Infants' preference for social interactions increases from 7 to 13 months of age

Supplementary Information

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Pre-registration, data, and analyses are openly accessible on the Open Science Framework for both experiments (anonymized links):

Experiment 1: https://osf.io/42nyv/
Experiment 2: https://osf.io/s4uy7/

General Supplementary Information

Additional Information Eye Tracking Task

Content of the video stimuli. We manipulated the relation between the two adults as interacting or non-interacting by using the relative positioning of their bodies (facing versus standing back-to-back), gaze direction (eye contact versus looking away), the execution of an action (co-regulated versus individually). These criteria were a result of the following considerations in the planning phase:

Even though prior research has shown that (even static) body orientation and gaze direction is sufficient to guide 9-month-old infants to facing dyads (Handl et al., 2013), we decided to include the execution of an action, as we aimed to increase the co-regulated turn-taking aspect between the two actors to really highlight their interactive relationship. In similar previous studies this has been done, for example, by showing infants a turn-taking conversation between two people (Augusti et al., 2010; Beier & Spelke, 2012). Since in our study, in contrast to these studies, we presented social interaction and control video simultaneously, we needed to create stimuli without an auditory component.

In addition to co-regulated activity between the two actors, we further decided to only include (a) neutral interactions (i.e., without pro- nor anti-social meaning), (b) interactions that could be cut in the center to horizontally mirror the videos of the separate actors in the control condition (which would not have been possible if the actors would pass an object, e.g., a ball), (c) interactions that were not physically impossible in the mirrored back-to-back videos (to avoid saliency due to impossible actions), and (d) interactions that were too "interactive" even in isolation to remove the interactive aspect in the control condition as much as possible (e.g., waving hands while standing back-to-back could have been interpreted as interacting with another individual outside the visible region of the video). For the same reason, the agents in the control videos were positioned in such a way that they never

"touched" the border of the video. Criterion (b) was particularly important as we presented the stimuli in a forced-choice preferential looking procedure. Differences in motion or synchronicity might have had an effect on infants' preferential orienting (Valdesolo & DeSteno, 2011).

Based on the previously described criteria, we created stimuli showing the three interactions clapping game, leaning heads and touching hands. The actors first looked forward for two seconds before turning toward or away from one another (as in Augusti et al., 2010). All three interactions contained mutual touch between the actors, which was not planned initially, but consistent with stimuli used by Galazka and collegues (2014).

Creating the video stimuli. We filmed the actors individually to ensure flexible and accurate positioning of the dyad partners, consistent timing of actions between actors and trials, and identical levels of motion between social and control stimuli within trials. The control stimuli were created by horizontally mirroring the actions of the individual actors. We filmed the individuals in front of a green screen. This way, we could control for color and luminance differences between and within videos. We used Adobe Premiere Pro for cutting and editing the videos. Adobe Premiere's Ultra Key tool was used to isolate the actors from the background and replace it with an even colored, grey background layer which was identical over all videos.

Actors. Four female actors acted in the stimuli. They all wore white t-shirts, had their hair tied back, and did not wear any glasses or jewelry. We combined the four actors in four dyadic arrangements. This means that every actor was seen together with two different actors, one time on the right side and one time on the left side. Each of the four dyads of actors recurred in all three interactions but never occurred in the same position twice. Each of the three interactions (and corresponding control video) were shown in four possible diagonal arrangements on the screen (see Figure S1).

Video duration. Each trial lasted 12 seconds. Our decision to use a video duration of 12 seconds was based on our observation during piloting that this time was long enough to give the youngest participants (7-month-olds) enough time to look at both videos, while being short enough to keep the oldest infants' attention throughout 12 trials.

