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Infants' Visual Processing of Faces and Objects: Age-Related Changes in Interest, and Stability of Individual Differences

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Abstract

Longitudinal measures of infant visual processing of faces and objects were collected from a sample of healthy infants ($N=40$) every month from 6 to 9 months of age. Infants performed two habituation tasks each month, one with novel female faces as stimuli, and another with novel complex objects. Different individual faces and objects served as habituation (i.e., visual learning) and dishabituation (i.e., novelty response) stimuli. Measures included overall looking time to the habituation stimuli, slope of habituation, and recovery to the dishabituation stimuli. Infants were more interested in faces than objects, but this was contextualized by task order. The order effect suggests a “habituation of habituation” effect. Infants showed an age-related decrease in interest in objects, but no decrease in interest in faces. This contradicts claims that infants shift around 6-7 months from interest in faces to interest in objects. The results showed modest between-month stability of interest in faces, but little stability in any other behavioral measures. This implies that habituation is driven more by unexplained subject \times session \times stimulus variance than by “infant IQ.”

Keywords: Infant habituation; face processing; longitudinal studies; object perception; infant cognition; stimulus effects; visual preferences.

Introduction

Visual stimulus processing in infants is typically studied in a habituation paradigm. An infant is presented with a stimulus repeatedly until she or he habituates (i.e., meets some criterion of diminished looking time). A novel stimulus is then presented. If the new stimulus is perceived as different, the infant increases the duration of looking at the stimulus. This paradigm is a robust, reliable way to assess visual discrimination in the first year (Fagan, 1970; Fantz, 1964).

Habituation is used to assess more than stimulus discrimination. Psychologists commonly use habituation to estimate infants' cognitive capacity. Total looking time, or longest look to a stimulus, are considered inversely related to cognitive efficiency (Bornstein, Pêcheux, & Lécuyer, 1988). Whereas processing speed in children and adults is used as a proxy for overall cognitive efficiency (Salthouse, 1996), there is no analogous measure of cognitive speed in infants. Thus, speed of habituation is taken to indicate how

quickly infants process a stimulus. Also, dishabituation might relate to infants' interest in novelty, which might reflect curiosity. These ideas are bolstered by findings that infant habituation predicts later cognitive skills. For example, Thomson, Faulkner, and Fagan (1991) found a correlation between infants' novelty preference and Bayley Scales of Infant Development scores (BSID, a standardized test of cognitive, language, and social skills) at 12 and 24 months of age. Also, a meta-analysis by McCall and Carriger (1993) showed a consistent relation between habituation in the first year and IQ from 1 to 8 years. Thus, there is correlational evidence of a relation between infant habituation speed and later cognitive performance.

If this correlation is the result of some broad factor such as cognitive efficiency, we might expect individual infants to show consistent habituation speed (relative to their cohort) across time and task. However, few studies have tested longitudinal stability of habituation. In one study of infants at 3, 4, 7, and 9 months, the strongest long-term stability was found in longest-look (i.e., peak) duration (Colombo, Mitchell, O'Brien, & Hotowitz, 1987). However, cross-age stability was modest. Also, Bornstein and Suess (2000) found low stability of total looking time over several months. Thus, it is unclear how stable individual infant's rate of habituation is.

A complication in addressing this question is that infants might habituate differently to different stimuli (Arteberry & Bornstein, 2002). For example, infants like to look at high-contrast, colorful, moderately complex objects (e.g., baby toys) (Fantz, 1964). They also like to look at faces (Johnson, Dziurawiec, Ellis, & Morton, 1991). However, it is not clear whether infants like to examine pictures of objects and faces to the same degree, or prefer one to the other. If the latter is true, we do not know how uniform these preferences might be across infants. For instance, children with autism spectrum disorder spend less time looking at faces than age-matched controls (Hutt & Ounsted, 1966). Perhaps some children are relatively faster to habituate to only one kind of stimulus (e.g., faces) but not the other. A related question is, how stable are individual differences in preferences? Does an infant who strongly prefers faces show a long-lived face-preference in looking time?

The answers to these questions will affect how we interpret infant habituation. If habituation is an index of individual differences in cognitive speed, we should find consistent performance from month to month. We might also find consistency in dishabituation (akin to curiosity or attraction to novelty). However, there is no guarantee of stability across different classes of stimuli. For example, perhaps infants show stable processing time (or interest) for faces, but no month-to-month consistency in looking times to objects. Thus, one of our goals was to address how infants' stable or changeable interests or preferences impact their information-processing speed.

