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No evidence for familiarity preferences after partial exposure to visual concepts in preschoolers and infants

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Abstract

From birth, humans make decisions about what to look at and for how long. A classic framework proposes encoding as a key driver of looking behavior in development - in early stages of encoding, infants and young children prefer to engage with familiar stimuli, while at later stages of encoding they prefer novel stimuli. Though this framework is often invoked when interpreting looking time studies, it is rarely validated empirically. Here, we test these predictions by explicitly manipulating exposure durations within-subjects. While we found robust evidence for habituation and novelty preferences, limiting exposure to visual concepts did not result in familiarity preferences in any age group. Our findings suggest that limited exposure does not generically lead to familiarity preferences, and that interpretations of observed familiarity preferences should be made with care. We argue for the development of formal frameworks which link the learning problem faced by participants to their attentional preferences.

Keywords: psychology; cognitive development; learning

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 (Dweck, 2017; Haith, 1980; Raz & Saxe, 2020). Developmental psychologists have long relied on infants' ability to decide what to look at and for how long, making inferences about infants' mental representations (Aslin, 2007; Baillargeon, Spelke, & Wasserman, 1985; Fantz, 1963). In a typical study measuring looking time, infants are presented with the same stimulus repeatedly until their looking time decreases (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 factors 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 preferences.

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 have 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 novelty preferences in 8-month olds in one condition and familiarity preferences 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 role. Across the cognitive sciences, computational models facilitate theory-building and provoke more precise formulations of cognitive phenomena (Guest & Martin, 2021; Smaldino, 2020). For infant looking, formal models of learning have successfully predicted infants' habituation and subsequent preferences for novel stimuli. However, in contrast to Hunter & Ames (1988)'s framework, these formal models generally do not predict that infants will show familiarity preferences 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 preferences could be explained by a rational learner that takes noisy perceptual samples to maximize information gain (RANCH). This model accurately predicted adult looking time patterns in a self-paced habituation paradigm, reproducing both habituation and novelty preferences. However, RANCH does not predict familiarity preferences at any stage of encoding, because its policy to maximize information gain would always prioritize learning about a novel stimulus over a repeated fa-

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miliar 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, an ideal learner model tracked the relative probability of objects appearing in specific locations in a continuous stream of events, and infants' probability of looking away from each successive object had a U-shaped link to the models' surprisal. It has been suggested that infants' tendency to stay most engaged with moderately predictable events may be a reflection of familiarity preferences at early stages of encoding.

A more recent formal model used rational information gathering agents to explain infant looking behaviors, and directly predicted 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. information "need": how frequently the information about each stimulus will be used). A trade-off between information gain and information need generates 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, however, it is necessary to have quantitative estimates of habituation, novelty preferences, and familiarity preferences from behavioral data. Under what circumstances do familiar stimuli evoke longer looking, 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 experiments with preschoolers and infants to test the conditions under which familiarity preferences could be elicited. For preschoolers, we adapted a self-paced looking time paradigm that was previously used to capture habituation and novelty preferences in adults (Cao et al., 2022). For infants, we developed a new within-participants measurement paradigm. This set of experiments allows us to directly investigate whether familiarity preferences arise when 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 familiarity preferences in either preschoolers or infants.

Experiment 1

Hunter & Ames (1988) posit that younger participants are more likely to exhibit familiarity preferences after the same amount of exposure to a stimulus due to their reduced encoding speed. There is some empirical evidence suggesting that younger infants show familiarity preferences in tasks in which older infants show novelty preferences (Cyr & Shi, 2013; Thiessen & Saffran, 2003). This age-related change in preferences may explain the lack of familiarity preferences observed in adults (Cao et al., 2022; Gustafsson, Francoeur, Blanchette, & Sirois, 2021). It is possible that adults can process stimuli so fast that even brief exposure is sufficient for completing stimulus encoding. While most research on looking preferences has been with infant participants, there are two main reasons to investigate this phenomenon with preschoolers. First, preschoolers could help us understand the developmental trajectories of novelty preferences and familiarity preferences. Second, preschoolers are developing learners that are relatively easier to measure, compared to the infant participants. By working with preschoolers, we could acquire a relatively large dataset to measure the phenomena of interest with reasonable precision.We therefore tested young children in an experimental paradigm that has captured habituation and novelty preferences in adults (Fig. 1: left panel, Cao et al., 2022).

