Running head: INFANT FACES REACH AWARENESS MORE SLOWLY

Sorry, baby: Infant faces reach awareness more slowly than adult faces

Timo Stein[1], Lillian Tyack[2], & Sara C. Verosky[2*]

[1]Brain and Cognition, Department of Psychology, University of Amsterdam, Amsterdam, Netherlands

[2]Department of Psychology, Oberlin College, Oberlin, Ohio 44074, United States of America

*Corresponding author: Sara Verosky, sverosky@oberlin.edu

Abstract

Past research has found an attentional bias for positive relative to neutral stimuli, with a greater attentional bias for stimuli that are more motivationally relevant. Baby faces are an example of a motivationally relevant stimulus because they elicit caretaking behaviors. Building on previous work demonstrating that baby faces capture attention, the current study used breaking continuous flash suppression (bCFS) to investigate whether infant faces are prioritized for access to awareness. On each trial of the task, a face was shown to one eye and a rapidly changing Mondrian pattern to the other. Participants were asked to report the location of the face as soon as it emerged from suppression. The faces were either infant or adult faces, presented in upright or inverted orientation. Despite evidence suggesting that infant faces might reach awareness more quickly than adult faces, the opposite was found: adult faces reached awareness more quickly than infant faces. Moreover, a stronger face inversion effect was observed for adult versus infant faces, indicating that the shorter suppression times for adult faces were due to increased expertise with adult faces. A past bCFS study demonstrated an own-age face effect for young adults, but it left open the possibility that this effect was due to the youthful appearance of the young versus old faces. The current results rule out this possibility and provide further support for the idea that experience with faces of one's own social group facilitates the access of those faces to awareness.

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In a world replete with stimuli, people preferentially attend to stimuli with emotional valence (Vuilleumier, 2005; Yiend, 2010). While much of the research on attention to emotional stimuli has focused on threatening stimuli (e.g., Ohman, Flykt, & Esteves, 2001; Ohman & Mineka, 2001), a recent meta-analysis found an attentional bias for positive as compared to neutral stimuli (Pool, Brosch, Delplanque, & Sander, 2016). This meta-analysis suggests that one reason why some studies have failed to find an attentional bias for positive stimuli has to do with the motivational relevance of the stimuli used. For example, while happy facial expressions are often compared to angry or fearful expressions, happy expressions differ from these other expressions in that they do not require an immediate response. In the meta-analysis, there was a larger attentional bias for positive stimuli with greater motivational relevance, including baby faces, erotic attractive stimuli, money, self-related and food stimuli as compared to happy faces and a general mix of positive stimuli (Pool et al., 2016).

One reason why baby faces are considered motivationally relevant is their evolutionary importance. The set of physical features that is characteristic of infant faces is called the baby schema or Kindchenschema (Lorenz, 1943) and it is thought to elicit caregiving behaviors, which are important for reproductive success. Infant, adult, and animal faces that have been manipulated to look more infant-like are perceived as cuter by adults (Borgi, Cogliati-Dezza, Brelsford, Meints, & Cirulli, 2014; Glocker et al., 2009a; Little, 2012) and by children as young as 3-6 years of age (Borgi et al., 2014). Moreover, adult faces that naturally resemble baby faces are judged as possessing more childlike traits, such as warmth, honesty, and naïveté (Berry & McArthur, 1985; Zebrowitz & Montepare, 2008). Infant faces that have been parametrically manipulated to look more infant-like have also been found to lead to increased activity in reward-related areas of the brain (Glocker et al., 2009b).

The motivational relevance of baby faces is reflected in their enhanced visual processing. For example, baby faces have been found to capture attention. In studies using the dot probe paradigm, participants show faster target detection and better orientation discrimination for a target when it appears in a spatial location cued by an infant versus adult face (Brosch, Sander, Pourtois, & Scherer, 2008; Brosch, Sander, & Scherer, 2007; Hodsoll, Quinn, & Hodsoll, 2010). In one of these studies, both baby faces and angry faces were found to capture attention (Brosch et al., 2008). In addition, there was a similar increase in the target-locked P1 component for trials cued by baby faces and angry faces, indicating early orientation of attention to both positive and negative stimuli. More generally, the attentional bias for positive stimuli has been found to be larger in paradigms measuring early versus late attentional processes (Pool et al., 2016). Building on this work, the goal of the current study was to investigate whether infant faces have even earlier effects on visual processing than those previously seen.

