Familiarity preference something something???

Gal Raz[1] (galraz@mit.edu), Anjie Cao[2] (anjiecao@stanford.edu),
Michael C. Frank[2] (mcfrank@stanford.edu), and Rebecca Saxe[1] (saxe@mit.edu)
[1]Department of Brain and Cognitive Sciences, MIT, [2]Department of Psychology, Stanford University

Abstract

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Introduction

Throughout development, humans are inundated with visual information. Infants and young children constantly decide how much time to spend looking at what is in front of them and when to move on to something else [Haith (1980); dweck2017needs; raz2020learning]. Developmental psychologists have long relied on infants' ability to decide what to look at, when making inferences about infants' mental representations [Aslin (2007); baillargeon1985object; fantz1963pattern]. In a typical study measuring looking time, infants are presented with the same stimulus repeatedly until their looking time decreases (i.e. habituation). Then, they are presented with a new stimulus, and the change in their looking time is used as evidence for cognitive capacities. Despite extensive use of looking time as a measure, the rules underlying infants' decision to keep looking or look away are not well understood. In this paper, we conduct a direct empirical test of the relationships between prior exposure and looking time to familiar and novel stimuli.

One dominant framework for infant looking is that the dynamics of looking time are governed by the dynamics of learning (Hunter & Ames, 1988). This framework has been used to derive qualitative predictions about looking time as a function of prior exposure and stimulus complexity. If infants have sufficient prior exposure to complete encoding of one stimulus, they should look longer at a novel stimulus that offers new opportunities to learn, showing a novelty preference. In contrast, when infants have only limited prior exposure or partially encoded one stimulus, they might look at that same stimulus for longer to learn more about it, showing a familiarity preference.

However, empirical studies that systematically quantify familiarity preferences for visual stimuli tend to be older, have smaller sample sizes, and limited or no data available, making them unsuitable for evaluating the robustness of the phenomenon (e.g., Hunter, Ames, & Koopman, 1983; Rose, Gottfried, Melloy-Carminar, & Bridger, 1982). Furthermore, this theoretical framework does not include formal criteria to judge the completeness of encoding, limiting the precision of predictions for new experiments. The dynamics in this framework are instead often invoked retroactively, to explain unexpected findings. For example, Johnson et al. (2009) studied rule learning in 8- and 11-month old infants, finding a novelty preference in 8-month olds in one condition and a familiarity preference in 11-month olds in three others (as well as four conditions with no significant differences). They interpreted these differences post hoc as indicating some combination of greater complexity for certain rules over others and faster encoding by older children.

To move from post hoc interpretations towards predictive frameworks of looking time experiments, computational models are beginning to play a bigger role in the literature. Across the cognitive sciences, computational models are playing an essential role in facilitating theory-building and elucidating cognitive phenomena precisely (Guest & Martin, 2021; Smaldino, 2020). For infant looking, formal models of learning have successfully predicted infants' habituation and subsequent preferences for novel stimuli ('dishabituation'). However, in contrast to Hunter & Ames (1988)'s framework, these formal models often do not predict that infants will show a familiarity preference when given limited learning experience (Sirois & Mareschal, 2002). In a recent example of such a model, Cao, Raz, Saxe, & Frank (2022) proposed that habituation and novelty preference could be explained by a rational learner that takes noisy perceptual samples to maximize information gain (RANCH: Cao et al., 2022). This model accurately predicted adult looking time patterns in a self-paced habituation paradigm, reproducing both habituation and novelty preferences. However, RANCH also did not predict familiarity preferences at any stage of encoding, because its learning policy to maximize information gain would always prioritize learning about a novel stimulus over a repeated familiar stimulus, just to varying degrees.

