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Measuring Early Emergence of Self-Awareness in Infants Using Eye Tracking

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Abstract

Recent attention has been paid to the neurological, evolutionary, and developmental correlates of human self-face recognition. In the present study, we examined 12-, 18-, and 24-month-olds using eye tracking to determine if there was a unique visual scan path of faces for self-recognizers as compared to non-recognizers. Results indicated that overall, 12- and 24-month-olds have different scan-paths compared to 18-month-olds. Eighteen-month-olds have an increased number of fixations and fixation time spent on the eyes, mouth and top half of the face, while 12- and 24 month-olds have more fixations on the nose and bottom half of the face. Furthermore, self-recognizers have a generally unique scan-path of self-faces in comparison to non-self-faces, having increased attention to the upper features and mouth on the self-face. This distinction between age groups and self-recognizers presents significant implications for development and the progression of self-awareness.

Measuring Early Emergence of Self-Awareness in Infants Using Eye Tracking

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The study of self-awareness involves uncovering the very core of human understanding of consciousness (Duval & Silvia, 2012). Self-awareness is defined as the comprehension of the separation between the self and others (Duval & Silvia, 2012). Self-recognition, the ability to recognize oneself, is a potential tool in measuring self-awareness, as it is a physical representation of seeing the self existing as its own entity. Self-recognition and self-awareness are intertwined, providing an important addition to the progression of complex cognition (Keenan, Gallup, & Falk, 2001). Discovering ways to further establish the presence of self-awareness may assist in building a stable understanding of the development of self.

Those who are able identify themselves are believed to possess self-awareness (Gallup, 1979). Self-recognition, typically measured by the mirror task (Gallup, 1970), determines if individuals are able to recognize themselves. This ability to differentiate the self from others is a quality few species possess. Other than humans, only orangutans, bonobos, and chimpanzees have shown definitive evidence of self-recognition as measured by the mirror task (Bard & Leavens, 2009; Gallup, 1979; Kano & Call, 2014; Zazzo, 1981). Other mammals such as dolphins and elephants have shown suggestive evidence as demonstrated by mirror task responses as well (Reiss & Marino, 2001; Plotnik, de Waal & Reiss, 2006). From an evolutionary standpoint, mammals found to pass the mirror task possess complex nervous systems and have been shown to demonstrate advanced abstract cognitions and behaviors including self-awareness. The development of self-awareness is linked to not only self-recognition, but also other complex behaviors such as, mindfulness, and self-regulation (Platek, Keenan, Gallup & Mohamed, 2004). Higher-level cognition is likely necessary to possess self-recognition; therefore it does not seem to exist in species with less complex neural architecture (Vago & Silbersweig, 2012).

Gallup (1970) developed the mirror task to measure self-recognition, which may indicate self-awareness in both animals and humans. There are variations of this task, but the primary version involves placing a mark of rouge on the forehead of the participant, and observing if subsequent touches are aimed at the dot upon seeing their reflection (Gallup, 1979; Amsterdam, 1972). This task has been replicated (Gallup, Anderson & Shillito, 2002; Platek, Keenan, Gallup & Mohamed, 2004; Toda & Platt, 2015) and researchers have linked self-awareness to the emergence of not only self-recognition but also other behaviors, such as photographic, video, and voice identification, as well as personal pronoun usage (Courage, Edison & Howe, 2004; Lewis & Ramsay, 2004). This work provides evidence that self-awareness emergence, as indicated by mirror recognition, is an important cognitive process that assists in the individual's development.

The mirror task has been used to demonstrate when self-awareness develops in humans during infancy (Amsterdam, 1972). This test has provided consistent evidence that self-recognition develops between 18 and 24 months of age. Typically, 55% of 18 month olds are able to self-recognize (Bard et al., 2009; Lewis & Brooks-Gunn, 1979). Other behaviors related to self-awareness, such as pretend play and synchronic imitation (Nielsen & Dissanayake, 2004) have been shown to develop around the 18-month mark as well. This is a critical learning period where significant changes in development occur, thus suggesting that various development abilities, many of which pertaining to the self, emerge during the 18-month time period.

Stapel et al. (2016) provided concurrent evidence that 18-month-olds are at a unique time in infancy. In this study, EEG was recorded in 18-month-olds while the infants viewed their own face as well as others faces. Brain readings were compared to mirror task results. Regardless of whether the mirror task was passed, the 18-month-old infants had a unique cognitive response to their own face that was evident in EEG activity (Stapel, van Wijk, & Hunnius, 2016). Given that the 18-month-olds don't pass the mirror task but still show specific brain activation of self-faces, we proposed that this indicated the 18-month-olds are learning about faces as the ability to self-recognize begins to emerge. The aim of the present study is to provide evidence that 18-month-olds, whether or not they pass the task, are at a precarious time in which they are beginning to encode and process the information provided by faces.

Eye tracking in infants has been used to understand particulars of cognitive processing and comprehension (Aslin, & McMurray, 2004; Bronson, 1983; Gredeback, Johnson & von Hofsten, 2009; Karatekin, 2007). Both fixation time to an image, as well as the movement pattern over the visual field, have a strong relationship with an individual's mental capacity and cognitive processing ability (Aslin, & McMurray, 2004; Oakes, 2012).

Gaze patterns during facial processing also develop throughout infancy. Face processing tactics alter progressively as children develop (Bronson, 1994). From birth until two months of age, faces are perceived as similar to a two-dimensional object, only partially being processed (Kessen, Salapatek, & Haith, 1972). Infant gazes, at this age, rest more on the outer edges of the face compared to adult scanning paths (Maurer & Salapatek, 1976; Hainline, 1978; Milewski, 1976). At two months of age, the focus of their gaze begins to shift inward from the perimeter of the face. Infants are then initiating visual scanning patterns among the inner-features (Maurer & Salapatek, 1976). This attention to the central region of the face, rather than the periphery, draws the visual scan path to more distinguishing features, such as the eyes and nose. Infants attend to the nose and mouth, devoting extra attentiveness to the eyes (Haith, Bergman & Moore, 1977; Hunnius & Geuze, 2004).

Face scanning patterns become increasingly complex with age, containing more fixations (Hainline, 1978). Thus, infants face processing abilities are not only informative for providing evidence of their comprehension, but also for predicting and aiding abilities later in life. Eye fixation patterns have yet to be significantly linked to self-awareness. Kano and Tomonaga, (2010) have evaluated eye tracking as an efficient tactic for measuring visual scan paths and revealing abilities that are unable to be measured directly.

Thus the present study attempts to link gaze patterns with development throughout infancy and the emergence of self-awareness. This was studied through the comparison of results of the mirror task with eye tracking patterns of self, familiar and unfamiliar faces for 12-, 18-, and 24-month-olds. Specifically, we predicted that individuals that passed the mirror task would have a unique scan pattern of their own face, in comparison to other faces. We also predicted that age would impact the scan-paths, as age interacts with self-awareness development.

Method

Participants

Fifty-one infants that were from the New York/New Jersey metropolitan region were recruited from a larger cognition and language study. Of this sample, 13 infants were excluded due to fussiness/inadequate data, ($N = 8$) or eye tracking error (i.e, failure to calibrate) ($N = 5$). A total of 38 infants (26 male and 12 female) were included in the final sample (ten 12-month-olds. 7 male and 3 female, $M = 11.39$, $SD = 0.38$), sixteen18-month-olds (9 male and 7 female, $M = 17.71$, $SD = 0.68$), and twelve 24-month-olds (10 male and 2 female, $M = 23.26$, $SD = .86$)). The majority of participants were Caucasian, nine participants were of other ethnicity (3 Asian, 2 Hispanic, 4 mixed-race). Parents were given an in-person plea, in which a research assistant inquired if they would like to participate in an additional study, before participating in either study. Parents who agreed to their infants' participation did so upon informed consent and completion of the initial cognition and language study. This study was approved by the Montclair State University IRB.