The current study used breaking continuous flash suppression (bCFS) to investigate whether infant faces are prioritized for access to awareness. In continuous flash suppression (CFS), a series of rapidly changing Mondrian patterns shown to one eye is used to suppress a stimulus shown to the other eye for lengths of time up to several seconds (Tsuchiya & Koch, 2005). In bCFS, participants are asked to report the location or identity of the stimulus as soon as they detect it, and the amount of time it takes for the stimulus to break suppression is taken as a measure of access to conscious awareness (Jiang, Costello, & He, 2007; Stein, 2019; Stein, Hebart, & Sterzer, 2011).

Upright faces have consistently been found to break suppression more quickly than inverted faces (e.g., Jiang et al., 2007; Stein et al., 2011; Zhou, Zhang, Liu, Yang, & Qu, 2010; for a review see Stein, 2019), indicating an advantage for the processing of familiar information.

Since upright and inverted stimuli are perfectly matched in terms of their lower-level visual properties, inversion offers a convenient way to control for the physical properties of a stimulus. If an effect is still seen when the stimulus is inverted, this suggests the effect is due to the physical properties of the stimulus, rather than the meaning extracted from it.

Faces with fearful expressions have been found to break suppression more quickly than faces with neutral expressions (Gray, Adams, Hedger, Newton, & Garner, 2013; Stein, Seymour, Hebart, & Sterzer, 2014a; Yang, Zald, & Blake, 2007) or happy expressions (Gray et al., 2013; Tsuchiya, Moradi, Felsen, Yamazaki, & Adolphs, 2009; Yang et al., 2007). However, fearful faces continue to overcome suppression more quickly even under conditions that disrupt expression recognition, such as inversion (Gray et al., 2013; Yang et al., 2007). Moreover, faces with angry expressions have been found to break suppression more slowly than faces with neutral expressions (Gray et al., 2013), further suggesting that extraction of emotional meaning is not responsible for the fear prioritization effect. However, an alternative explanation for the fear prioritization effect is that the fearful facial expression itself evolved to match the general properties of the visual system.

Age also influences the speed with which faces reach conscious awareness. For young Caucasian perceivers, young faces have been found to break into awareness more quickly than old faces (Stein, End, & Sterzer, 2014b). For the same perceivers, Caucasian faces have also been found to break into awareness more quickly than Black faces. In both cases, effects were seen for upright faces, but not inverted faces. Moreover, the face inversion effect was larger for young faces and same-race faces, fitting with other work showing that expertise is related to larger inversion effects (Stein, Reeder, & Peelen, 2016). A similar effect was subsequently demonstrated for Asian perceivers viewing Asian versus Caucasian faces (Yuan, Hu, Chen, &

Bodenhausen, & Fu, 2019). While these data suggest that experience with one's own age and racial groups leads to faster detection of own-age and own-race faces, the studies only used single groups of perceivers and they did not show a reversal of the observed effects for other groups of perceivers. Therefore, for the studies examining race, it is possible that the faces of the racial groups tested break into awareness more quickly regardless of the perceiver. Similarly, for the study examining age, it is possible that more youthful-looking faces break into awareness more quickly.

Another factor that influences suppression times is facial attractiveness. More attractive faces have been found to reach awareness more quickly (Hung, Nieh, & Hsieh, 2016; Nakamura & Kawabata, 2018). However, attractiveness continues to affect suppression times even when faces are inverted, suggesting the effect is due to low-level visual properties (Nakamura & Kawabata, 2018). Since faces that have been manipulated to look more infant-like are perceived as cuter (Borgi et al., 2014; Little, 2012), these data on attractiveness and bCFS also suggest that infant faces may break into awareness more quickly than adult faces.

The current study used bCFS to measure detection and inversion effects for infant versus adult faces. On each trial of the task, a face was shown to one eye and a rapidly changing Mondrian pattern to the other. Participants were asked to report the location of the stimulus as soon as it emerged from suppression. Since baby faces have been found to capture attention (Brosch et al., 2007, 2008; Hodsoll et al., 2010), we predicted that infant faces would reach awareness more quickly than adult faces. However, given the bias for detecting own-age faces (Stein et al., 2014b), we also considered the fact that it would be possible to make the opposite prediction. The infant and adult faces were presented in both upright and inverted orientations, allowing us to control for differences in physical stimulus properties. In addition, we collected attractiveness ratings for the faces and asked participants to report the amount of experience they had with babies in order to examine whether attractiveness or self-reported expertise would play a role in any observed effects.