By contrast, other models do seem to contain either indirect or direct predictions of familiarity preference. Kidd, Piantadosi, & Aslin (2012) proposed the "Goldilocks effect" – infants' tendency to focus on things that are neither too simple nor too complex - as a formal account of infant looking. In this work, a Dirichlet-multinomial model was used to learn the relative probability of objects appearing in specific locations and related to infants' lookaway probabilities. A U-shaped linking function between the model output and attention fit the infants' behavior best, and although this effect was documented in a paradigm that is very different from a typical looking time paradigm – infants were looking at a stream of rapidly changing events and their look-aways were recorded – it has been proposed that the preference for intermediately complex events may account for familiarity preferences (CITE; Stahl TICS paper i think). More recent work that uses rational information gathering agents to explain infant looking behaviors directly predicts familiarity preferences (Karni, Mattar, Emberson, & Daw, 2022). This model is similar to RANCH in that its learning policy considers information gain, but it also considers another source of value (i.e. Need: how frequently the information about each stimulus will be used). These dual processes generate non-monotonic changes in looking time, which predict both familiarity preferences and novelty preferences.

To evaluate and compare the predictions of these different model types, it is necessary to have quantitative estimates of habituation, novelty preferences, and familiarity preferences in infants. Under what circumstances do infants look longer at a stimulus, following limited exposure and thus potentially partial encoding?

In this paper, we aim to offer a stronger empirical foundation for understanding how the duration of exposure influences looking preferences. We conducted a set of experiments with preschoolers and infants designed to test the conditions under which a familiarity preference could be elicited. For preschoolers, we adapted a self-paced looking time paradigm that was previously used to capture habituation and novelty preference in adults (Cao et al., 2022). For infants, we developed a novel within-participants measurement paradigm. This set of experiments allow us to examine the validity of the assumption that the field of developmental psychology holds: familiarity preference would arise when the learners have limited experience with stimuli. To preview, while preschoolers and infants show both habituation and novelty preferences in our paradigm, we found no evidence for a familiarity preference for either preschoolers or infants.

Experiment 1

Hunter & Ames (1988) posit that younger participants are more likely to exhibit familiarity preferences for a given stimulus due to their reduced encoding speed. There was empirical evidence showing that younger infants would show familiarity preferences in tasks in which older infants show novelty preferences (Cyr grammar study). This age-related change in preference may explain the lack of familiarity preference observed in adults [Cao et al. (2022); Gustafson]. It is possible that adults can process so fast that even brief exposure is sufficient for completing the stimuli encoding.

To test this age hypothesis, we decided to test young children on an experimental paradigm that has captured habituation and novelty preference in adults (Cao et al., 2022). According to Hunter and Ames (1988), young children should be slower in processing information, making them more likely to show a familiarity preference.

Methods

Participants

66 children completed a task modified from the adult self-paced looking time studies reported in CITE. Following our pre-registration (LINK), 2 children were excluded from the analysis because their performance in the attention-check task failed to meet the inclusion criteria (answering 4 out of the 8 attention check questions correctly). We also excluded trials with looking time that were three absolute deviations away from the median in the log-transformed space across participants (*N* = 83;). The final datasets includes 64 children in total (3YO: N = 18; 4YO: N = 26; 5YO: N = 20). All participants were recruited in a university-affiliated research preschool.

Stimuli

We used a subset of stimuli created for the adult self-paced looking time studies. In the previous study, we created a set of animated creatures using Spore (a game developed by Maxis in 2008). Half of the creatures had high perceptual complexity, and half had low perceptual complexity. We used the high perceptual complexity stimuli for the current study.

Procedures

Children were tested individually in a test room by an experimenter. The experimenter invited the child to "meet some monster friends" and then familiarized the child with the laptop computer used to present the experiment. Before the test, each child went through a practice phase where they practiced pressing the space bar to move on to the next trial. The child was instructed that they can press the key and move on to meet more monster friends whenever they want.

On each trial, the child would see an animated creature appear on the screen. The child can move on to the next trial by pressing the space bar. Each block consisted of six trials. Usually, the same creature will be shown repeatedly (the background stimulus), but each block could contain either zero or one deviant trial. Deviant trials were trials that present a different creature from the background stimulus. Deviant trials appeared on the second, the fourth, or the sixth trial of the block. Each child saw eight blocks in total.