Materials

Mirror task. The mirror task was administered with a 35 cm x 35 cm stand-alone mirror positioned on a table approximately 65 cm in front of the child. A black cloth was adhered to the top of the mirror for convenient covering and uncovering of the mirror. Red odorless lipstick was used to mark the center of the infant's forehead. The infant's reaction was determined as "pass" or "fail" by two research assistants observing the task. Infants who touched the dot or pointed at the mirror stating their name were coded as "pass". (Figure 16)

All testing was recorded using two Panasonic Operating Digital Video Camcorders, model 3CCD/3DCC. The first camera recorded the participant, while the second camera recorded the mirror. Three over-head observation cameras interfacing with Intelligent Video Solutions were also used. Overhead lighting was kept consistent throughout the procedure.

Photographs. Photographs of the parent and child were taken with a 12-megapixel camera in the waiting room. Lighting was held consistent. Parents and children were asked to make a neutral expression and remove any accessories that obstructed the face such as hats or eyewear. Photographs were then imported into Photoshop and cropped to outline the face (Figure 1). Photoshop was also employed to ensure the faces were centered and rotated to align with a horizontal axis. The faces were imported into the Tobii X2-60 Studio Software to create conditions unique to each participant.

The infant's eyes were calibrated to the Tobii X2-60 using a five-point calibration system. The calibration was repeated until an accurate eye measurement was obtained. A Samsung plasma television screen (103 cm x 58 cm) was used to present the stimuli to the infant seated on their parent's lap approximately 65 cm from the table-mounted Tobii eye tracker. Television brightness and volume settings were consistent across participants.

The main independent variables were mirror self-recognition (Pass, Fail), age (12-, 18-, 24-month-old), and face type (Self, Caregiver, Unfamiliar adult, Unfamiliar baby). The primary dependent variables were scan-path, total fixation duration, and fixation count within areas of interest. To control for familiarity, unfamiliar adult and unfamiliar infant photographs of similar appearance to the self and caregiver photographs (i.e. race and gender) were used.

The order of the faces was counterbalanced; infants viewed the faces in one of four possible orders. All photographs, in each condition, were presented to the infant three times, for three seconds each, against a black background. A flashing red dot accompanied by Baby Einstein music appeared in-between the presentation of each face to maintain the infants attention and reset the infant's eyes to the center of the screen. The stimulus was presented for a total of 72 seconds. (Figure 2)

The same recording devices used during the mirror task were used during the video presentation.

Procedure

Participants initially arrived at the Cognitive and Language Development Laboratory for a language study (Data published elsewhere, For description, see Lakusta, Spinelli, & Garcia, 2017). Prior to commencing the consent procedure, this study's protocol was explained by a research assistant with an in-person-plea script. All participants were volunteers who did not receive any additional compensation. Participants did receive $10 and a prize for their child for participation in the language study at the end of their visit, which was not contingent on their involvement in the present study.

Before they began, a research assistant took two photographs of both the caregiver and the infant. While the parent completed demographic and developmental surveys for the language study in the waiting room, one research assistant returned to the testing room to edit the photos and import them into the Tobii Studio program. Participants were then escorted into the laboratory from the waiting room, where they participated in the initial language study (see: Lakusta, Spinelli, & Garcia, 2017).

Upon completion of the initial language study, participants began either the mirror task or eye-tracking task. For the duration of the mirror task, the mirror was positioned on a table in front of the child, and the mirror task was completed. The infant was shown their reflection for approximately 30 seconds for a baseline behavioral reaction, and then the mirror was covered. A research assistant maintained the infant's attention with jingling keys, while a second research assistant marked the infant's forehead. The research assistant who applied the mark simultaneously touched the infant's cheek, to distract from the feeling of the lipstick being applied. The infant was given a brief time gap of 20 seconds to ensure the infant did not notice the tactile change. Next, the cloth was removed from the mirror for 60 seconds. Infants were identified as self-recognizers if they touched the dot, attempted to wipe the mark from their forehead while looking in the mirror or immediately thereafter, or pointed at the mirror saying their name. If they did not react to their reflection after 60 seconds, parents asked, "Who is that?" or "What's different?". No infants were included that passed after verbal prompting. The mirror task was used as a baseline for self-awareness, to compare to eye tracking results.

Infants were given a break to have the mark removed with a wipe and have time to adjust prior to the start of the second task. Once they were settled, participants viewed the stimuli video containing the unfamiliar adult, unfamiliar baby, self, and caregiver faces. The infants were seated on their parent's lap as their eye gazes were recorded using the Tobii X2-60 eye tracker. Parents were asked to keep their eyes closed throughout the video to prevent eye-tracking discrepancies, and to refrain from attempting to influence the child's looking time (i.e, pointing or encouraging the child to look). The infants were instructed to look at the screen during calibration and prior to the start of the video to maintain their attention. Once the task was completed, the infants were able to pick out their prize and parents signed a receipt indicating they received their payment for the initial language study. The study was then explained in further detail and parents were given the opportunity to view their child's eye-tracking video, if so desired.

Analysis

Mirror Task

Infants needed to touch the mark, attempt to wipe the dot off of their forehead, or state their name while pointing at the mirror in order to be coded as a self-recognizer. Those who touched the mark before they saw themselves in the mirror, covered their faces with their arms, or refused to look at their reflection were not analyzed due to either fussiness or inconclusive results.

Eye Tracking

Areas of Interests (AOIs) were created for each feature (i.e, left eye, right eye, nose and mouth), and sides of the faces (i.e, top half, bottom half, left side and right side, Figure 3). Total fixation duration (duration of all fixations within an AOI) and fixation count (number of times the participant fixates on an AOI) were extracted for every AOI on each face. Looking time was standardized by creating a proportion of feature viewing time in relation to the total time spent on the entire face (Kano, & Call, 2014). Participants who did not have an accurate 5-point calibration or did not maintain a minimum of 50% looking time for at least 2 of the 3 trials for each type of face were excluded (*N* = 4).

Results

Mirror Task

In this mirror recognition task, none of infants in the 12-month-old age group (*N*=10), 50% of 18-month-olds (*N*=8), and 100% of 24-month-olds (*N*=12) passed the mirror task.

Mirror Task Performance vs. Scan-path

In order to determine the differential scan-path between self and other faces for recognizers versus non-recognizers, a chi-squared analysis was performed. The mode of each of the first four fixations across all three trials was used to create an average scan-path for non-self faces. The total number of infants with fixations that were consistent with this average scan-path for non-self faces was compared to the self-face. There was not a common scan-path so each fixation was analyzed separately. 3.88% had a pattern of nose-nose-nose-nose, 1.66% had mouth-mouth-nose-nose, and 1.66% had mouth-nose-nose-nose and 1.14% had nose-left eye-left eye-left eye. Eighteen-month-olds were separated between self-recognizers and non-self-recognizers and compared to 12- and 24-month-olds.