Method

Participants

Forty healthy infants (18 girls, 22 boys) were recruited between three to four months of age to participate longitudinally at six months (mean age = 188 days), seven months (mean age = 219 days), eight months (mean age = 249 days), and nine months (mean age = 278 days). Each monthly visit was scheduled within a 10-day window based on the child's birthday. Infants were recruited through announcements and flyers at local hospitals, and visits and flyers at mother-infant recreational groups and infant play groups in San Diego, CA. Infants and parents were of middle-class socioeconomic level; 88% were white and 12% were of African American, Asian American or Hispanic descent. Parents' mean age was 32.4 years and mean education was 16.6 years. Recruitment and testing procedures were approved by the UCSD Human Research Participants Protection committee.

Stimulus and Apparatus

Pictures of 8 faces and 8 objects were used as habituation and dishabituation stimuli. Faces were taken from the Computer Vision Center's AR Face Database (Martinez & Benavente, 1998). We selected faces of young women of apparent Euro-American ethnicity, with mildly pleasant expressions but not full smiles. Lighting, angle, image size, and image resolution are all controlled in the database. All faces are photographed in front of a light background and are stripped of salient non-facial objects like large jewelry or eyeglasses. (See Figure 1.)

Object stimuli were pictures of unfamiliar geometric objects. All objects were colorful and had similar levels of detail. (See Figure 2.) A group of parents had rated a large set of candidate object pictures for familiarity and attractiveness to infants. Low-familiarity but attractive objects were chosen based on these results. All objects were photographed on a white background.

Different face and object stimuli were presented at each testing session. The stimuli were projected onto a white screen, and measured 30.5cm^2 . The room lights were kept low while the infant and parent were seated and prepared for testing; the light was gradually dimmed to near-darkness for the test session. Infants requiring postural

support sat in a Bumbo® placed on the caregivers lap. Caregivers wore shaded glasses and earphones playing music so that they could not see the pictures or hear infants' vocal reaction. A Cannon GL camera placed directly in front of infants was used to capture a zoomed-in frontal view of infants' faces. (See Figure 3.)

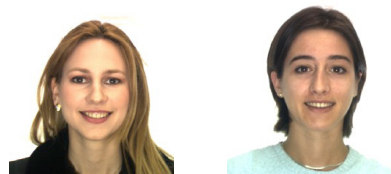


Figure 1: Example of habituation and novel face stimuli (from Martinez & Benavente, 1998)

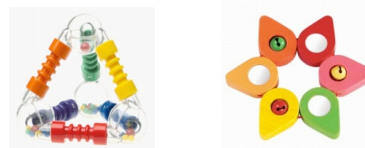


Figure 2: Example of habituation and novel object stimuli



Figure 3: Infant participant orienting attentively to stimulus image. Even though infant has shifted away from the center of the camera field and twisted her body, the stimulus image is clearly reflected (as a white box) in the center of her cornea.

Design and Procedure

During each visit infants performed two habituation tasks. At 6 and 8 months object-habituation was the first task and face-habituation was the second task (see Figure 1 and 2). At 7 and 9 months face-habituation was the first task and object-habituation was the second task.

Parents were seated 91 cm from the projector screen and instructed to secure the infant on their lap. The experimenter then placed the earphones and glasses on the parent and exited. Another experimenter (E2) in an adjacent room then darkened the room and began the task.

Training and Coding. E2 watched the infant's face from a monitor in the control room, and recorded the infants' fixations and look aways. E2 was trained extensively to record infant looking by watching previously taped habituation sessions, until a high accuracy criterion was

attained. E2 watched for white squares reflected on infants' corneas; these are reflections of the stimulus that are centered on the cornea when the infant looks at the stimuli. E2 depressed a button whenever an infant was looking, and released the button when the infant looked away or most of the stimulus square was outside of the pupil.

To calculate reliability, 15% randomly chosen sessions were coded frame-by-frame off-line. A different coder found the first and last frames for the fixation in each trial. Correlations between online and offline coding were $r = .998$ ($p < .01$) for peak looking times, and $r = .995$ ($p < .01$) for total looking time to the habituation stimulus.

Task and Trials For each habituation task, infants were presented with one stimulus for a maximum of 12 trials. Custom software (InfAttend) tracked the looking time on each trial while E2 depressed the button, and ended when the button had been released (i.e., look-away periods) for 1 s. The program then imposed a 1 sec ISI and advanced to the next presentation. The presentation automatically ended if the infant looked for 20 sec. Habituation was monitored automatically: when looking duration of the last two trials averaged less than 50% of the mean of the two peak (i.e., longest) trials, the next trial presented the novel (dishabituation) stimulus.