At the offset of each block, a memory task was presented to ensure children are appropriately attending to the task. The memory task was a 2-Alternative Forced Choice (2AFC) question, asking the children to identify which of the two stimuli they have seen before. The pair of stimuli contained one stimulus used as a background stimulus in the preceding block and a novel stimulus that did not appear anywhere else in the experiment.

Results and discussion

Children included in the final dataset showed a high level of accuracy (*M* = 0.97; *SD* = 0.08) in responding to the memory

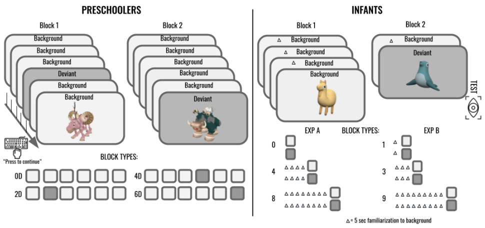


Figure 1: Experimental design and examples of simple and complex stimuli. In each block, a deviant could appear on the second, fourth (as depicted here) or sixth trial or not at all. Stimuli within a block were either all simple or all complex.

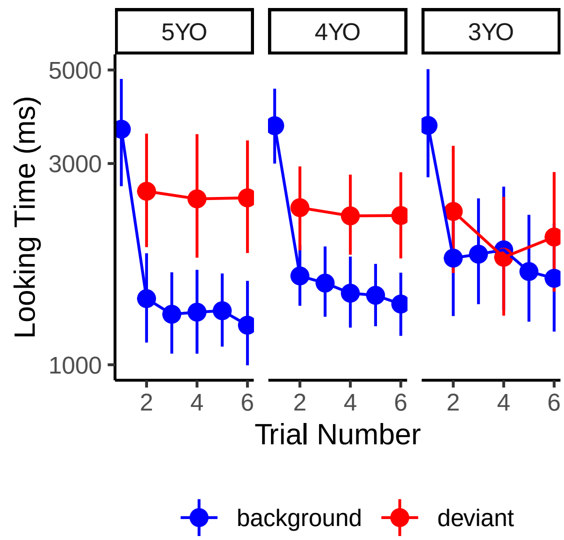
task question. This suggests that the children were engaged in the experiment.

We anticipated that the preschooler children would show patterns of habituation and dishabituation similar to adults. We also expected to see developmental changes in the shape of habituation trajectories. Our pre-registered mixed-effect model included a three-way interaction term between age (in months; scaled and centered), trial number, and trial type (background or deviant) to predict log-transformed looking time. The interaction between the trial number and trial type was significant, suggesting the paradigm has captured habituation and novelty preference in preschoolers ($\beta = 0.14$, $SE = 0.02$, $t = 6.22$, $p < 0.01$). However, we did not find any significant interaction with age, nor was the main effect significant (all $p > 0.1$).

We also explored the potential familiarity preference by comparing the looking time at the second background trial and the second deviant trial. Under the Hunter & Ames (1988) framework, the second trial in each block may be most likely to yield a familiarity preference, since participants have had the least amount of familiarization with the background stimulus in a block. If there was a familiarity preference, participants should look longer at a background trial than a deviant trial. However, we did not find evidence supporting this prediction. We ran a mixed effect model predicting looking time at the second trial with trial type as the predictor. There was a significant trial type effect in the opposite direction, suggesting participants looked longer at the deviant trial than the background trial even with as little as one trial of familiarization time ($\beta = 0.41$, $SE = 0.03$, $t = 12.24$, $p < 0.01$).

In summary, this experiment captured habituation and novelty preferences in preschoolers, replicating the patterns we saw in the previous adult samples (CITE). However, under the current paradigm, we did not find any evidence of a familiarity preferences.