The common scan-path of non-self faces used for the 12-month-olds was nose-nose-nose-nose. The amount of infants who had nose for each of the first four fixations for non-self-faces was totaled (Fixation 1: 29, Fixation 2: 40, Fixation 3: 38, Fixation 4: 38) and compared to the number of 12-month-olds who used this scan path for self-face

(Fixation 1: 6, Fixation 2: 11, Fixation 3: 15, Fixation 4: 6). These totals were altered to be in relation to the total number of infants (Self: 29, Non-self: 88), and analyzed using a chi squared comparison. (Fixation1: x^2 (1, N = 117) = 5.99, p = .0143, Fixation 2: x^2 (1, N = 117) = 2.009, p = .156, Fixation 3: x^2 (1, N = 117) = 2.617, p = .106, Fixation 4: x^2 (1, N = 117) = 18.145, p < .001) The 12-month-olds showed evidence of a significant difference for the first and fourth fixations only, the first fixation being marginally significant.

Eighteen-month-olds who were not self-recognizers used the common non-self scan-path of mouth-nose-nose-left eye. Total number of infants that had these fixations for non-self faces (Fixation 1: 18, Fixation 2: 26, Fixation 3: 20, Fixation 4: 21) was compared to the total of 18-month-old non-recognizers with these fixations for the self-face (Fixation 1: 5, Fixation 2: 6, Fixation 3: 5, Fixation 4: 6) and calculated in relation to the total number of infants observed (Self: 22, Non-self: 69). A chi-squared comparison was performed to determine if there was a significant difference in the number of infants using this pattern for self versus non-self faces (Fixation1: x^2 (1, N = 94) = .404, p = .666, Fixation 2: x^2 (1, N = 94) = 3.183, p = .118, Fixation 3: x^2 (1, N = 94) = 1.314, p = .343, Fixation 4: x^2 (1, N = 94) = .326, p = .737). There were not any significant differences in the four fixations between scan-paths of self and other faces.

Eighteen-month-olds who were deemed recognizers, as per mirror task results, had a common non-self scan-path of nose-nose-left eye-left eye. The amount of times these fixations were used for non-self faces (Fixation 1: 28, Fixation 2: 19, Fixation 3: 30, Fixation 4: 24) was observed in comparison to frequency when viewing self-face (Fixation 1: 6, Fixation 2: 10, Fixation 3: 6, Fixation 4: 4). These were placed in relation to the total number of infants viewing the stimuli (Self: 22, Non-self: 69). When presenting these differences in a chi-squared test of the self and non-self scan-paths, all four fixations provided evidence of a strong significant difference. (Fixation1: x^2 (1, N = 94) = 5.067, p = .042, Fixation 2: x^2 (1, N = 94) = 12.85, p < .001, Fixation 3: x^2 (1, N = 94) = 17.967, p < .001, Fixation 4: x^2 (1, N = 94) = 19.457, p < .001). Eighteen-month-olds who were self-recognizers had a significantly higher amount of infants with the non-self common scan path for non-self-faces than for self-faces.

These tests were also used for the 24-month-old age group. The total number of infants (Self: 32, Non-self: 105), with the common non-self scan-path of nose-nose-nose-nose, was determined for self-faces (Fixation 1: 10, Fixation 2: 16, Fixation 3: 15, Fixation 4: 11) and non-self faces (Fixation 1: 43, Fixation 2: 39, Fixation 3: 33, Fixation 4: 35). Using a chi-squared comparison, the difference between infants with this pattern for self and non-self faces was tested for significance (Fixation1: x^2 (1, N = 137) = 4.088, p = .043, Fixation 2: x^2 (1, N = 137) = 7.434, p = .006, Fixation 3: x^2 (1, N = 137) = 11.625, p < .001, Fixation 4: x^2 (1, N = 137) = .051, p = .821). Three out of these four fixations present a strong significant difference between the infants who use the common scan-path for the self and non-self faces.

Across the majority of the first four fixations, those who passed the self-awareness task (50% of 18-month-olds and 100% of the 24-month-olds) had consistently different scan-paths of their own face in comparison to those who did not pass the mirror task. The 12-month-olds had a significant difference between self and other faces for only 50% of the first four fixations and none of the 18-month-old non-recognizers showed evidence of a significant difference between self and non-self scan-paths.

Age vs. Eyes.

A 3 x 4 ANOVA was utilized to determine if there was a significant difference between age and time spent on each AOI. This revealed a significant main effect between age groups for multiple features across all face types. All fixation times were divided by the time spent on the whole face to standardize results.

The mean total fixation duration of the left eye across all face types (Figure 5) varied significantly between age groups ($F\ (2{,}140) = 14.776$, $p < .001$, $r^2 = .191$). LSD multiple comparison revealed that the 18-month-olds maintained higher fixation times on the left eye than the 12-month-olds ($p < .001$) and 24-month-olds ($p < .001$). The 12-month-olds (M = 137.446, SD = 160.713) and 24-month-olds (M =100.422, SD = 135.615) had significantly lower fixation duration than the 18-month-olds (M = 274.234, SD = 207.498).

Observing the mean total fixation duration of the right eye, ($F\ (2{,}140) = .395$, $p = .675$, $r^2 = .045$) and the mean fixation count of the right eye, ($F\ (2{,}140) = .111$, p = .895, $r^2 = .022$) presented insignificant results. There was no significant difference when observing looking times of the right eye in relation to age.

The 18-month-olds overall have an increased mean total fixation duration of both eyes ($F\ (2{,}140) = 5.6$, $p = .005$, $r^2 = .107$) (Figure 6). This illuminated additional evidence of significant variation between 18-month-olds and the alternative age groups via LSD multiple comparison (12-month-olds ($p = .012$) and 24-month-olds ($p = .003$)). When comparing means, the 18-month-olds (M = 427.049, SD = 477.901) possessed uniquely high fixation duration from the 12- (M = 239.842, SD = 218.657) and 24-month-olds (M = 218.013, SD = 251.420).

The analysis of fixation count for the left eye revealed a similar dissimilarity between age groups (F (2,140) = 10. 2, p < .001, r^2 = .152). 12- (p = .001) and 24- (p < .001) month-olds fixation counts receded in comparison to 18-month-olds (Figure 12). With similarly low fixation counts, 12- (M = .134, SD = .154) and 24- (M = .113, SD = .152) month-olds were unrelated to the 18-month-olds (M = .246, SD = .181).

Mean fixation counts of both eyes followed this trend (F (2,140) = 5.987, p = .003 r^2 = .095), with LSD multiple comparison uncovering significance between 12- and 18- month-olds (p = .008), in addition to 24- and 18-month-olds (p = .003) (Figure 13). The 12- (M = .234, SD = .204) and 24- (M = .224, SD = .238) month-olds exhibit significantly less fixations than 18-month-olds.

Age vs. Nose and Mouth.

A 3x4 ANOVA was performed to determine if these different looking times were also consistent with the lower-features of the face. The mean total fixation duration of the nose presented a significant difference, (F (2,140) = 6.791, p = .015, r^2 = .076), (Figure 7) the LSD multiple comparison displaying a substantial difference between 12- and 18-month-olds (p = .004). The nose was the only feature in which the 12- (M = 401.797, SD = 232.667) and 24- (M = 336.035, SD = 264.785) –month-olds had increased fixation time in comparison to 18-month-olds (M = 254.400, SD = 243.749). This difference did not appear for fixation count of the nose (F (2,140) = 2.823, p = .063, r^2 = .072).

Similarly, the total fixation duration of the mouth presented a main effect for age, (F (2,140) = 4.047, p = .02, r^2 = .086), (Figure 8) and an LSD multiple comparison identified the time disparities between 18-month-olds and 24-month-olds as significant (p

= .006). Only the 24-month-olds (M = 108.102, SD = 121.886) presented a significant increased fixation duration in comparison to the 18-month-olds (M = 196.464, SD = 181.113). Despite the lack of significance, the 12-month-olds (M = 175.17, SD = 176.627) decreased means indicate they are trending in the direction of the 24-month-olds. The fixation count of the mouth had no indication of a difference according to age (F (2,140) = .466, p = .629, r^2 = .037). Generally, across all features except the nose, 18-month-olds have an increased fixation duration and fixation count in comparison to the 12- and 24-month-olds.