Methods

Participants 66 children completed a task modified from the adult self-paced looking time studies reported in Cao et al. (2022). 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 times that were three absolute deviations away from the median in the log-transformed space across participants (Total trial N = 3564; Excluded trial N = 83, 2.33% of the total trials). The final dataset included 64 children in total (3yr: N = 18; 4yr: N = 26; 5yr: N = 20). All participants were recruited in a university-affiliated research preschool.

Stimuli We used a subset of stimuli used in a prior adult self-paced looking time study, a set of animated creatures from the computer game Spore (developed by Maxis in 2008). The creatures all move in place. There were 24 different animated creatures in total.

Procedure 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 a random animated creature drawn from the stimuli set appear on the screen. The child could move on to the next trial by pressing the space bar. Each block consisted of six trials. Usually, the same creature was 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 deviant trial

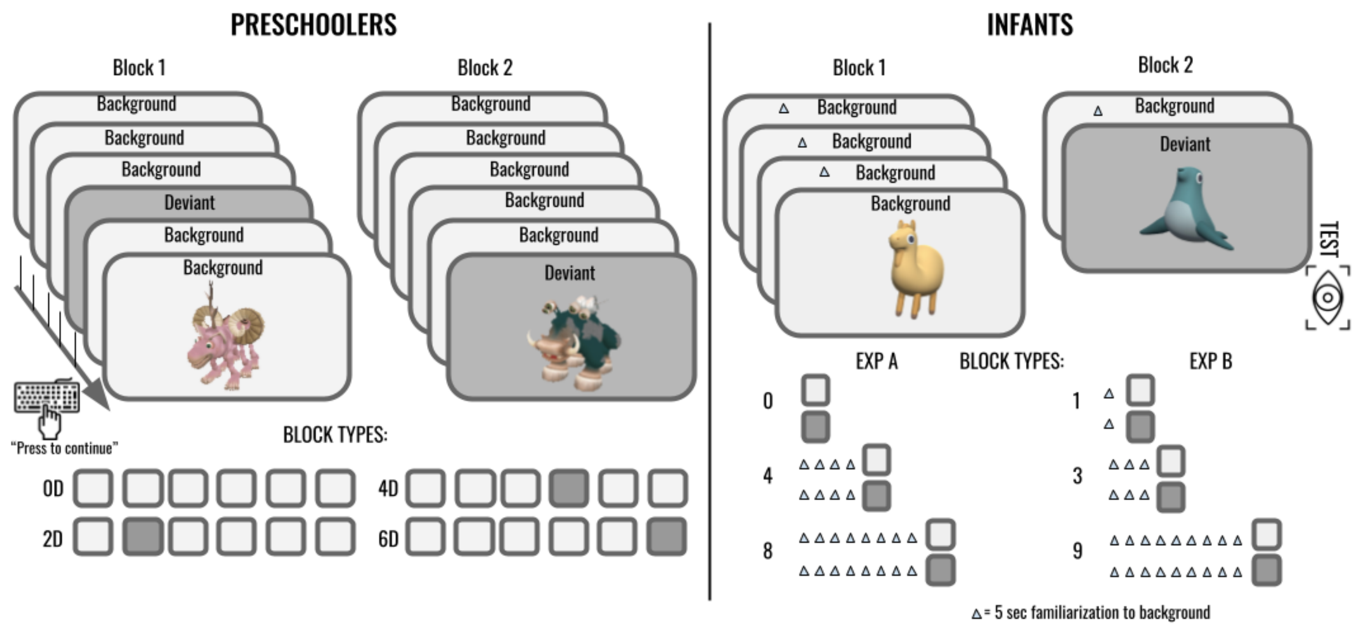

Figure 1: Experimental design of preschooler and infant experiments. There were four main differences: 1) Preschoolers responded with button presses, infants through lookaways, 2) preschoolers saw background trials after deviants, whereas deviants always appeared at the end in the infant experiments, 3) in the experiment with preschoolers, all trials were self-paced; whereas in infants, only the last trial was self-paced and 4) preschooler and infant paradigms used different sets of animate stimuli.

contained a different creature. Each child saw eight blocks in total.