Additional Information Free Play

Free play coding categories. Our pre-registered coding scheme included the three infant behaviors "general look at parent", "eye contact", and "joint attention look". We decided to focus on those three behaviors to be able to examine changes and variability in social engagement between 7 and 11 months of age. For this purpose, we created a coding scheme that was sensitive to different levels of social interactions, including both "earlier" developing interaction patterns (i.e., face-to-face interactions), as well as "richer" interaction behaviors presumably shown with increasing age (i.e., joint attention). We added the fourth category "look at parent's face" to our coding scheme after seeing parts of the video recordings for the first time and prior to coding. The reason for adding this category was to get a more precise picture of infants' social engagement, as it would reflect infants' motivation to engage in eye contact without necessarily requiring the parent to look back to them. Accordingly, looks at the parent's face did not reflect higher social engagement skills as compared to eye contact. Figure S3 provides an illustration of the total occurrences of the four infant behaviors.

Free play coding procedure. The coding of the free play sessions was conducted in Microsoft Excel and proceeded as follows: The coder watched each video recording (5 min) in sixty 5-second intervals in reduced speed (0.35x). For each interval, the coder decided if the infant showed one of the four relevant behaviors. Behaviors were only coded if the face of the child was visible. If a behavior was not shown, the infant received a "0" in the respective category. If none of the behaviors were shown, the infant received a "0" in all categories. If an

infant showed one of the four behaviors at least once during the 5-second interval, they received a "1" in the respective category, even if the behavior occurred more than one time during the interval. Based on the hierarchical structure of the four coding behaviors, infants automatically received a "1" in all "lower" behavior categories, when showing behaviors from category 2 ("looks at parent's face"), category 3 ("eye contact"), and category 4 ("joint attention looks", see Figure S2).

To give an example: If an infant and their parent looked at each other's eyes during one coding interval, not only category 3 ("eye contact") was scored with a "1", but also the lower categories, since eye contact necessarily involves a general interest in the parent (category 1), as well as looking at the parent's face (category 2). Note that this hierarchical coding was only used during the coding procedure. For calculating the social engagement proportion score, we used the "highest" looking behavior displayed in each interval (i.e., "Sum" row in Figure S2). If a behavior was shown longer than 5 seconds, succeeding intervals were coded with the respective behavior. Table S1 provides an overview about the detailed coding instructions for all coded behaviors.

Social engagement proportion score. The proportion score that we used for the main analyses of the free play data, was created based on our observation during coding, that most "general looks at the parent" (category 1) were actually looks at toys that parents held in their hands. An infant who constantly looked at a toy in their parent's hand would thus frequently receive a "1" in category 1, even without being necessarily interested in their parent (but potentially rather the toy). Using total frequencies of category 1 behaviors as a measure of infants' active social engagement would thus carry the risk of overestimating their actual social interest—especially in parent-child dyads in which the parents were particularly active. To control for such potential confounding, we relativized the sum of the higher-order social behaviors (i.e., the number of intervals during which behaviors from category 2, 3, or 4 were

shown) at the total amount of all coded behaviors (i.e., the number of intervals during which behaviors from category 1, 2, 3, and 4 were shown) for each individual child.

By using this proportion score instead of the raw sum of the four behaviors, we aimed to (a) isolate infants' actual social interest from their overall looking behaviors related to their parent, (b) indirectly control for individual differences in the parental activity level, and (c) improve differentiation between different levels of social engagement at the group level. To give an example: Consider a mother constantly moving a rattle within their child's field of vision. Even though this child might have low social interest, they might reveal high scores in category 1 when being interested in the rattle. However, compared to a child with higher social interest and the same amount of "general looks at their parent", this child would likely receive a lower social engagement score, as the more socially motivated child would presumably show more eye contact and joint attention looks in addition to (or in combination with) their looks at the parent-toy interaction.

To calculate the number of intervals during which the behaviors were shown, we scored the "highest" looking behavior that a child had shown in each interval (see "Sum" row in Figure S2). For example, the exemplary child in Figure S2 would have shown behavior 1 in two of the seven visible intervals, behavior 3 in three intervals, behavior 4 in one interval, whereas behavior 2 never occurred.