Age vs. Proportions

To see if there was a difference in scan-patterns pertaining to regions of the face, the face was separated into four proportions, the left, right, top, and bottom halves. These proportions revealed a main effect for the mean total fixation duration on the top half of the face (F (2,140) = 5.709, p = .004, r^2 = .142), (Figure 9). In post-hoc tests, a LSD multiple comparison revealed the difference between 18-month-olds and both of the other age groups. (p = .005). Presenting increased fixation duration from the 12- (M = 332.829, SD = 277.726) and 24- (M = 344.958, SD = 293.337) month-olds, the 18-month-old age group (M = 547.382, SD = 475.982) displayed another unique factor in their face processing techniques.

The mean fixation count within the top half of the face was subject to a 3 x 4 ANOVA as well, and significance was identified, (F (2,140) = 6.340, p = .002, r^2 = .160) (Figure 11) specifically between 18-month-olds in comparison to the 12- (p = .003) and 24- (p = .005) month-old groups also recognized through LSD testing. This was further evidence of the separation between 18-month-olds (M = .51, SD = .307) and the other age groups. The 12- (M = .338, SD = .256) and 24- (M = .357, SD = .266) month-olds had a decreased number of fixations within the top half of the face, in relation to the 18-month-olds.

While there was not a significant difference between age and total fixation duration of the bottom half of the face (F (2,140) = 1.279, p = .282, r^2 = .059), there was for fixation count. After analyzing the mean fixation count of the bottom half of the face, a significant disparity was discovered (F (2,140) = 3.052, p = .05, r^2 = .132), identifies significance between 12- and 18-month-olds (p = .018) (Figure 14). The trend indicates the 24-month-olds are moving towards a significant difference from the 18-month-olds. The 18-month-olds (M = .525, SD = .302) had a reduced quantity of fixations in comparison to both 12- (M = .648, SD = .276) and 24- (M = .614, SD = .408) month-olds.

An ANOVA was performed on the left and right halves of the faces, to determine if the lateral preference of fixations was altered by age. Both total fixation duration of the left (F (2, 140) = 2.824, p = .063, r^2 = .064) and mean fixation count of the left (F (2,140) = 1.408, p = .248, r^2 = .058) presented no significant differences. Similarly, the right side of the face did not reveal any significant distinctions for total fixation duration (F(2,140) = 1.741, p = .179, r^2 = .060) or fixation count (F(2,140) = 1.699, p = .187, r^2 = .050). Overall, side of the face did not alter with age.

These varied patterns between age groups existed across all four types of faces presented, and the trends suggested the most extreme difference is emerging in the self-face scan-paths. While not all of the features and proportions presented significant results, trends for all features and proportions suggested 18-month-olds process faces in a contrasting method to other age groups. The 18-month-olds paying increased attention to upper-features and the mouth while the 12- and 24-month-olds focus mainly on the nose and the bottom-half of the face.

Discussion

The mirror task behavioral responses were consistent with results from Gallup (1979) and Stapel et al. (2016). The present evidence suggests that as per mirror task standards, 12-month-olds do not possess self-awareness, 50% of 18-month-olds are self-aware, and by 24-months of age infants have achieved self-awareness.

The present study's results give further support to findings by Gallup (1979), that mirror recognition is an accurate measure of self-awareness capabilities. Eye tracking results of the self and other faces compared to mirror task results indicated differential face scanning tactics of self and other faces for those who possessed self-awareness abilities. Eighteen-month-old and 24-month-old recognizers were altering their patterns between self and other faces consistently across the majority of trials. Further research should compare face-scanning patterns across age groups within-subjects to confirm these results.

The present study also revealed evidence that face scan-paths alter throughout infancy, which corroborates studies showing that face processing abilities change over time (Bronson, 1994; Hainline, 1978). Evidence was found in support of Maurer & Salapatek, 1979 that infants focus on inner-features and the central region of the face. In addition, the present study supports the concept that 18 month-olds are at a distinct period of development, (Bertenthal & Fischer, 1978; Nielsen & Dissanayake, 2004; Stapel et al.,

2016) revealing 18-month-olds unique scan-paths in comparison to 12- and 24-month-olds. This suggests a strong relationship between age and facial processing abilities.

Our findings do not align with Stapel et al. (2016) findings that 18-month-olds have unique brain scans of their own face, regardless of mirror task performance. Our results posit that there is an alteration in gaze between recognizers and non-recognizers. These ideas present evidence that mirror-task might be an indication of complete mastery of self-awareness. However, there may be unique brain activity as infants are beginning to process their own face as different, even if they are not consciously aware, thus presenting a stepping-stone to self-awareness. Unique brain scans found by Stapel et al. (2016), in conjunction with the unique gaze patterns of 18-month-olds discovered in the present study, establish implications of 18-month-olds are in a unique stage of learning and thus, are processing information differently than other age groups.

On average, 18-month-olds express increased interest in the eyes, mouth, and top half of the face, while 12- and 24-month-olds allot increased attention to the nose and bottom half of the face. This was consistent across each type of face for both total fixation duration as well as fixation count. Previous research has indicated evidence of the eyes and mouth being important features for emotion processing, identification and overall having a higher level of social importance (Birmingham, Bischof & Kingstone, 2008; Wegrzyn, Vogt, Kireclioglu, Schneider & Kissler, 2017). The nose, and bottom half of the face, areas of the face of lesser importance in processing, consume the majority of 12- and 24-month-olds focus, while the more expressive and influential aspects of the face receive concentrated attention from the 18-month-olds.

Utilizing the mode of the first four fixations of each trial, an average scan-path was uncovered, (Figure 15) displaying 18-month-olds increased pattern variation and attention to upper features. On average 18-month-olds present a tendency to visit an increased number of features, unlike the other age groups, covering a higher percentage of face-area. For example, 12-month-olds typically in their first four fixations only look at the nose and mouth, 18-month-olds observe the left eye, nose, mouth and right eye, and 24-month-olds attend to the nose.

It is proposed that 12- and 24-month-olds are confident in their comprehension of faces. 12-month-olds are not developed enough to attempt to understand, while 24-month-olds are confident in their capability to recognize their own faces. Eighteen-month-olds are more interested in the faces because they have begun to understand, and have increased interest in the faces. It is exciting and intriguing to the 18-month-olds, as it is new information that finally makes sense to them.

The different scan-paths between self and other faces by self-recognizers provide support for our hypothesis that there is an alteration in the scan-path of self-faces that enable infants to begin to self-recognize. There is less attention focused on the nose, and more attention on more salient features, like the eyes and mouth, when recognizers are viewing the self-face. Scan-paths of non-self faces place an increased emphasis on the nose and less prominent aspects of the face. Similar to the 18-month-olds overall having an attention to the eyes and mouth due to interest and comprehension, recognizers appear to have a similar increased attention on self-faces. 18-month-olds and 24-month-olds, in order to identify the faces, especially their own face, need to have an altered scan-path of the self-face. 18-month-olds have a unique scan-path relative to other age groups and furthermore, recognizers view self and other faces in an increasingly different manner. This provides significant evidence that and the mirror task is an accurate measure of self-awareness and overall 18-month-olds are at a precarious time in infancy.