Method

Participants

Sample size for the experiment was determined prior to data collection. Thirty-four participants (19 female, 15 male; *M* = 19.0 years, *SD* = 0.9) were recruited through the Oberlin College subject pool. The sample size of *N* = 34 results in 80% power to detect an effect with a medium standardized mean difference effect size (d_z of 0.5) at an alpha level of 5%. The standardized mean difference effect size is often used in repeated measures designs and is calculated as $d_z = \frac{M_{\text{diff}}}{s_{\text{diff}}}$ where the numerator is the difference between the means of two repeated measures and the denominator is the standard deviation of the difference scores (e.g., Lakens, 2013). Because other studies in the bCFS literature have reported relatively sizable effects, we decided it was unnecessary to use a small effect size for the sample size calculation. However, because we wanted to be able to detect a possible interaction between face category and face orientation, and more generally because we wanted to ensure our experiment would have sufficient power, we chose to use a medium effect size for the sample size calculation instead of a large effect size. We only tested participants who did not wear glasses and who said they had normal or corrected-to-normal vision. Participants were naïve to the research question. They participated for partial course credit or payment. Informed consent was obtained following a protocol approved by the Oberlin College Institutional Review board.

Stimuli

Participants viewed a 24-inch LCD screen (1920 × 1080 pixels resolution) dichoptically through a custom-built mirror stereoscope. Visual stimuli were presented with Matlab (The MathWorks, Natick, MA), using the Psychtoolbox (Brainard, 1997) functions. The observer's head was stabilized by a chin-and-head rest at a viewing distance of approximately 84 cm. The mirrors of the stereoscope were adjusted for each observer to yield stable binocular fusion. The screen was black. Throughout the experiment, two fusion contours (4.8° × 4.8° of visual angle) consisting of random black and white pixels (width 0.2°) were displayed side-by-side on the screen such that one contour was shown to each eye (distance between the centers of the two contours 10°). In the center of each contour a small white fixation cross was presented, and the remainder of the space enclosed by the contour was mid-gray. Participants were asked to maintain fixation throughout the experiment (moving the eyes between trials if necessary).

Stimuli were 15 emotionally neutral face photographs of adults taken from the Radboud Faces database (Langner et al., 2010), and 15 emotionally neutral infant faces from the Tromso Infant face database (Maack et al., 2017). The adult faces included 5 female models (1, 12, 22, 27, 37) and 10 male models (9, 10, 12, 15, 23, 25, 28, 33, 46, 47), and the infant faces included 8 female models (A02, A03, A05, A10, A12, A16, A17, A19) and 7 male models (A04, A06, A07, A13-A15, A18). Because it is difficult to determine the sex of infant faces based on appearance, we did not match the adult and infant faces on this variable. Instead, we did our best to match pairs of adult face and infant faces on overall physical appearance. Both the overall set of neutral photographs of adults in the Radboud Faces database (*M*=3.0, *SD*=.3) and the set of photographs of infants used in the current study (*M*=3.0, *SD*=.2) were rated as neutral in validation studies using a 5-point scale to measure valence (Langner et al., 2010; Maack et al., 2017).

After selecting the faces, we removed hair and outer facial features, converted the stimuli to gray, and resized the stimuli to fit in the center of a square (2.2° × 2.2°). The contrast within the area corresponding to the face was equated, and the outer face contour was blurred into the background. To induce CFS, we generated 160 Mondrian masks (4.8° × 4.8°) consisting of randomly arranged circles (diameter 0.1–0.8°).

Procedure and design

Figure 1 shows a schematic bCFS example trial. Each trial started with a 1-s fixation period in which only the fusion contours and the fixation crosses were presented. Mondrian masks changing every 100 ms were then presented to one eye, and an upright or inverted face was gradually introduced to the other eye by decreasing its transparency to zero over the first second of a trial. Beginning one second after trial onset, the contrast of the CFS masks was linearly decreased to zero over 9 s. The face was presented until response, or for a maximum trial length of 10 s. Faces were presented in four different positions, either above, below, left or right of the fixation cross (distance of the center of the square target image to the fixation cross 1.3°). Participants were asked to press one of the four arrow keys on the keyboard corresponding to the four possible face locations to indicate as quickly and accurately as possible in which location a face or any part of a face became visible.