After the first task was completed, the infant and parent took a 1-3 min break to have a snack or drink, or diaper change, so they would be comfortable for the second task.

When infants participated at 6 months they had already been to the lab twice to participate in other cognitive tests, including habituation. Thus, in every session infants were already familiar with laboratory settings and personnel, procedures in the testing room, and even habituation tests. Thus, task or setting familiarity cannot explain age differences. Also, infants saw different stimuli in each session, so stimulus novelty was constant across sessions.

Measures

Several habituation measures were calculated for both tasks (i.e., object; face): looking durations on each trial, and total looking time until habituation; number of trials to habituate (i.e., slope); and peak looking duration. Novelty response was calculated as looking time to the dishabituation stimulus, compared to the mean of the two shortest looking times to the habituation stimulus.

Results

Stimulus Type Effects

Infants were more interested in faces than in objects. Although this difference was mediated by an interaction with order (see below), the face preference was reflected in total looking time (Figure 4). To show this we examined total looking time in a 4 (Age) X 2 (Stimulus) MANOVA. The multivariate age effect was not significant, $F(3, 12) = 1.24$, $p = .337$. However, the effect of Stimulus was,

$F(1,14) = 6.60$, $p = .022$ ($\eta^2 = .32$), as was the Age X Stimulus interaction, $F(3,12) = 4.45$, $p = .025$ ($\eta^2 = .53$).

Within-subjects contrasts reveal a cubic age X stimulus effect, $F(1,14) = 12.00$, $p = .004$ ($\eta^2 = .46$), related to the order-related interaction described below.

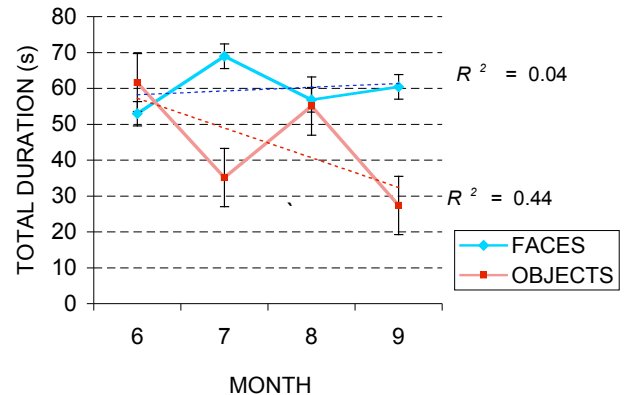


Figure 4: Infants' looking time to faces and objects at each month. Note that presentation order reversed monthly; this explains the oscillation across months of looking times to objects. Bars = SE. Best-fitting linear regression lines are shown for each stimulus, with R^2 indicating the age effect for each stimulus type. Note the significant age-related trend of declining attention to objects.

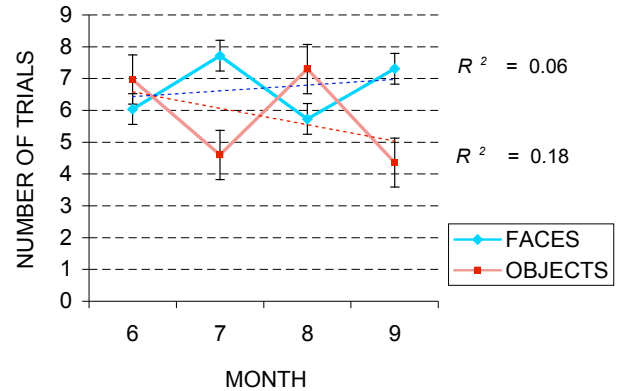


Figure 5: Trials to habituate to faces and objects, by age. Bars = SE. Best-fitting linear regression lines are shown with R^2 indicating the age effect for each stimulus type.

The same pattern of effects was apparent in the number of trials to habituation. A 4 X 2 MANOVA found a non-significant age effect, $F(3, 12) < 1$, but a significant Stimulus effect, $F(1,14) = 12.6$, $p = .003$ ($\eta^2 = .47$), and Age X Stimulus interaction, $F(3,12) = 10.67$, $p = .001$ ($\eta^2 = .73$). Again, within-subjects contrasts reveal a cubic Age X Stimulus effect, $F(1,14) = 29.4$, $p < .001$ ($\eta^2 = .68$).

For both the face habituation and object habituation task, there are no significant total looking time differences between the months that had the same order of presentation (i.e. 6 and 8; 7 and 9 months). Similarly, for both face and

object habituation, there are no significant number-of-trials differences between months with the same stimulus order.