The present study uses a liberal coding scheme to analyze the eye tracking data. Areas of interest were generous, encompassing the immediate area around each feature (see figure 3). From the perspective of an infant it is unknown what exact areas constitute as part of each feature. For example, this study included the eye socket within the operational definition of the eye, but infants may only believe the cornea or the eye itself constitutes as the eye. Future studies should address the differential definition of features between adults and infants.

This study utilizes 2-dimensional still photographs of faces. Results may vary if 3-dimensional or live faces are used in future studies. If features are moving, gaze patterns may vary. Infants perceive inanimate and animate images differently, and therefore may process live faces and photographs with unique visual scan paths. Further examinations should compare scan-paths of 2-D, 3-D and live images.

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Figures

Figure 1 Sample faces used for eye-tracking stimuli.

Figure 2 Trial outline.

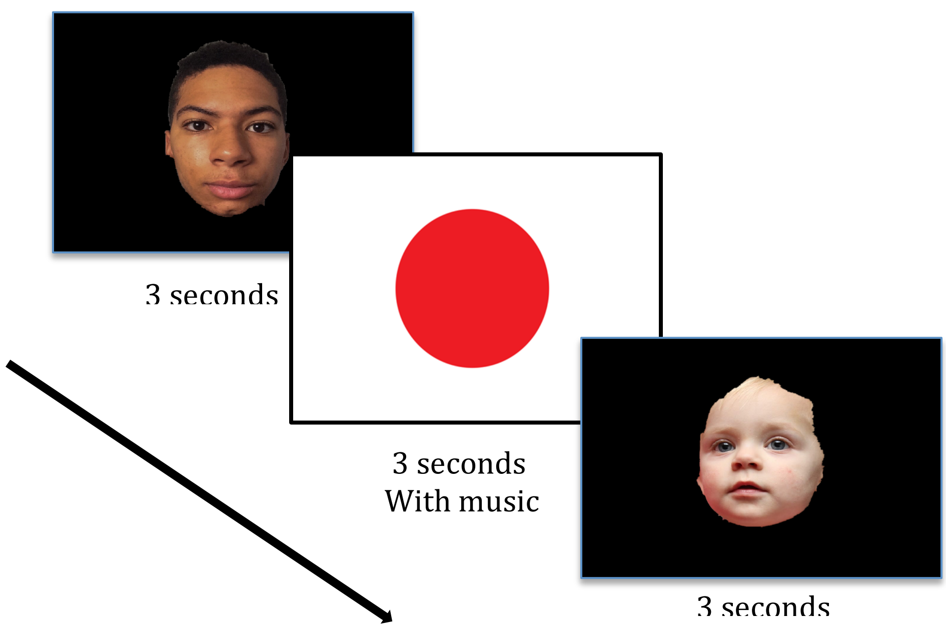


Figure 3 Areas of Interest

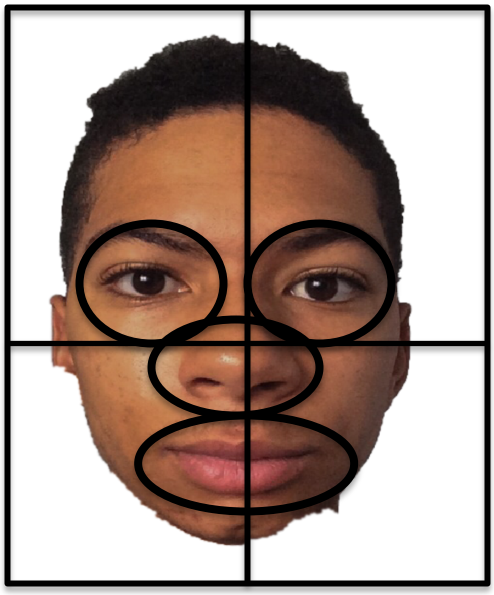


Figure 4 Overlay of participant's scan-paths.