The bCFS task consisted of 120 trials, in which all combinations eight conditions (two eyes for face presentation, two face categories, two face orientations) and 15 face identities occurred once. Face location was selected at random with the constraint that all four positions occurred equally often in each of the eight conditions. Trial order was randomized. There was one obligatory break after 60 trials. Before starting the experimental block, participants received eight practice trials.

After the bCFS task, participants rated the stimuli on attractiveness. Here, the overall setup was similar, and faces were presented in the same locations as in bCFS. However, no Mondrians were displayed, and upright faces were presented for a fixed duration of 500 ms with no fading-in. After face presentation, the question “How appealing?” was displayed and participants were asked to enter their ratings on using a scale from 1 to 4, without time constraints. This wording was used so that the question would apply equally to the infant and adult faces. There were 30 trials, in which each face was presented once, to a randomly selected eye, and at a randomly selected position. Finally, participants were asked to verbally report the amount of experience they had with babies on a scale of 1(very little) to 4(a lot).

Analyses

For bCFS, trials with incorrect or no localization responses (M = 11.7%, SD = 12.5) were excluded from further analyses. We have recently shown that raw median or mean bCFS suppression times often violate the assumption of normality and have advocated the use of log-transformation or of a latency-normalization procedure (Gayet & Stein, 2017). For the *log-transformation*, for each participant all RTs were first log-transformed (logarithm with base ten), and the inversion effect was calculated as the difference between the mean log-transformed RTs for inverted and upright faces. For illustration purposes and easy eyeballing of the results in standard units log-transformed RTs were transformed back. For the *latency-normalization procedure*, for each participant the inversion effect (calculated from median RTs) was divided by the overall median RT, such that it reflects a proportional difference in RTs caused by face inversion. For the attractiveness-rating task, we calculated mean ratings for every face exemplar.

Results

Breaking continuous flash suppression task. We first analyzed mean log-transformed suppression times with an ANOVA with the factors face category (adult, infant) and face orientation (upright, inverted). This analysis revealed significantly faster RTs for adult faces, $F(1, 33) = 73.72$, $p < .001$, $\eta_p^2 = .69$, (Figure, 2a), significantly faster RTs for upright faces, $F(1, 33) = 111.52$, $p < .001$, $\eta_p^2 = .77$, and a significant interaction, $F(1, 33) = 23.91$, $p < .001$, $\eta_p^2 = .42$, reflecting larger inversion effects for adult than for infant faces (Figure 2b). Similarly, normalized inversion effects were significantly larger for adult faces than for infant faces, $t(33) = 5.13$, $p < .001$, $d_z = 0.88$. The proportional effect of inversion, relative to overall RTs, was 36.5% ($SD = 21.1$) for adult faces, and 15.3% ($SD = 18.7$) for infant faces.

To simultaneously account for variability in suppression times between participants and between individual face exemplars used in the experiment, we performed linear mixed effects analyses on the log-transformed RTs using the lme4 package (Bates, Maechler, & Bolker, 2012) for R (R Core Team). To test for the main effects of face category and face orientation, a null model containing random intercepts for both participants and for individual face exemplars was compared against models containing the additional main effects, random intercepts for participants and face exemplar, and random slopes for the main effects for participants and face exemplar. To test for the interaction, a model with the orientation-by-category interaction was compared to a model with the two fixed factors only, including random intercepts and slopes for all effects in both models. Likelihood ratio tests were used to find the models that best fitted the data. This analysis also revealed significant effects of face category, $\chi^2(5) = 15.19$, $p = .010$, face orientation, $\chi^2(5) = 203.31$, $p < .001$, and a significant interaction, $\chi^2(9) = 20.20$, $p = .017$. Finally, to test for the influence of participant's gender, the fixed effect of gender was added to the main effect models and to the interaction model, and these were compared to the models not containing gender. There were no significant effects of gender, all $\chi^2(1) < 2.32$, all $p > .128$

Attractiveness rating task. Infant faces received higher mean attractiveness ratings than adult faces, $t(33) = 5.11$, $p < .001$, $d_z = 0.88$ (Figure 2d). Because (upright) adult faces were associated with shorter suppression times than (upright) infant faces, across all 30 face exemplars more attractive faces were associated with longer RTs, $r(28) = .53$, $p = .003$. However, this correlation was driven by the overall difference in attractiveness ratings between face categories. When correlating suppression times with attractiveness ratings separately for adult and infant faces, there were no significant correlations, both $r(13) < .16$, both $p > .58$. This can also be appreciated from Figure 3, where mean attractiveness ratings for adult and infant faces are plotted against the corresponding mean log-transformed RTs.