Additional Analyses and Results across Both Experiments

Parental gender. The primary caregiver participated in the free play phase of the study (over both experiments: n = 10 fathers and n = 101 mothers). To account for the possible influence of parental gender, we repeated the overall analysis of age on infants' social engagement score after excluding all father-child interactions (Beta = 0.08 ± SE = .02, $t(1,99) = 4.14$, $p < .001$, $\eta^2 = .15$).

Age group differences. To validate our findings from Experiment 1 regarding age group differences between 7- to 8.5-month-old infants and 9.5- to 11-month-olds, we repeated our analyses including infants from both Experiments who provided valid data in the required age ranges. For the eye tracking analysis this resulted in an extended sample of $n = 30$ per age group. For the free play analysis an extended sample of $n = 42$ in the younger age group and n = 34 in the older age group. The results from these additional analyses were consistent with our findings in Experiment 1: Only infants in the older age group preferentially looked at the social stimuli ($M = .54$, $SD = .07$; $t(29) = 3.47$, $p = .002$, $d = 0.63$). Infants in the younger age group did not show any preference ($M = .48$, $SD = .08$; $t(29) = –1.37$, $p = .18$, $d = 0.25$). Moreover, social behavior scores were significantly higher in the older age group ($M = .36$, $SD = .19$) compared to the younger age group ($M = .25$, $SD = .22$; $F(1,74) = 5.65$, $p = .02$, $\eta^2 = .07$).

Eye tracking model. Even though we used different eye tracking models in Experiment 1 (SMI RED250mobile) and Experiment 2 (SMI RED-m), we used the same SMI software to record and export the gaze data, the same event detection filters to define gaze events, and identical R scripts for processing the data. To statistically test whether eye tracking model had an influence on the overall analysis of the merged eye tracking data, we repeated our main model for infants' proportional looking time to the social interaction stimuli, including age as continuous predictor and eye tracking model as control variable. The effect of age on infants' proportional looking time to the social interaction stimuli remained stable (Beta = .04 ± $SE = .01$, $t(2,88) = 4.62$, $p < .001$, $\eta^2 = .20$). We did not find any effect of eye tracking model (Beta = .004 ± $SE = .02$, $t(2,88) = 0.24$, $p = .81$, $\eta^2 = .0004$).

Effect of age on correlational analysis. In addition to the linear model reported in the main manuscript in section "Overall analysis of individual differences across both experiments", we ran a partial correlation analysis to explore the impact of age on the relation between infants' visual preference and their active social attention behavior further. When

controlling for age, the partial correlation between infants' visual preference for others' interactions and their active social attention behavior was not statistically relevant ($N = 90$; $r(88) = .05$, $p = .63$, $R^2 = .0025$). Table S2 provides an overview of the correlational and post-hoc power analyses for both experiments as well as for the merged sample.

Supplementary Information Experiment 1

Additional Analyses and Results Eye Tracking

We ran some additional analyses to explore the eye tracking data further. First, to allow for a more direct comparison with the main analysis of Experiment 2, we conducted a model for the mean proportional looking time to the social interaction stimuli, including age as continuous rather than categorical predictor. The mean proportional looking time increased with age (Beta = .04 ± SE = .01, $t(1,38) = 2.87$, $p < .01$, $\eta^2 = .18$).

Second, we compared infants' looking preferences before and after the actors had started to turn towards or away from one another. We did not find any effects of condition during the first two seconds—neither in the older group ($M = .52$, $SD = .11$; $t(19) = 0.65$, $p = .52$, $d = 0.15$), nor in the younger group ($M = .51$, $SD = .09$; $t(19) = 0.76$, $p = .45$, $d = 0.17$), with no difference between age groups ($F(1,38) = 0.004$, $p = .95$, $\eta^2 = .0001$). During the last ten seconds, in contrast, the mean proportional looking time at the social stimuli was significantly greater in the older as compared to the younger sample ($F(1,38) = 9.16$, $p = .004$, $\eta^2 = .19$), with a looking preference for the social stimuli in only the older ($M = .56$, $SD = .09$; $t(19) = 3.10$, $p = .006$, $d = 0.69$), not the younger sample ($M = .47$, $SD = .10$; $t(19) = 0.77$, $p = .45$, $d = 0.29$).