Task Order Effects

Order effects (i.e., which test was first or second) were found in total looking time to objects. At 6 and 8 months, when objects were first, infants looked longer at the object than they did at 7 and 9 months (Tables 1 and 2) when objects were second. Follow-up *t*-tests showed that total looking times for objects significantly differed between 6 and 7, 6 and 9, 7 and 8, 8 and 9 months (all with a value of $p < .005$). Total looking times to faces also was lower when the face task was second; however, the difference was not significant.

Table 1: Mean total looking time to habituation stimulus at 6 and 8 months (*SD* in parentheses).

	6 months	8 months
Task 1: Objects	61.62 <i>s</i> (50.58)	55.06 <i>s</i> (28.35)
Task 2: Faces	52.93 <i>s</i> (36.44)	56.81 <i>s</i> (41.48)

Table 2: Mean total looking time to habituation stimulus at 7 and 9 months (*SD* in parentheses).

	7 months	9 months
Task 1: Faces	68.99 <i>s</i> (38.17)	60.44 <i>s</i> (35.61)
Task 2: Objects	35.13 <i>s</i> (18.86)	27.36 <i>s</i> (17.83)

This task order effect was also found for both objects and faces in number of trials to habituate. For each stimulus type, it took more trials to habituate if that stimulus was used in the first task than in the second (Tables 3 and 4). Follow-up *t*-tests showed that number of trials to habituate to objects differed between 6 and 7, 6 and 9, 7 and 8, and 8 and 9 months (all $ps < .05$).

Table 3: Mean total number of trials to habituate at 6 and 8 months (*SD* in parentheses).

	6 months	8 months
Task 1: Objects	6.97 (2.97)	7.30 (2.81)
Task 2: Faces	6.04 (2.22)	5.93 (2.62)

Table 4: Mean total number of trials to habituate at 7 and 9 months (*SD* in parentheses).

	7 months	9 months
Task 1: Faces	7.72 (2.77)	7.31 (2.47)
Task 2: Objects	4.60 (1.61)	4.36 (1.56)

The second- versus first-task differences shows that overall interest in visual examination of stimuli declined across time in the experimental context. This can be interpreted as a “habituation to habituation” effect (see Sirois & Mareschal, 2002). However, the effect is not uniform: it is modulated by infants’ face-preference. Infants’ interest is maintained or renewed if after habituating to an object, they are shown a face. In contrast, infants’ interest significantly decreases when an object is presented after the face habituation task. We do not know what stimulus properties or biases produced this difference in habituation-of-habituation, but it highlights the importance of examining stimulus-by-task interactions in infant habituation.

Individual Stability: Looking Time

Significant individual stability for total looking time to habituation faces was found between 6 and 8 months ($r = .56, p = .002$), 7 and 8 months ($r = .43, p = .020$), 7 and 9 months ($r = .49, p = .004$), and 8 and 9 months ($r = .43, p = .020$). Stability for looking time to objects was not significant between any pair of months.

There were no significant correlations between sessions in the number of trials to habituate to faces or objects.

Individual consistency across the object and face task within a month was found at 6 months for total looking time to habituate ($r = .53, p \leq .002$). No significant across-task correlation was found in later months.

Individual Stability: Dishabituation

Stability of dishabituation, or recovery of looking-time to a novel stimulus, was tested. At 6 months, total looking at the habituation face moderately predicted a greater novelty response to the new face ($r = .39, p = .024$). The same effect was found at 8 months ($r = .52, p = .002$) and at 9 months ($r = .41, p = .015$). For objects, the same effect was present at 6 months ($r = .44, p = .009$), at 7 months ($r = .43, p = .017$), and at 8 months ($r = .36, p = .033$).

Gender Differences: Stimulus Preference

Connellan, Baron-Cohen, Wheelwright, Batki, and Ahluwalia (2000) argue that male newborns prefer objects whereas female newborns showed preference for faces (mean age = 36.7 hrs). Baron-Cohen (2002) claims that there are deep-seated gender differences in social inference and intelligence. However, we did not find gender differences in interest to faces and objects at any age.

Connellan et al. (2000) suggest that the gender effect for stimuli preference present in 1-day-old infants could be due to a biological nature since none have yet had exposure to stimuli. However, infants learn prenatally as well as in their first minutes and hours (Butko, Fasel & Movellan, 2006). Infants between 6 and 9 months of age have had much more exposure to social and non-social stimuli, which might be expected to amplify any nascent gender-based preferences suggested by Connellan et al. (2000). However, no such difference was found.