At the offset of each block, we presented a memory task to ensure children were appropriately attending to the task. We asked them which of two creatures presented on the screen they had seen before.

Results

Data and analysis are available at `https://tinyurl.com/PokebabyCogSci2023`. Children included in the final dataset showed a high level of accuracy (M = 0.97; SD = 0.08) in responding to the memory task question. This suggests that the children were engaged in the experiment. We anticipated that the preschooler children would show patterns of habituation and novelty preferences similar to adults. We also expected to see developmental changes in the shape of habituation trajectories, with older children habituate faster than younger children. 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 (Fig. 2). The interaction between the trial number and trial type was significant, suggesting the paradigm has captured habituation and novelty preferences in preschoolers (β = 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 tested for familiarity preferences 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 is most likely to yield a familiarity preference, since participants have had the least amount of exposure to 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 (β = 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 seen in a previous adult sample (Cao et al., 2022). In addition, similar to the previous adult results, we did not find any evidence of familiarity preferences. One reason for not observing familiarity preferences may be that processing in preschoolers is already too fast to induce partial encoding in this paradigm. If so, we would need to test a younger population. However, given that the performance of 3-year-olds in this paradigm was noisier than their older peers (Fig. 2), the current paradigm would likely not be suitable for testing even younger children. In Experiment 2, we developed a new experimental paradigm to measure the relationship between exposure duration and looking preferences in preverbal infants.

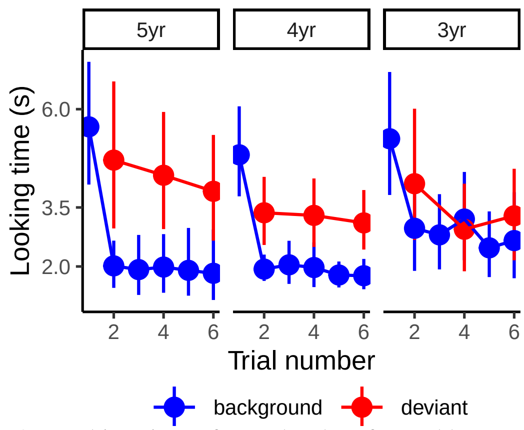

Figure 2: Looking time of preschoolers faceted by age showing habituation and dishabituation, but not familiarity preferences. Y-axis is log-transformed.

Experiment 2

In the infant paradigm, infants were familiarized to six unique stimuli for different exposure durations within a single session in a blocked design, followed by a test trial which either showed the same stimulus again or a new stimulus (Fig. 1, right panel). We chose this design as a contrast to the standard infant familiarization/habituation paradigm in which infants are familiarized to only one stimulus throughout an experiment. In such designs, the effects of exposure duration must be estimated between groups of infants. In contrast, in our design, by presenting individual infants with multiple blocks and varying exposure durations, we directly measured the effect of prior exposure on looking time, within participants.

To get a dense sample of possible exposure durations, we pre-registered and ran two experiments, sequentially, with two sets of exposure durations. The first experiment showed infants blocks containing 0, 4 or 8 exposure events (Exp A; pre-registered at this link). The second experiment showed infants blocks containing 1, 3 or 9 exposure events (Exp B; pre-registered at this link). If the predictions by Hunter & Ames (1988) hold in this paradigm, we expect infants to show familiarity preferences when provided with limited exposure (e.g. 1 to 4 familiarizations), whereas they should show novelty preferences when familiarized for longer (e.g. 8 or 9 familiarizations).