Third, we explored whether the infants' looking preference for the social interaction videos varied over trials or between the kinds of interactions that we used in our stimuli. For this purpose, we conducted a general linear mixed model (GLMM, Gaussian error distribution) for the mean proportional looking time to the social stimuli, including the

interaction between age group (between-subject factor) and type of interaction (within-subject factor: clapping, leaning, touching), and the interaction between age group (between-subject factor) and trial (within-subject factor: 12 trials) as fixed effects. In line with our main analysis, we additionally included gender as fixed effect in the model. As random effects, we included subject and gender as intercept, as well as the random slopes on subject for trial, type of interaction, and the interactions between age group and trial, and age group and type of interaction. Infants' looking preference did not differ between the different kinds of interactions, neither did it change over trials. We did not find any effect of interaction type or trial, neither in interaction with age group (age × trial: $\chi^2(1) = 1.73$, $p = .19$, estimate = −0.01, $SE = 0.009$; age × type of interaction: χ^2 (1) = 0.63, p = .43, estimate = −0.007, $SE = 0.009$), nor as overall main effects (trial: χ^2 (1) = 0.75, $p = .39$, estimate = 0.004, $SE = 0.005$; type of interaction: χ^2 (1) = 0.61, p = .43, estimate = −0.004, SE = 0.005). In line with our main analysis reported in the main manuscript, the model revealed a significant effect of age group on infants' looking preference (χ^2 (1) = 5.97, $p = .01$, estimate = 0.07, $SE = 0.03$). Further in line with our main analysis, gender had no significant effect on infants' looking preference ($\chi^2(1) = 0.03$, $p = .86$, estimate = −0.005, $SE = 0.43$). We thus conclude that the effect of age on infants' looking preference was independent from the kind of interaction and did not change over time.

Additional Analyses and Results Free Play

As an alternative approach to the proportion score of social engagement, we repeated our main analysis for the effect of age on social behavior, using the sum of the raw frequencies of occurrence of behaviors from categories 2 ("looks at parent's face"), category 3 ("eye contact"), and category 4 ("joint attention looks") as dependent variable (i.e., the numerator of the proportion score). Analogous to our findings based on the proportion score, this sum score was significantly higher in the older age group ($M = 11.05$, $SD = 6.78$)

compared to the younger age group (M = 6.40, SD = .6.28; $F(1,45) = 5.87$, $p = .02$, $\eta^2 = .12$, see Figure S4).

We initially added the 90-seconds sequence at the beginning of the free play based on findings from prior studies revealing differences in infants' joint attention behavior due to differences in parental engagement (e.g., Bigelow, MacLean, & Proctor, 2004). By restricting the parents' active behavior at the beginning of the free play, we aimed to standardize the first 90 seconds of the free play as much as possible without entirely diminishing the naturalness of the situation. We did not find any difference in infants' social engagement score before and after 90 seconds. Neither overall infants (before: M = .32, SD = .26; after: M = .26, SD = .21; $t(46) = 1.78$, $p = .08$), nor for the separate younger sample (before: M = .28, SD = .28; after: M = .21, SD = .20; $t(26) = 1.70$, $p = .10$) or older sample (before: M = .38, SD = .23; after: M = .34, SD = .19; $t(19) = 0.76$, $p = .45$). This suggests that the social engagement score was not significantly affected by the parental activity level.