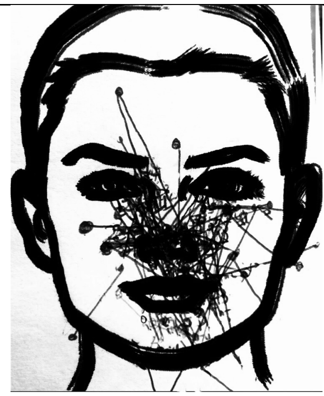
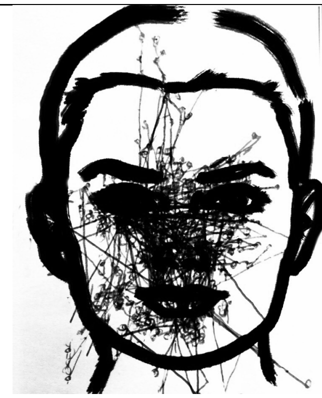
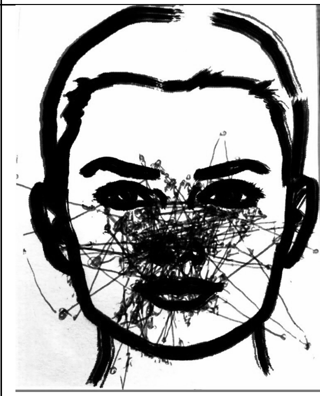
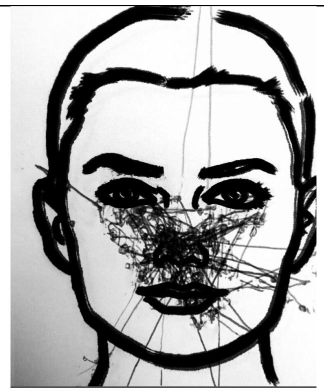
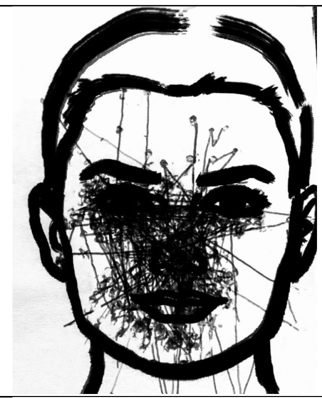
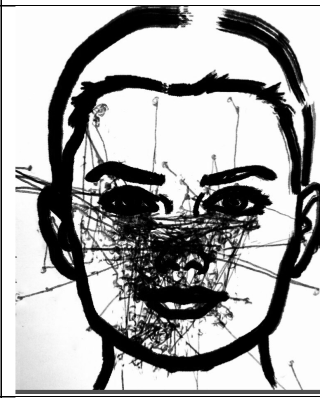
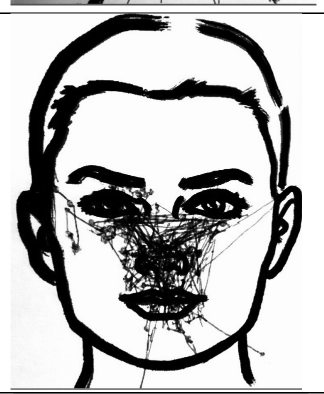
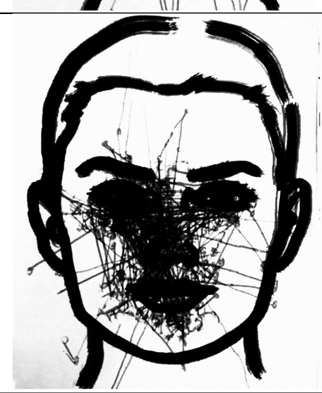
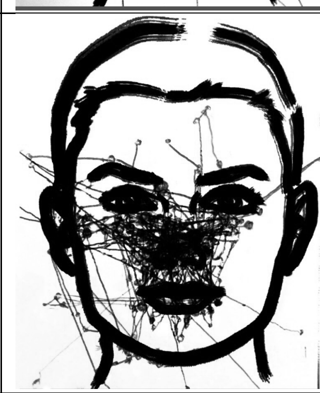
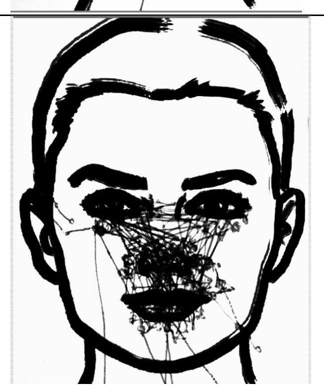
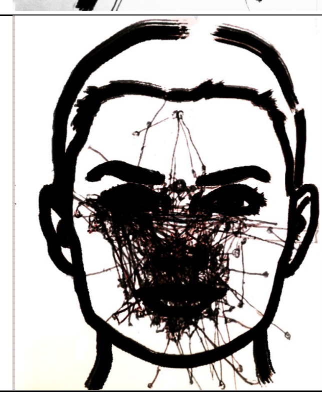
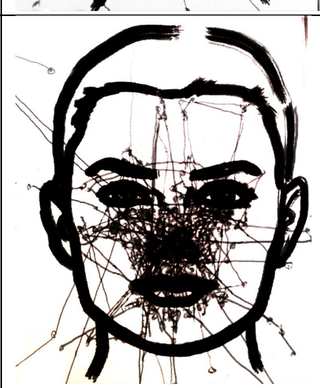
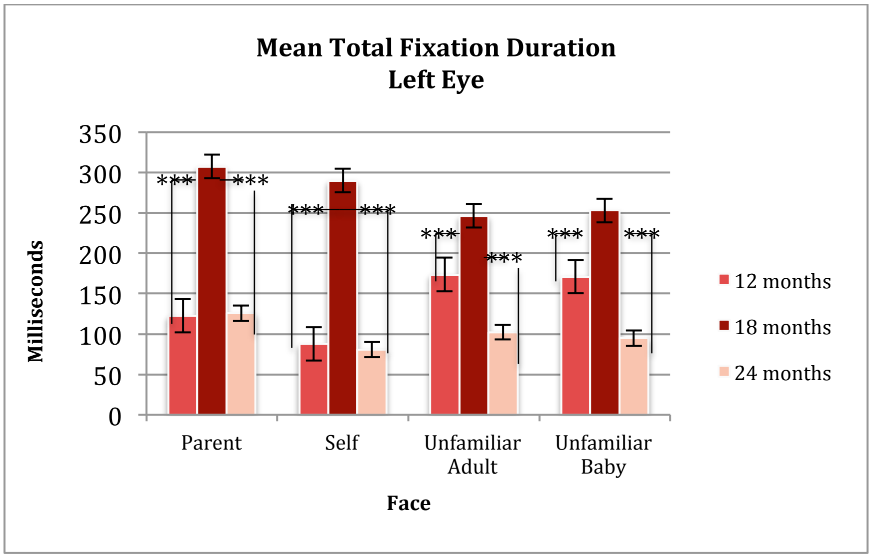
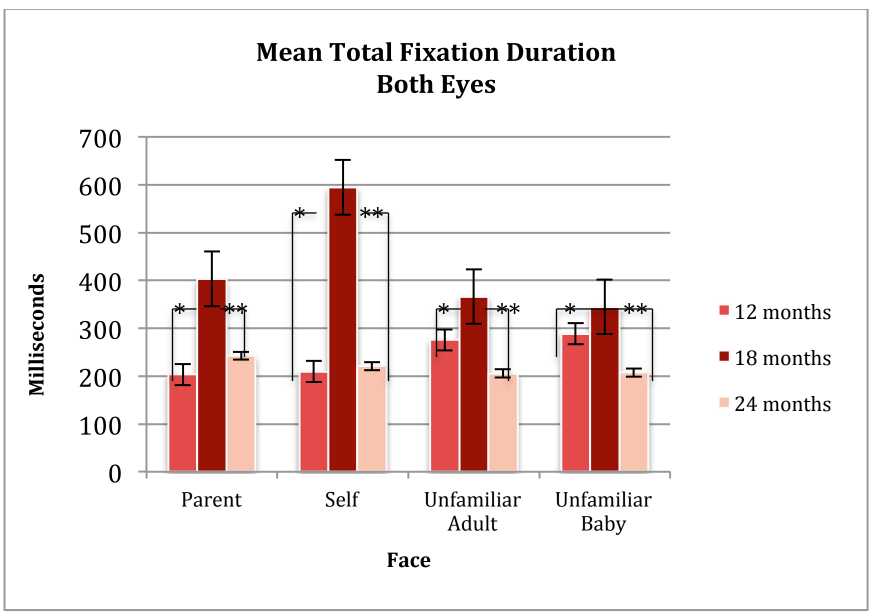
Face	**12-month-olds**	**18-month-olds**	**24-month-olds**
Self			
Parent			
Unfamiliar Adult			
Unfamiliar Baby			

Figure 5 Comparison between the mean total fixation duration of the left eye and age.



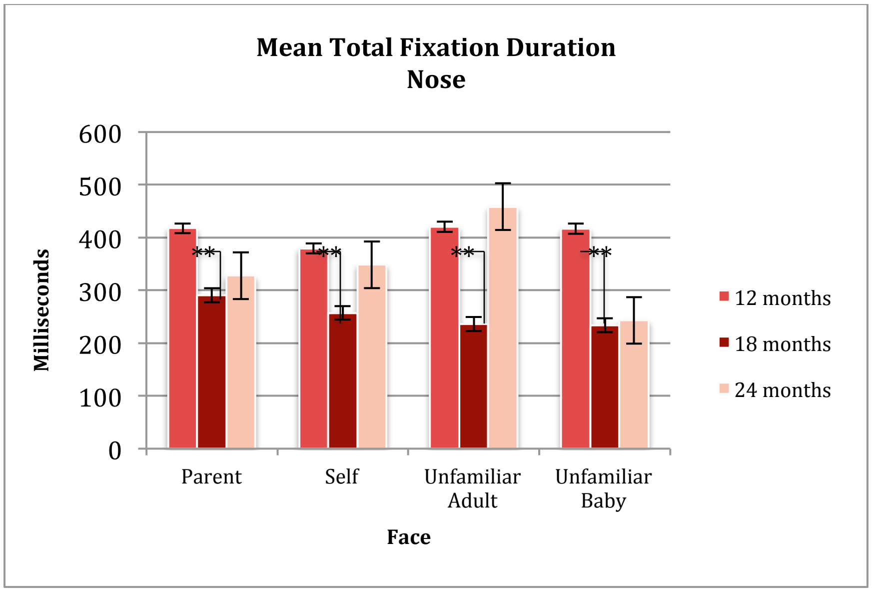
*p<.03, **p<.01, ***p<.001

Figure 6 Comparison between the mean total fixation duration of the both eyes and age.



