not reflected in infants' looking time at the cue in the post-test. Support for this assumption comes from the previously mentioned study by Tummeltshammer et al. (2018). Similar to our findings, infants in this study did not show increasing looking times to a reward-predictive cue from pre- to post-test. Infants' pupil size, however, increased in response to the cue, suggesting that the cue had acquired value without modulating infants' looking time. In contrast to the current study design, measuring such pupillary response would require a one-by-one presentation of the cues in the pre- and post-test. Similar to our findings in the preferential-looking task, we did not find infants to show a touching preference in the manual choice task, possibly because they did not transfer the meaning of the cue shapes on the screen to the plush versions off-screen.

Together, our findings contribute to the idea that infants find it intrinsically rewarding to observe others' social interactions. Without receiving any external reward, infants recognized, learned, and responded to the associative meaning of an arbitrary shape cue allowing them to anticipate and approach third-party interaction scenes. The decrease in saccadic latencies toward the social interaction targets suggests that the infant reward system labels social interactions as subjectively valuable, causing superior associative learning and "reward-seeking" behavior. Both reinforcement learning and future-directed seeking have previously been considered indicators of social reward (Berridge & Robinson, 2003; Chevallier et al., 2012; Haith et al., 1988; Vernetti et al., 2017). Based on these results, our findings extend the previous research on social reward by suggesting that not only direct social interactions but also third-party interactions have the potential to serve as a proximal motivator, increasing infants' attention, learning, and memory capacities (Tamir & Hughes, 2018). To gain a comprehensive understanding of possible reward mechanisms, future studies should investigate the affective component of reward. Additional measures such as pupil dilation or coding of facial expression could be used to measure infants' hedonic response to third-party interactions (Ariel & Castel, 2014; Hirshberg & Svejda, 1990; Tummeltshammer et al., 2018).

The enhanced learning performance for social interaction targets that we found in the visual learning task also aligns with prior work showing that attention-grabbing social cues modulate infants' responsivity (de Bordes et al., 2013). Following this interpretation, the mere prospect of observing a social interaction scene may have put infants in a state of heightened responsiveness, increasing their readiness to identify and learn the interaction-predictive cue–target association. Future studies are required to examine whether this increased responsiveness also promotes infants' processing of learnable content presented within the context of an observed social interaction (e.g., Cleveland & Striano, 2007). Importantly, the focus of this study was on processes *guiding* infants to situations in which they can observe others' interactions. We did not focus on processes enhancing infants' learning during the actual observation itself. Therefore, the logic of our study design was reversed (i.e., non-social stimulus cueing a social target) compared to previous studies investigating how infants use other people as social cue aiding them in detecting and learning about relevant content in their environment (e.g., Tummeltshammer et al., 2013; Wu et al., 2011). In direct interactions with others, communicative signals such as direct gaze increase infants' ability to follow referential cues (Del Bianco et al., 2019; Senju & Csibra, 2008), support infants' learning from other novel attention cues (Wu et al., 2014), and facilitate their encoding of cued target objects (Michel et al., 2019; Parise et al., 2008). Moreover, joint attentional engagement with others facilitates 9-month-olds' object processing (Cleveland & Striano, 2007), as well as 18-month-olds' action imitation (Nielsen, 2006) and word learning (Hirotani et al., 2009). It would be a crucial next step to investigate whether similar factors (e.g., third-party ostension) organize infants' attention and increase their learning during ongoing observation of others' interactions (for related studies with older children see, e.g., Fitch et al., 2020; Gräfenhain et al., 2009). In addition, considering the complexity and diversity of human interactions, future studies are required to assess which specific features of social interactions have an impact on infants' visual preference (e.g., proximity, touch, mutual gaze, and face-to-face orientation). Given the previous research on impairments in social attention and social motivation in children with Autism Spectrum Disorders (Chawarska & Shic, 2009; Chevallier et al., 2012; Vivanti et al., 2017), it would be highly relevant to investigate the incentive value of third-party interactions in a high-risk sample. Moreover, to get a more comprehensive insight into developmental trajectories, it would be important to test infants longitudinally at different ages and from different cultural backgrounds (Nielsen & Haun, 2016).

In summary, we could show that 13-month-olds' attention and learning are biased toward situations in which they can observe others' interactions. Our findings extend previous research on infants' preferential orienting to third-party interactions by showing that this preference goes beyond currently available situations. We could demonstrate that infants can detect and use initially meaningless cues in their environment to predict future opportunities to observe third-party interactions. At a broader level, this finding has significant implications for the understanding of how infants learn about their world. Given the importance of third-party social interactive settings for early learning, infants' ability to detect, anticipate, and approach social interactions even if they are not immediately visible can serve as an adaptive goal as it provides infants with possible learning opportunities.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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