Supplementary Information Experiment 2

Additional Analyses and Results

As described above, we repeated our main analysis for the effect of age on social behavior, using the sum score described in the section above (sum of behaviors from categories 2,3, and 4). Analogous to our findings based on the proportion score, the frequency of social behaviors increased with age both in the separate sample (Beta = 2.80 ± SE = .95, $t(1,62) = 2.95$, $p < .001$, $\eta^2 = .12$) and in the merged sample (Beta = 3.03 ± SE = .67, $t(1,109) = 4.51$, $p < .001$, $\eta^2 = .16$, see Figure S4). The social behavior sum score did not correlate with infants' proportional looking time at social interactions in the merged sample (N = 90; $r(88) = .13$, $p = .21$).

Since the analyses of the separate infant behaviors revealed a significant age effect for the occurrence of joint attention looks during free play, we ran exploratory analyses for the correlation between infants' joint attention looks and their orienting to third-party interactions. The proportional looking time at social interactions did not correlate with infants' joint attention score, neither in separate analyses of Experiment 2 ($N = 50$; $r(48) = .12$, $p = .41$), nor in the merged sample ($N = 90$; $r(88) = .15$, $p = .15$).

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Table S1

Detailed coding procedure for the four infant looking behaviors coded during parent-child free play

Infant looking behavior	Coding Instructions
1. General look at the parent	Infants receive a "1" if they look at their parent. This includes looks at objects if the parent holds it in their hand. *Notes.* If the mother "accidentally" crosses the infant's vision field, this episode should not be coded as general look (e.g., the infant looks at an object while the parent reaches for another object next to this object). The parent does not necessarily have to initiate the action (e.g., parent takes a rattle, then the child looks at rattle in her hand). It would also count if the child looks at a rattle before the parent touches it (if the child keeps looking at the rattle in their parent's hand).
2. Looking at the parent's face	Infants receive a "1" if they look at the face of their parent but the parent does not look back.
3. Eye contact between parent and infant	Infants receive a "1" if they looked at their parent's eyes with the parent looking back at their eyes. *Notes.* To distinguish "pure" eye contact from a joint attention look, follow the instructions given in the row below.
4. Joint attention looks between parent, infant and an object	Infants receive a "1" if they mutually look at the same object with their parent before or after they have engaged in mutual eye contact. *Notes.* In most cases a complete joint attention period (i.e., including eye contact and look at the object) lasts longer than one 5-sec interval. Since it is difficult to determine the timepoint when a joint attention look ends and "pure" eye contact or looking at the object begins, only those intervals during which the eye contact between parent and child is established should be coded as joint attention interval. If the child alternates their gaze between object and parent, multiple intervals in a row can be coded as joint attention. To give an

	example: An infant looks at an object in interval 1 (no joint attention interval), then looks at the parent's eyes in interval 2 (joint attention interval), then the infant looks back at the object within the same interval, before looking back to the parent's eyes in interval 3 (joint attention interval). To differentiate between eye contact and joint attention episode, the coder should first identify an interval in which eye contact between parent and infant takes place. Then, the coder should check the sequence immediately before the eye contact had started and after it ends. If child and parent both look at an object together in one of these periods, the coder should go back to the interval in which the eye contact is first established and code it as joint attention look. If not, the corresponding interval should be coded as eye contact.

Table S2

Results from correlation analyses between infants' proportional looking time at others' social interactions (eye tracking) and their active social engagement scores (free play)

	N	*r*	R^2	*p*	*Power*
Experiment 1	40	.15	.02	.36	.15
Experiment 2	50	.23	.05	.11	.37
Experiment 1 & 2 (merged)	90	.24	.06	.03*	.63

Notes. *N* = Number of participants included in the correlation analysis.

Table S3

Results from post-hoc power analyses for the two main analyses over a merged sample (Experiment 1 and Experiment 2)

Dependent variable	*N*	*Beta*	*SE*	*t*	*η²*	*p*	*Power*
Prop. looking time at others' social interactions	91	.04	.01	5.09	.23	<.001	.99
Active social engagement score	111	.09	.02	4.49	.16	<.001	.99

Notes. Results from linear models for the dependent variables, including age (in days) as continuous predictor.