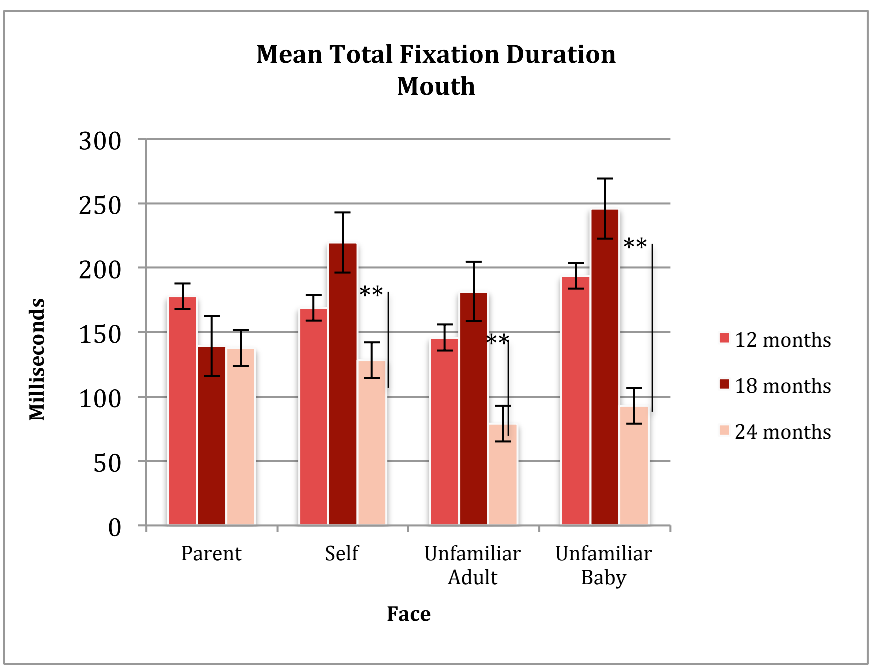
*p<.03, **p<.01, ***p<.001

Figure 7 Comparison between the mean total fixation duration of the nose and age.



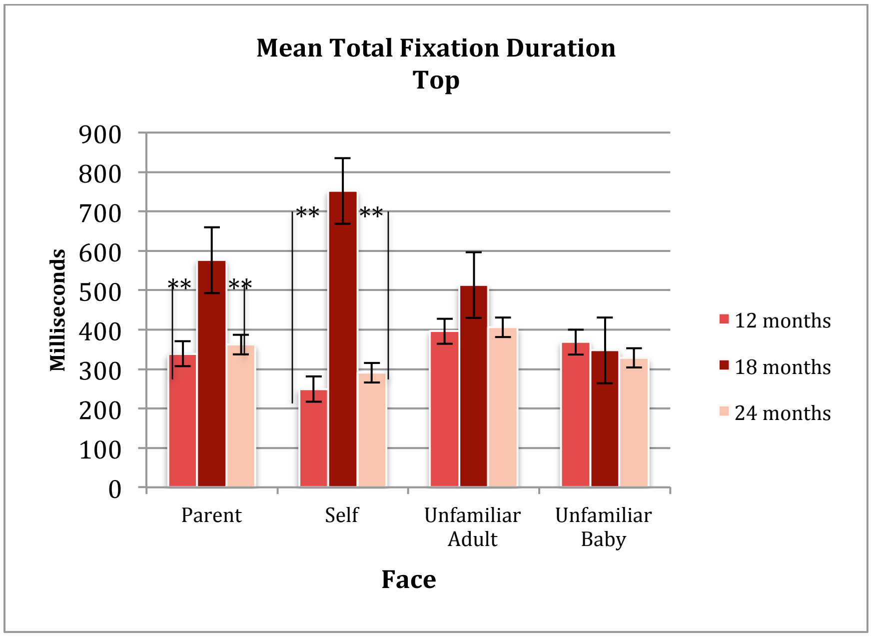
*$p<.03$, **$p<.01$, ***$p<.001$

Figure 8 Comparison between the mean total fixation duration of the mouth and age.



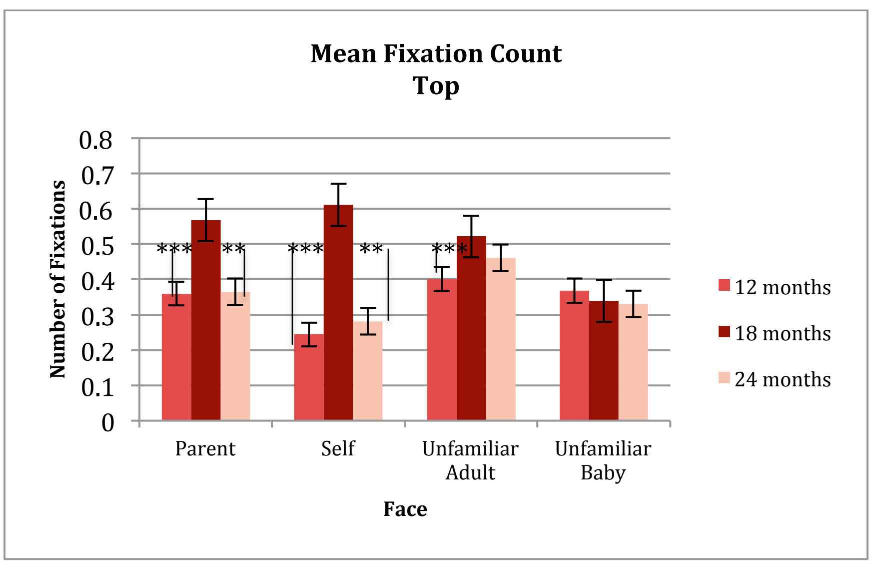
*$p<.03$, **$p<.01$, ***$p<.001$

Figure 9 Comparison between the mean total fixation duration of the top half of the face and age.



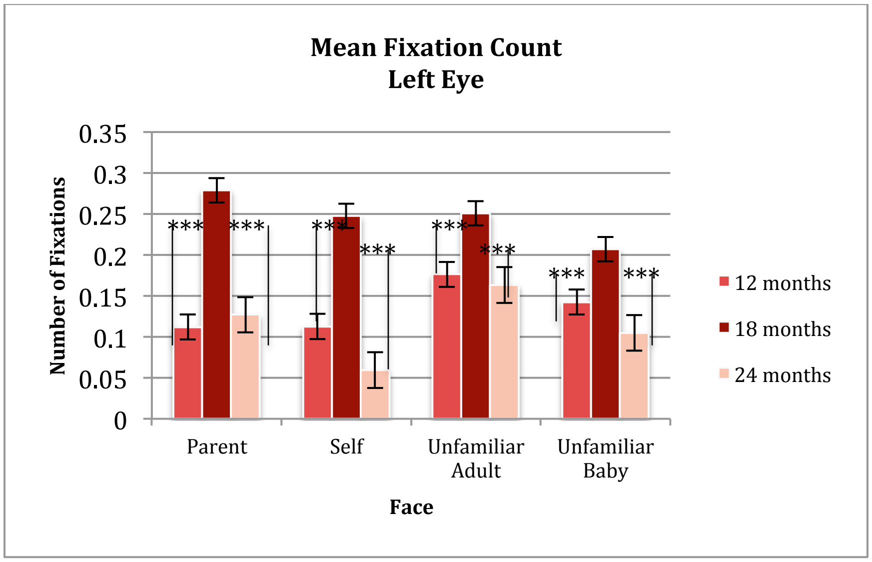
*p<.03, **p<.01, ***p<.001

Figure 11 Comparison between the mean fixation count of the top half of the face and age.