Discussion

These findings suggest that infant habituation to faces is moderately stable between 6 and 9 months of age, at least with respect to total looking time. However, there was no stability across months in looking-time to objects. Also, there was no stability in the slope of habituation (i.e., number of trials to habituate) for either faces or objects.

These results complement Colombo et al.'s (1987) findings of moderate stability in visual habituation from 3 to 9 months. They found stability in duration of looking to faces, but not in trials-to-habituate or in dishabituation. Consistent with Colombo et al.'s findings, we found stability in looking time to faces, but not in trials-to-habituate or in dishabituation. Our results establish that those effects are somewhat specific to faces. However, we found moderate stability between habituation time and dishabituation at some months, for faces and objects. The reason for this is unclear; perhaps general attention or arousal states contribute to consistent patterns of visual examination from habituation to dishabituation trials.

Some studies of habituation use peak (i.e., longest single trial) looking time as a measure of processing efficiency or of interest. We focused on total looking time on the assumption that it would carry less trial-by-trial error variance. However, we did examine peak fixation times (not reported here). This revealed very limited stability across months.

One implication is that longitudinal prediction of infant cognitive efficiency is stimulus-dependent. Researchers have not known how different stimuli in habituation tests predict individual differences in infants' cognitive speed. Our data show that stability is dependent on the type of stimulus tested, as well as the type of response measured and the age of the infant. It is unclear why stability is greater for faces than for objects. It might be that interest in faces is related to dimensions of temperament that relate to sociability; these dimensions show some stability in infants (Garcia-Coll et al., 1992). Conversely, interest in objects—particularly pictorial representations of objects, which do not allow typical multimodal exploration—might be highly subject to episodic and stimulus-specific preferences. It was not true, contrary to claims by Baron-Cohen (2002) and colleagues, that gender predicted stimulus-interest.

It should be noted that “stimulus” here, and in most studies, refers to pictorial representations, which are unnatural in many ways. The use of live models and real

objects might considerably alter these patterns, and this would be an intriguing direction for future research. Notably, in ongoing research we are testing whether the face-habituation trends generalize from static faces to dynamic faces (i.e., videos of rotating faces).

Our findings do not support the claim that infants' interest in faces declines, and interest in objects increases, after about 6 or 7 months (Adamson & Bakeman, 1991). We found no decrease in face interest, but a mild decline in object interest from 6 to 9 months. Although the claim that interest in faces declines during this period is based on very different types of data, our results suggest that there is not a general reversal of interest, but perhaps only a task-specific one. Currently there are no data or theories to explain this. One possibility is that as infants' response capabilities in dynamic environments expand, their relative interests in faces and objects start to differentiate. Their interest might become primed by the response “channels” that become viable in a given situation. Notably, during this age range infants gain response capabilities for object manipulation and for social interaction. These capabilities can be enacted only when responding to real, near-at-hand objects, on the one hand, and live, interactive people, on the other. Thus, we would expect infants' interests to be governed by situations that permit these expanding response channels. By contrast, in a narrow response channel like looking time, with stimuli that are static and non-interactive, we might detect only muted effects of changing interests in people and objects. Thus, infants' expanding action repertoire might influence their interest in people and objects.

Infants attend to objects and faces for approximately equal durations when presented first. However, this is not true when they are presented second. The comparable first-task interest to faces and objects could be due to the novelty of the task. It is known that habituation itself declines with repeated testing (Thompson & Spencer, 1966); this is known as “habituation of habituation.” However, these data suggest that infants from 6 to 9 months show more habituation of habituation when a more interesting stimulus, a face, is followed by a less (or less-consistently) interesting stimulus, an object.

For this reason, we cannot make broad generalizations about infants' relative interest in faces versus objects. The differences depend on the sequential context of exposure, as well as the infant's age. Also, infants' familiarity with faces and objects cannot be controlled in any obvious way. We used novel exemplars of faces and objects, but it is unlikely that unfamiliar objects are novel to infants in the same way as unfamiliar faces. Infants have much experience with face processing, and are likely able to make fairly fine discriminations. They also have fast-growing experience with objects, but the nature of their experience is quite different. We can, nonetheless, compare the same infant on the same stimulus types across months, and see if they show parallel stability across stimulus types. The current data show that they do not

The results show that it is not possible to use a single—or even several—visual habituation tasks to draw valid inferences about individual infants' visual information-processing traits. Stable traits, such as they are, appear to be conditional and subtle.

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