Table S4

Results from post-hoc power analyses for all main analyses in Experiment 1

	ANOVAs				
Dependent variable	*N*	*F*	η^2	*p*	*Power*
Prop. looking time at others' social interactions	40	7.50	.16	.009	.69
Social engagement Score	47	5.06	.10	.03	.56
	One-sample tests against chance level				
	N	*t*	*d*	*p*	*Power*
Prop. looking time at others' social interactions *(Group 1: 7- to 8.5-month-olds)*	20	–1.56	.35	.13	.35
Prop. looking time to social interaction *(Group 2: 9.5- to 11-month-olds)*	20	2.38	.53	.03	.66

Notes. In the two analyses of variance (ANOVAs) age group was included as categorical between-subject factor.

Table S5

Results from post-hoc power analyses for all main analyses in Experiment 2

Dependent variable	*N*	*Beta*	*SE*	*t*	η^2	*p*	*Power*
Prop. looking time at others' social interactions	51	.04	.01	3.73	.22	<.001	.91
Social engagement Score	64	.09	.03	3.35	.15	<.001	.86

Notes. Results from linear models for the dependent variables, including age (in days) as continuous predictor.

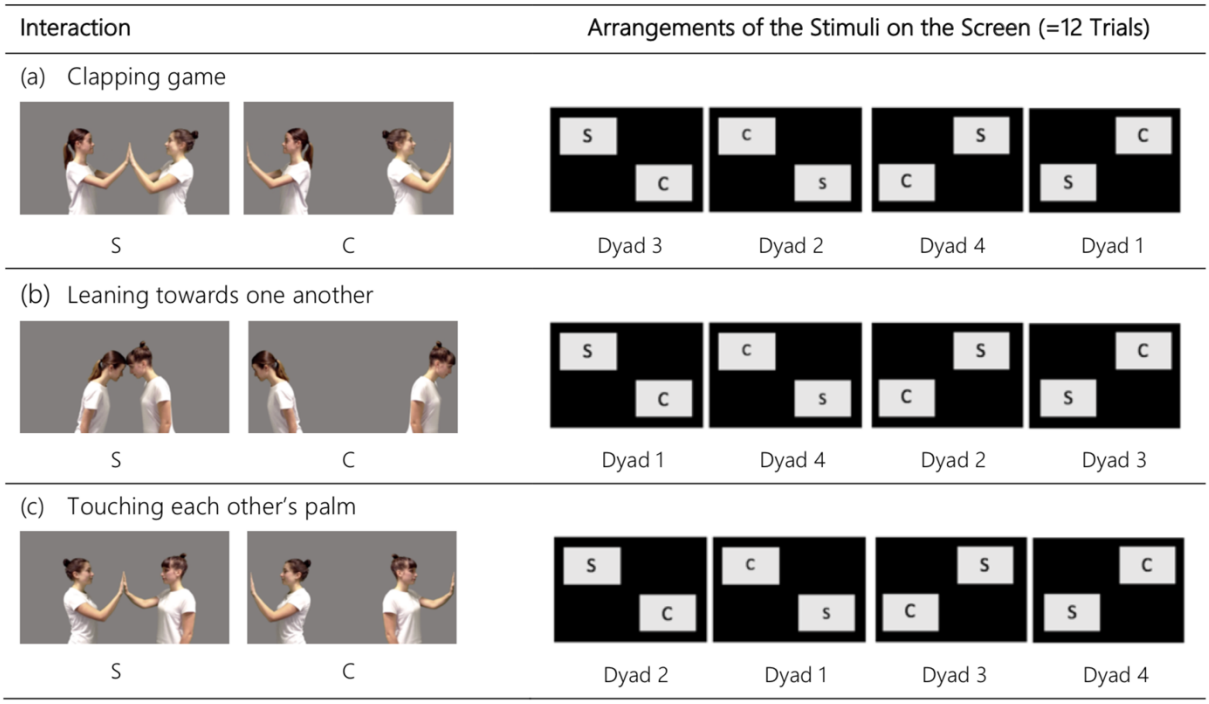

Figure S1. Positioning of the videos on screen for the twelve experimental trials. In the left column, control and social stimulus are exemplarily illustrated for each of the three interactions with one of the four possible dyads. S = social interaction, C = non-interactive control.