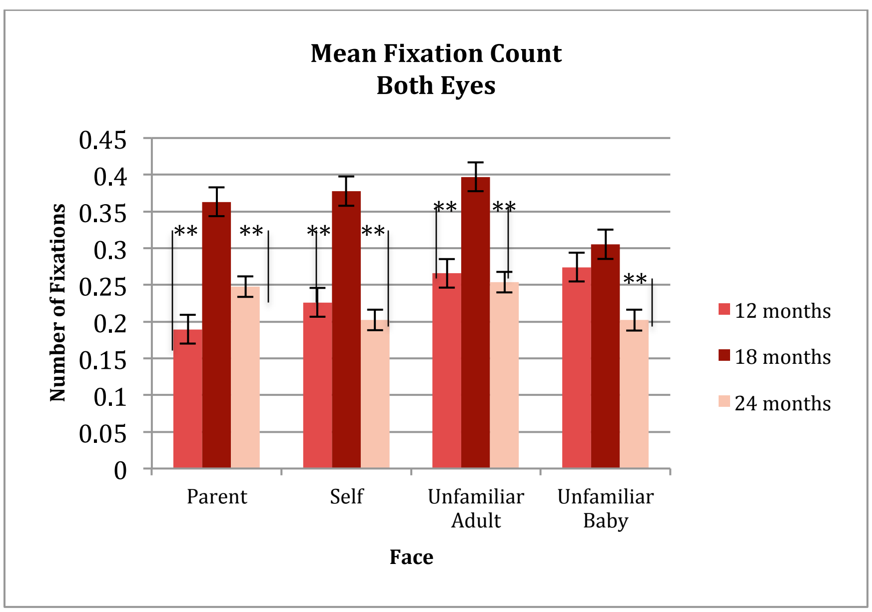
*p<.03, **p<.01, ***p<.001

Figure 12 Comparison between the mean fixation count of the left eye and age.



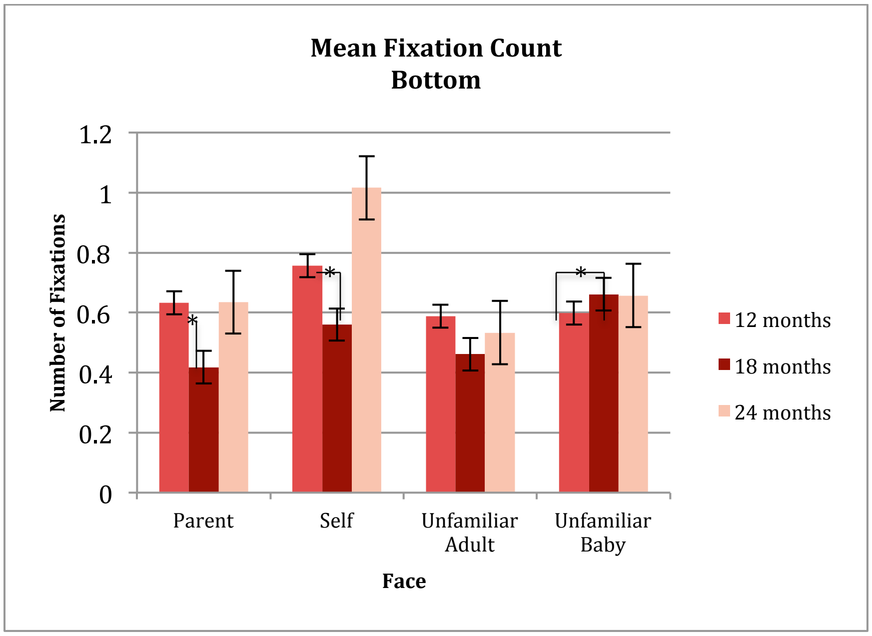
*p<.03, **p<.01, ***p<.001

Figure 13 Comparison between the mean fixation count of both eyes and age.



*p<.03, **p<.01, ***p<.001

Figure 14 Comparison between the mean fixation count of the bottom half of the face and age.



**p*<.03, ***p*<.01, ****p*<.001

Figure 15 Average scan-paths for 12-, 18-, and 24-month-olds.

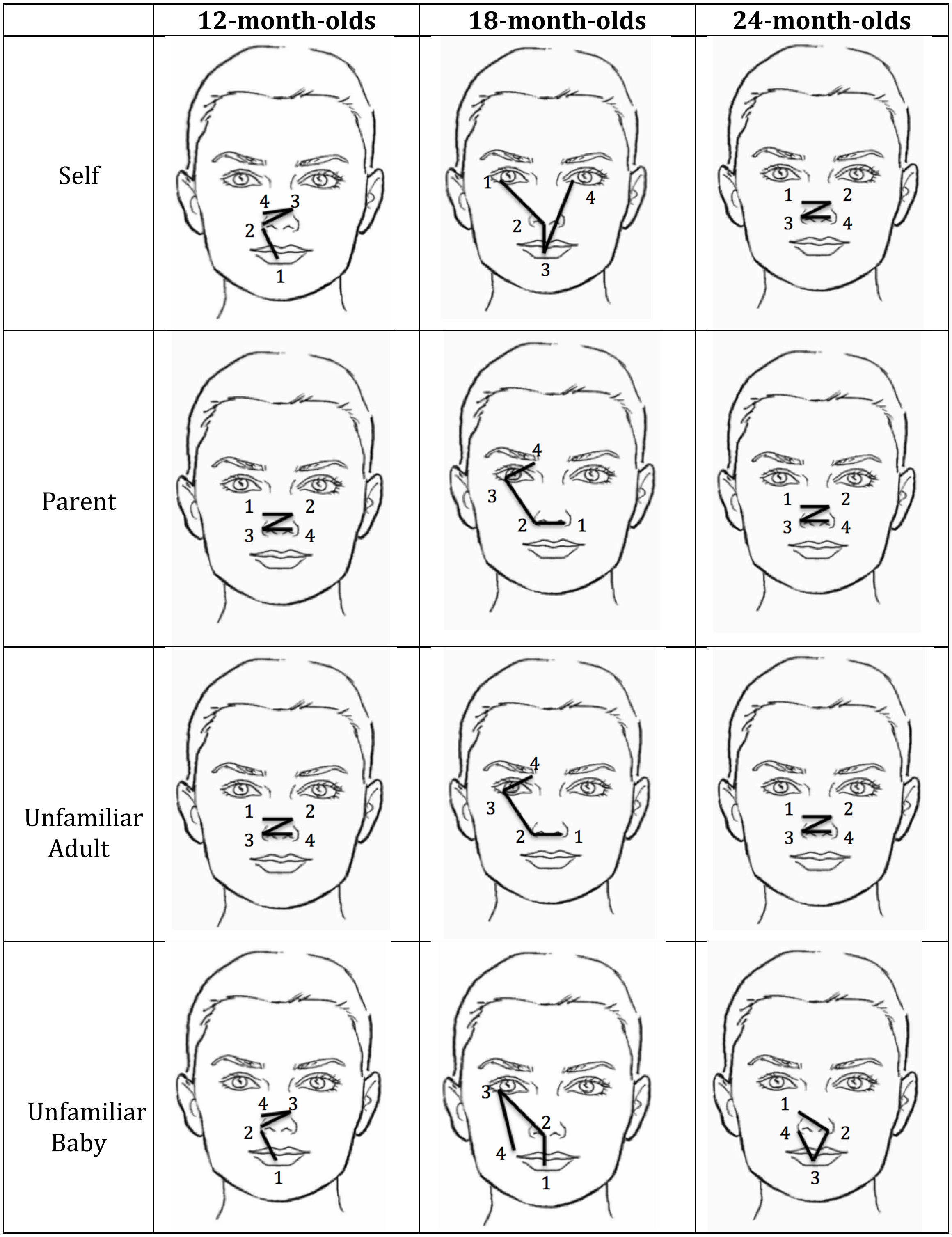


Figure 16 Example of infant passing the mirror task.