It is possible that processing in preschoolers is already too fast for us to induce partial encoding in this paradigm. In order to capture familiarity preference, we would need to work with an even younger population (or a more complex stimulus). However, the performance of 3-year-olds in this paradigm was noisier than their older peers (Figure X). This trend suggested that the current paradigm would not be suitable for testing even younger children. In Experiment 2, we developed a new experimental paradigm to measure habituation and looking preferences within participants in preverbal infants.



Experiment 2

Methods

In the infant paradigm, infants are familiarized to six unique stimuli for different exposure durations within a single session in a blocked design. This is in contrast to the standard infant familiarization/habituation paradigm in which infants are familiarized to only one stimulus throughout the experiment, which makes the effect of exposure duration difficult to estimate. By presenting infants with multiple blocks with varying familiarization times, we can directly measure the effect of familiarization on looking time within participants.

To get a dense estimate of exposure durations, we pre-registered and ran two experiments, sequentially, with two sets of exposure durations. The first experiment showed infants blocks of 0, 4 or 8 familiarizations (Exp A; pre-registered here). The second experiment showed infants blocks of 1, 3 or 9 familiarizations (Exp B; pre-registered here).

Participants

We tested a combined sample of 61 7-10 month old infants, with 29 in Exp A and 32 in Exp B (M_{age} = 9.58 months, 29 female). 0 participants were excluded completely due to fussiness. We also excluded an additional individual test trials in which 1) infants looked at the stimuli for less than a total 2 seconds, 2) there were momentary external distractions in the home of the infant or 3) the gaze classifier (see **Looking time coding**) had an average classification confidence of less than 50%. Data collection was performed synchronously on Zoom, and infants were recruited from Lookit (Scott & Schulz, 2017) and Facebook.

Stimuli

Infants saw a different stimulus set from the preschoolers. In two initial studies, not shown here, we showed infants the Spore stimulus set used in preschoolers, in a slightly different experimental paradigm, and failed to elicit replicable habituation, novelty or familiarity preferences. In the current studies, we presented infants with a series of animated animals, which we created using "Quirky Animals" assets from Unity link. The animals were walking, crawling or swimming, depending on the species.

Procedure

This experiment followed a block structure, where each block was divided into two sections: 1) a familiarization period and 2) a test event. Each block was preceded by our lab-standard attention getter, a salient rotating star. During the familiarization period, the infant was familiarized to a particular animal, the background, in a series of familiarization trials. Each familiarization trial was a 5 second sequence: curtains open for 1 second, the animated animal was presented for 3 seconds, and then the curtains closed again for 1 second. We refer to the number of times the curtain opened and closed as the "familiarization duration", which varied between blocks.

During the test event, the infant saw either the same background animal again, or a novel animal, the deviant. The onset of the test event was not marked by any visual markers, but a bell sound is played as the curtains open, to maximize the chance of engagement during the test trial. The test event used an infant-controlled procedure, in which the experimenter terminated the trial when the infant looked away for more than three consecutive seconds. Looking time was defined as the total time that the infant spends looking at the screen from the onset of the stimulus until the first two consecutive seconds of the infant looking away from the screen. The discrepancy between the experimenter criterion and the looking time criterion was to be conservative in stopping trials to avoid early trial terminations. If the infant did not look away after 60 seconds of being presented with the test event, the next block automatically began and infants' looking time for this test event was recorded as 60 seconds.

Each baby saw six blocks: Three different familiarization durations (0, 4 and 8 in Exp. A, and 1, 3 and 9 in Exp. B) appeared twice each, once for each test event type (background or deviant).