	1	2	3	4	5	6		60
	0 00-05'	0 06-10'	0 11-15'	0 16-20'	0 21-25'	0 26-30'	...	4 56-60'
1) General look at parent	0	1	1	1	1	1		1
2) Look at parent's face	0	0	1	1	1	0		1
3) Eye contact	0	0	1	1	1	0	...	1
4) Joint attention look	0	0	0	1	0	0		0
Sum	0	1	3	4	3	1	...	3

Figure S2. Illustration of the hierarchical structure of the free play coding procedure. Screenshot from Microsoft Excel for one simulated child. Visible is the coding for the first six 5-second intervals as well as the last interval (Total number of intervals = 60). The "Sum" row reveals the "highest" looking behavior that the child had shown in each interval. This value was included for the calculation of the social engagement score (e.g., eye contact with their parent during interval 3, 5, and 60).

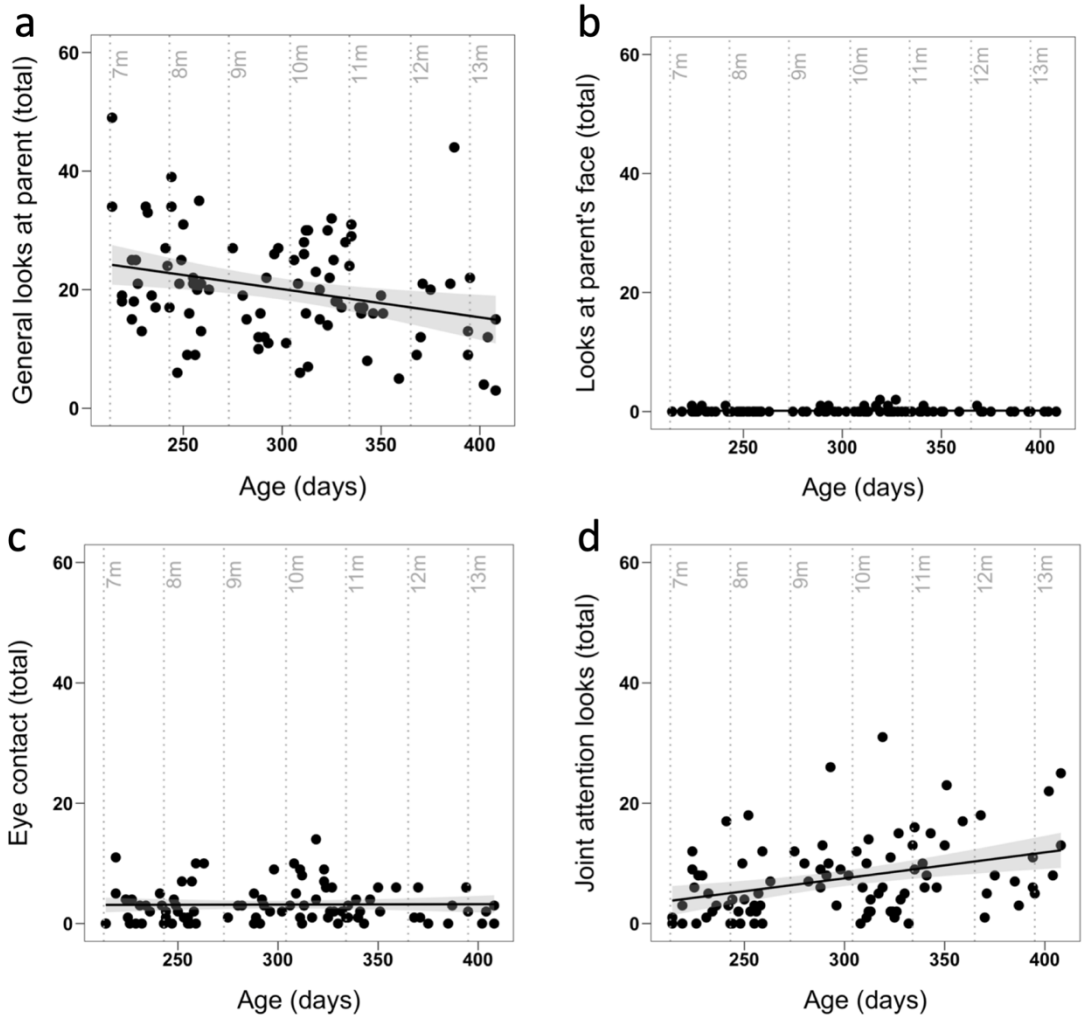