In addition, we again performed linear mixed effects analyses on the log-transformed RTs and compared a model with the fixed factor face exemplar to a model with the fixed factor attractiveness (participant's rating for a given face exemplar), including random slopes and intercepts for participants. When not considering other fixed factors, the exemplar-model provided a better fit to the data than the attractiveness-model, $\chi^2(1) = 51.24$, $p < .001$. When modeling the other fixed factors as well (category, orientation, and their interaction), there was no significant difference between a model containing the additional fixed factor face exemplar and a model containing the additional fixed factor attractiveness, $\chi^2(1) < 0.1$.

Experience with babies. Finally, we correlated self-reported experience with babies with suppression times and attractiveness ratings. Greater experience with babies was associated with higher attractiveness ratings for infant faces, $r(32) = .39$, $p = .023$. However, there was no significant correlation with log-transformed RTs for upright infant faces, $r(32) = -.18$, $p = .304$, and the correlation with normalized inversion effects for infant faces only approached statistical significance, $r(32) = .31$, $p = .074$.

Discussion

Baby faces are motivationally relevant stimuli because they are thought to elicit caretaking behaviors. Past work using the dot probe task has demonstrated that baby faces capture attention (Brosch et al., 2007, 2008; Hodsoll et al., 2010), and that they modulate the amplitude of the P1 ERP component (Brosch et al., 2008). Based on these studies, we used bCFS to investigate whether infant faces would be prioritized for access to awareness. In contrast to our prediction, we did not find evidence that infant faces broke into awareness more quickly than adult faces. Thus, while baby faces have early effects on attention, our data suggest that they do not receive differential visual processing until after they have reached awareness.

Instead of finding that baby faces reached awareness more quickly than adult faces, we found the opposite: adult faces reached awareness more quickly than infant faces. Importantly, we also found that there was a stronger face inversion effect for adult versus infant faces. Since past work has found larger inversion effects for faces and other objects of expertise (Stein et al., 2016; Zhou et al., 2010), these results indicate that the shorter suppression times for adult faces were due to increased expertise with adult faces.

Our results fit with those of a previous study demonstrating an own-age bias in face detection in young adults (Stein et al., 2014b). This previous study only included a single group of perceivers, and therefore it left open the possibility that the observed effects were due to the youthful appearance of young versus old faces. By demonstrating that infant faces break suppression more slowly than adult faces, the current study helps to rule out this alternative explanation. Thus, the current results provide further support for the idea that a perceiver's experience with members of their own social group facilitates access of those faces to awareness (Stein et al., 2014b; Yuan et al., 2019).

Infant faces in the current study were evaluated as more attractive than adult faces. This finding is consistent with studies demonstrating that faces that look more infant-like are perceived as cuter (Borgi et al., 2014; Glocker et al., 2009a, 2009b; Little, 2012). Since infant faces broke suppression more slowly than adult faces, this meant that attractiveness was associated with slower suppression times overall. However, this effect was driven by face category: looking separately at infant and adult faces, there was no relationship between attractiveness and suppression times. Previous studies have demonstrated that attractive faces break suppression more quickly (Hung et al., 2016; Nakamura & Kawabata, 2018), and evidence suggests this is due to low-level properties of the faces (Nakamura & Kawabata, 2018). In contrast to the current study, these previous studies used a larger number of individual faces, which likely meant the faces spanned a broader range of attractiveness. Different stimuli could potentially explain why we failed to observe an effect of attractiveness on suppression times.

Participants in the current study were undergraduate students who, on average, reported not having had much experience with babies. Self-reported experience with babies did not relate to suppression times. However, participants who reported having more experience with babies did find the infant faces relatively more attractive. While the studies demonstrating attentional capture by baby faces also relied on student participants (Brosch et al., 2007, 2008; Hodsoll et al., 2010), an open question is whether perceivers with more experience with babies would show different effects under bCFS. For example, parents of young children have been found to rate infant facial expressions of emotion as more clear than other groups of perceivers (Maack et al., 2017), and it is possible that they would also find infant faces especially motivationally relevant.