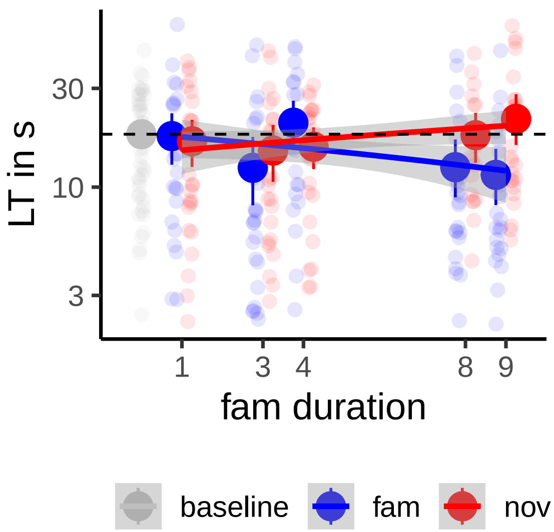
Looking time coding

To code the infants' gaze we used iCatcher+, a validated tool developed for robust and automatic annotation of infants' gaze direction from video (Erel, Potter, Jaffe-Dax, Lew-Williams, & Bermano, 2022). To obtain trial-wise looking times, we merged iCatcher+ annotations with trial timing information, thereby fully replacing manual coding of looking times.

Results and discussion

We pre-registered several linear mixed-effects models to test for habituation, novelty preferences and familiarity preferences in our paradigm. All models included a fixed effect of block number, and a random effect of subject. To test the prediction that partial encoding elicits familiarity preferences, while complete encoding elicits novelty preferences, we pre-registered a model which allows for a non-linear interaction between exposure duration by adding a quadratic effect of familiarization duration, and its interaction with novelty.We found that neither the main effect, nor the interaction of that quadratic term were significant (Main effect: $\beta = 0.63$; $SE = 0.89$; $t = 0.71$; $p = 0.48$; interaction: $\beta = 0.75$; $SE = 1.63$; $t = 0.46$; $p = 0.65$), while the interaction of novelty with the linear term was significant ($\beta = 4.32$; $SE = 1.6$; $t = 2.71$; $p = 0.01$). This suggests that looking at the deviant increased as a function familiarization duration, but that there is no special effect of partial encoding as posited by H&A. Furthermore, there was a significant decrease in looking times to the familiar items as a function of familiarization duration, indicating that infants habituated to familiar stimuli in our paradigm ($\beta = -2.66$; $SE = 0.9$; $t = -2.97$; $p = 0$). Novelty preferences (i.e. longer looking times at the deviant than the background) were robust after 8 ($\beta = 0.5$; $SE = 0.19$; $t = 2.7$; $p = 0.01$) and 9 familiarizations ($\beta = 0.63$; $SE = 0.16$; $t = 4.08$; $p < 0.01$), as well as in the combined dataset ($\beta = 0.57$; $SE = 0.14$; $t = 4.19$; $p < 0.01$).

We next tested specifically for the existence of familiarity preference in our dataset. Similar to the preschooler experiment, we hypothesized that familiarity preferences are most likely to emerge in test trials following short familiarizations. However, we did not find a significant effect of novelty on looking times after 1 ($\beta = -0.05$; $SE = 0.19$; $t = -0.24$; $p = 0.81$), 3 ($\beta = 0.35$; $SE = 0.2$; $t = 1.72$; $p = 0.1$) or 4 familiarizations ($\beta = -0.19$; $SE = 0.21$; $t = -0.89$; $p = 0.38$). Even when maximizing power by combining test events following all three familiarizations, there was no evidence of a familiarty preferences ($\beta = 0.05$; $SE = 0.12$; $t = 0.44$; $p = 0.66$). To address whether the youngest infants in our sample may show familiarity preferences, we ran an exploratory analysis asking whether age interacted with the effect of novelty in the individual or combined short exposure trials and found no evidence of age playing a role (all p's > 0.4).



General discussion

Overall, we developed a novel looking time paradigm for infants and preschoolers which tests the relationship between exposure duration and attentional preferences within-subjects. In this paradigm, we found strong evidence for habituation and novelty preferences. In contrast, despite prematurely interrupting familiarization to induce partial encoding, we failed to find attentional preferences for familiar stimuli in either preschoolers or infants, suggesting that partial exposure did not lead to familiarity preferences. Both the presence of novelty preferences and habituation and the absence of familiarity preferences were consistent across age groups, suggesting developmental continuity in our paradigm.