Figure S3. Scatterplots for the total number of occurrences of the four coded infant behaviors during free play. The dots represent individual data points for a merged sample including participants from Experiment 1 and 2. The vertical dashed lines indicate age in months. The linear regression lines with confidence ribbons fit to the data of the plot. Statistically significant was only (a) the decrease in general looks at the parent ($p = .01$), and (d) the increase in joint attention looks ($p < .001$).

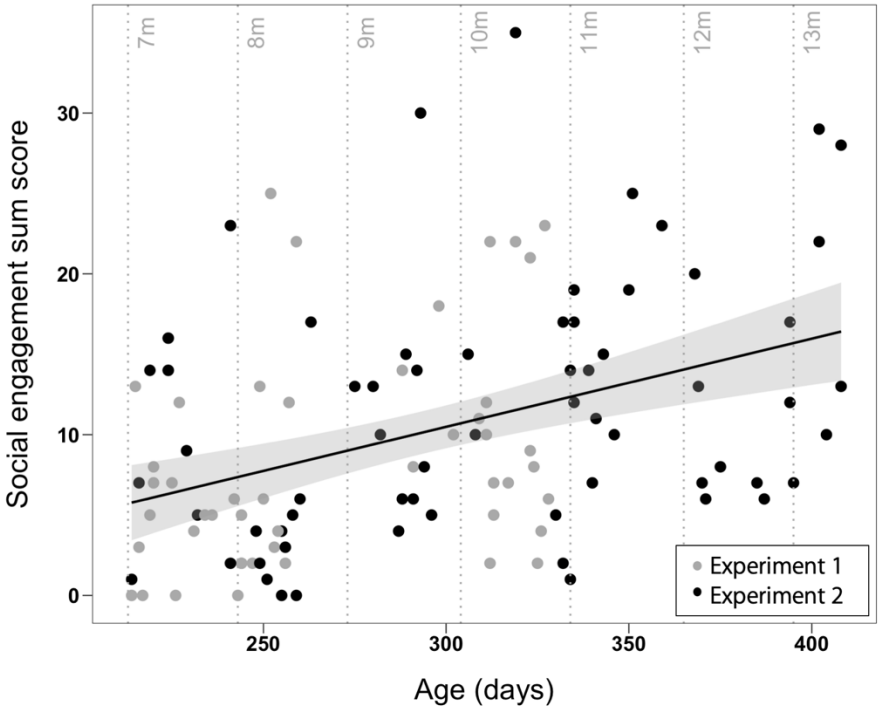

Figure S4. Scatterplot with individual data points illustrating the effect of age on infants' social engagement sum score ($p < .001$). The social engagement sum score represents the sum of the frequencies of behaviors from category 2 ("looks at parent's face"), category 3 ("eye contact"), and category 4 ("joint attention looks"). The vertically dashed lines indicate age in months. The linear regression lines with confidence ribbons fit to the overall data of the plots.