Another way to control for visual expertise would be to manipulate faces in a single age-group to look more infant-like. Along these lines, a study examined suppression times for male and female faces that naturally varied in their resemblance to baby faces (Zheng, Luo, Hu, & Peng, 2018). While adult female faces resembling baby faces broke suppression more quickly than adult female faces that were more mature-looking, the reverse was true for adult male faces. However, because the faces were only presented in upright orientation, it is not clear whether the observed effects are due to low-level visual properties of the faces. Future work could investigate whether this effect holds with a more controlled set of stimuli, where the faces have been manipulated to look more infant-like.

Although we equated the overall contrast of the faces across the adult and infant faces sets, we did not equate the distribution of high-contrast areas within the faces. The reason we did not do this is because we wanted to avoid inadvertently equating the very features that might lead to differential detection of adult versus infant faces. This means that differences in the distribution of high-contrast areas, for example having more defined eyebrows, could explain the overall faster detection of adult faces. However, the fact that we observed a larger inversion effect for adult versus infant faces indicates that differences in suppression times between the two stimulus sets are not simply due to this factor.

Another potential difference between the sets of adult and infant faces is perceived proximity. Since the adult and infant faces are scaled to the same size, the infant faces appear to be somewhat closer to the observer. Although it is possible that perceived proximity influences access to awareness, we are not aware of any studies that have addressed this question.

However, because we would expect that stimuli that appear closer would be prioritized for access to awareness, it seems unlikely that proximity could explain that current pattern of results, where the infant faces reach awareness more slowly than adult faces. Moreover, we also suspect that the small size of the stimuli in the current study may attenuate any differences in perceived proximity between the face sets.

In summary, we did not find evidence that infant faces receive prioritized access to awareness. While it is possible that infant faces or faces that look infant-like might reach awareness more quickly than adult faces under certain circumstances, on balance our data suggest that infant faces do not receive differential visual processing until after they have reached awareness. Instead, our results provide further support for an own-age bias in face perception, where experience with own-age faces leads them to reach awareness more quickly.

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Figures

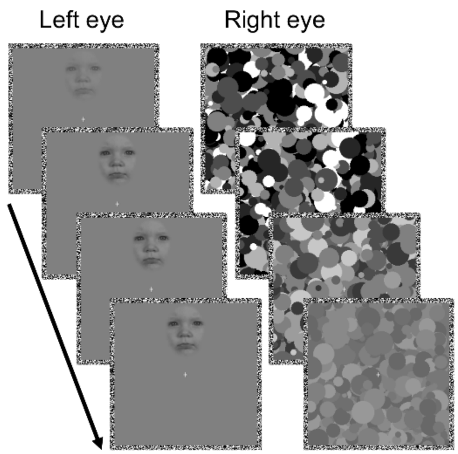

Figure 1: Schematic example breaking continuous flash suppression trial. A face was presented to one eye and Mondrian masks changing every 100 ms to the other eye.