These results are consistent with the idea that, in the current setting, the decision of how long to look at a stimulus can be understood in light of a simple information gain model, like the one presented in Cao et al. (2022), across the lifespan. In contrast, our evidence does not support the idea that attention in development could be driven by a "knowledge gap" motivating infants and children to complete their encoding of familiar stimuli. If such a gap existed, it was too short to detect in our studies. The failure to find familiarity preferences through targeted partial encoding should also serve as a caution to interpretations of looking time results in which familiarity preferences are identified post-hoc, as it shows that such preferences may not arise generically. Some of these may instead be false positives.

Of course, not finding familiarity preferences in our settings does not rule out their existence, in our paradigm or in general. First, familiarity preferences may be more subtle than novelty preferences, so that the statistical power that is needed to find familiarity preferences is higher than that achieved in the current study. A current large-scale study by the ManyBabies consortium (ManyBabies5, under review) which aims to test the predictions made by H&A may give insight into this possibility. Second, evoking familiarity preferences may depend on the presentation mode of stimuli: While in our studies participants see one stimulus, familiar or novel, at a time, many studies reporting familiarity preferences follow a preferential looking set-up in which infants are presented with both familiar and novel stimuli simultaneously, and their relative looking time at each is recorded. It may be that familiarity preferences arise due to the recognition of a familiar stimulus among other stimuli, in which case our current paradigm would not be suited to detect them [though see gustafsson2021visual]. Third, prior work has emphasized the role of affective processes in familiarity preferences. The mere exposure effect, a widely documented phenomenon in social psychology, suggested that brief exposure to certain stimuli would be sufficient to provoke a more positive affect (CITE). Therefore, it is possible that many documented familiarity preferences arise because of underlying positive affect. Including measurements that more directly tap into liking, such as reaching or pointing, and relating them to looking time, may help isolate the contribution of affect component in familiarity preferences. Finally, and most importantly perhaps, the learning context in which participants find themselves likely plays a critical role in whether they will exhibit familiarity preferences. This context-dependence is reflected in meta-analyses investigating familiarity preferences in different paradigms. For example, when tested on word segmentation, infants show a persistent preference for familiar stimuli throughout the first year (Bergmann & Cristia, 2016). In contrast, when tested on statistical learning of novel words, infants show a consistent preference for novel stimuli, from 4-month- to 11 months of age (Black & Bergmann, 2017). These seemingly contradictory results highlight the need for theories that formalize the relationship between the learning problem faced by participants and their attentional preferences. Recent computational work has begun to provide normative accounts of how context affects optimal exploration. For example, in environments in which past and present are correlated, a preference for familiar stimuli may arise to prepare for future encounters, while in uncorrelated environments, novelty preferences are optimal (under some assumptions; see [dubey2020reconciling]). Similarly, in a rational analysis of attentional preferences, (Cao et al., 2022) show that ideal learners attempting to maximize their expected information gain consistently seek novelty when trying to learn a single concept. But it is possible that once the learning goal or constraints on learning change e.g. by attempting to learn hierarchical concepts or imposing switch costs on learning new concepts, optimal information-seeking may include attending to familiar stimuli. In conclusion, we find robust evidence for habituation and novelty preferences in preschoolers and infants, while failing to observe a non-linearity in information seeking behavior, despite attempting to induce partial encoding through a novel looking paradigm in which we manipulate exposure within-subjects. Our findings suggest that familiarity preferences do not arise under all circumstances of limited exposure to stimuli, and that post-hoc rationalizations of familiarity preferences observed in infant looking time data should be made with care. Instead, we argue for the need for new theories and data to understand the requisite features of stimuli and learning contexts that elicit familiarity preferences.

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