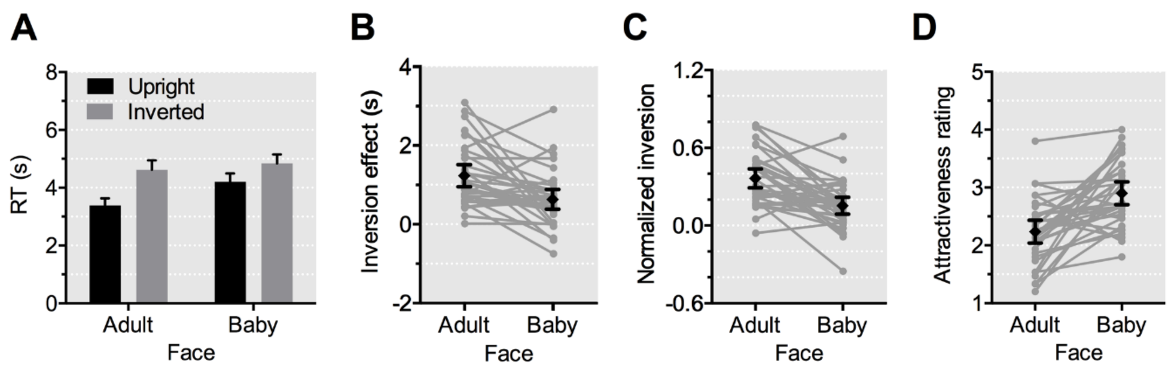

Figure 2: Results from (a–c) the breaking continuous flash suppression and (d) the attractiveness rating tasks. (a) Bars show average suppression times for adult and infant faces, separately for upright and inverted orientations. For intuitive eyeballing of the differences in standard units (seconds) in these plots, log-transformed suppression times were back-transformed. Error bars represent between-subject standard errors for each condition. (b) Inversion effects based on log-transformed suppression times, here back-transformed for plotting purposes. (c) Inversion effects after the latency-normalization procedure. (d) Mean attractiveness ratings. In (b–d), every gray circle and line represents data from an individual participant, black symbols show the group means, and error bars denote 95% confidence intervals.

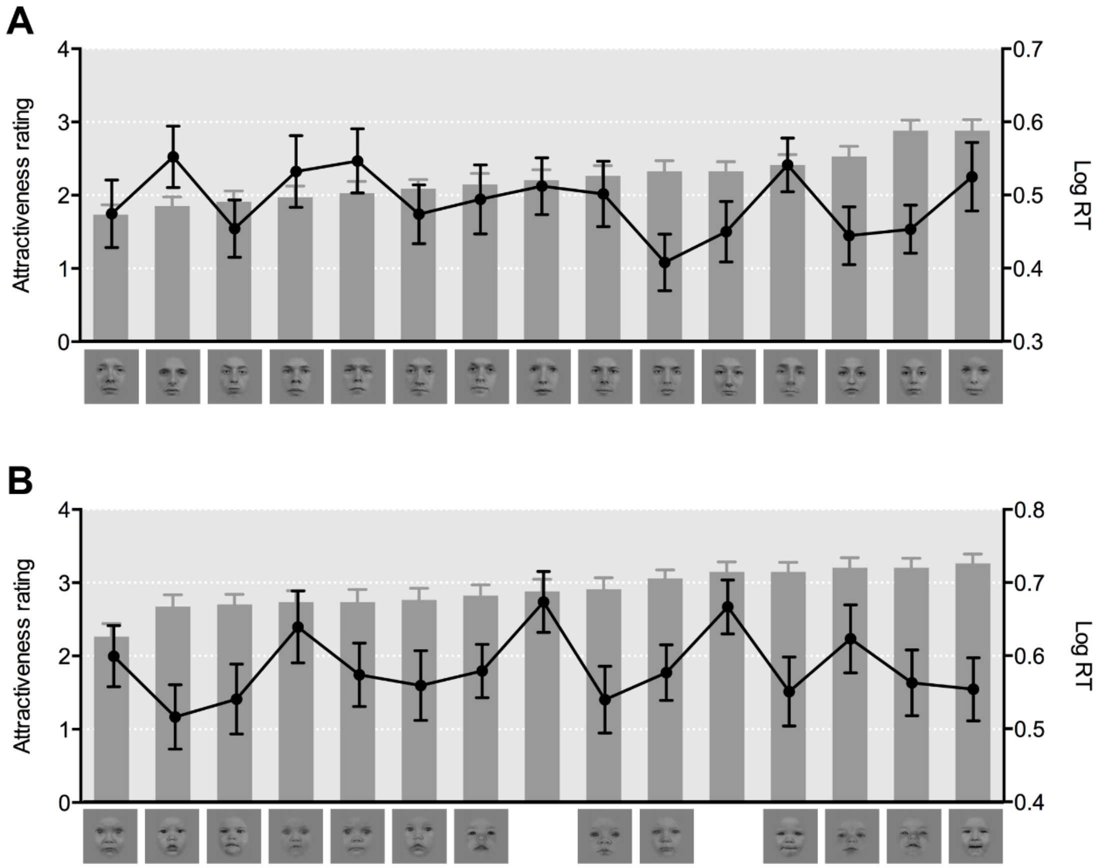

Figure 3: Mean attractiveness ratings for each face exemplar (left y-axis, gray bars) plotted against mean log-transformed suppression times for every (upright) face exemplar (right y-axis, black symbols), for (a) adult faces, and (b) infant faces. Two of the infant faces are not shown in the figure because we did not have permission to publish them. Note the difference in right y-axis scales (adult faces were associated with shorter overall suppression times). All error bars represent SEMs.