Methods

Participants We tested a combined sample of 66 7-10 month old infants, with 31 in Exp A and 35 in Exp B (M_{age} = 9.52 months, 31 female). 6 participants were excluded completely due to fussiness. An additional 53 individual test events (out of 360, 15% of trials) did not make it into the final analysis because 1) infants fussed out of the experiment at an earlier stage of the experiment, 2) infants looked at the stimuli for less than a total 2 seconds, 3) there were momentary external distractions in the home of the infant or 4) 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 included here (but see OSF repository), 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, created using "Quirky Animals" assets from Unity (Fig. 1, link to assets). The animals were walking, crawling or swimming, depending on the species.

Procedure The experiment was conducted via Zoom. Parents were instructed to find a quiet room with minimal distractions, place their child in a high chair (preferred) or on their lap, and to remain neutral throughout the experiment. Infants were placed as close as possible to the screen without allowing them to interact with the keyboard. 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 an "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 moves in place for 3 seconds, and then the curtains close for 1 second. The number of familiarization trials (the "exposure duration") 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 played as the curtains opened, to maximize the chance of engagement during the test event. The test event used an infant-controlled procedure: the experimenter terminated the trial when the infant looked away for more than three consecutive seconds. Looking time was then defined as the total time that the infant spent looking at the screen from the onset of the stimulus until the first two consecutive seconds of the infant looking away from the screen. 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 that test event was recorded as 60 seconds.

Each infant saw six blocks: Three different exposure 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). The longer exposure durations (8 or 9) were chosen based on our previous pilot studies with a different stimulus set (OSF repository), and the shorter durations were chosen to provide limited learning experience with the background. The order of blocks was counterbalanced between infants, and pairs of animals (background and deviant) were counterbalanced to be associated with each block type.

Which animal was shown as the background and which as the deviant (if it was a deviant test trial) was randomized in each block.

Looking time coding To code the infants' looking time we used iCatcher+, a validated tool developed for robust and automatic annotation of infants' gaze direction from video (Erel et al., in press). We quality-controlled all the automatic annotations via visual inspection by blinded coders, and overrode or excluded wrong annotations when necessary using a lab-standard procedure. To obtain trial-wise looking time, we merged iCatcher+ annotations with trial timing information, thereby fully replacing manual coding of looking time.

Results

Data and analysis are available at `https://tinyurl.com/PokebabyCogSci2023`. 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. We did not include a random effect of stimulus since we found that the variance of this random effect was small relative to the subject effects and fitting our mixed-effects models with random effects of stimulus caused convergence issues.

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 exposure duration, and its interaction with novelty. We found that neither the main effect, nor the interaction of that quadratic term were significant, while the interaction of novelty with the linear term was significant (Table 1). This result suggests that looking at the deviant increased as a function familiarization duration (Fig. 3), but that there was no special effect of partial encoding as posited by Hunter & Ames (1988). Furthermore, there was a significant decrease in looking time to the familiar items as a function of familiarization duration, indicating that infants habituated to familiar stimuli in our paradigm (β = -5.01; *SE* = 0.95; *t* = -5.25; *p* = 0). Novelty preferences (i.e. longer looking at the deviant than the background) were significant after 8 exposures (β = 0.79; *SE* = 0.22; *t* = 3.58; *p* = 0.002), 9 exposures (β = 0.74; *SE* = 0.15; *t* = 4.85; $p < 0.001$), as well as in the combined dataset (β = 0.77; *SE* = 0.15; *t* = 5.08; $p < 0.001$).

We next tested specifically for familiarity preferences in our dataset. Similar to the preschooler experiment, we hypothesized that familiarity preferences are most likely to emerge in test events following short exposure durations. To do so, we ran mixed-effects models which fit looking time at test events following short exposures specifically, with novelty as a predictor. However, we did not find a significant effect of novelty on looking time after 1 (β = -0.04; *SE* = 0.19; *t* = -0.21; *p* = 0.84), 3 (β = 0.36; *SE* = 0.19; *t* = 1.85; *p* = 0.08) or 4 exposures (β = -0.15; *SE* = 0.2; *t* = -0.76; *p* = 0.46). Even when maximizing power by combining test events following all three short exposure durations, there was no evidence of familiarity preferences (β = 0.08; *SE* = 0.12; *t* = 0.65; *p* = 0.52).

Lastly, 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 blocks. We found no evidence of age playing a role (all p's > 0.4).

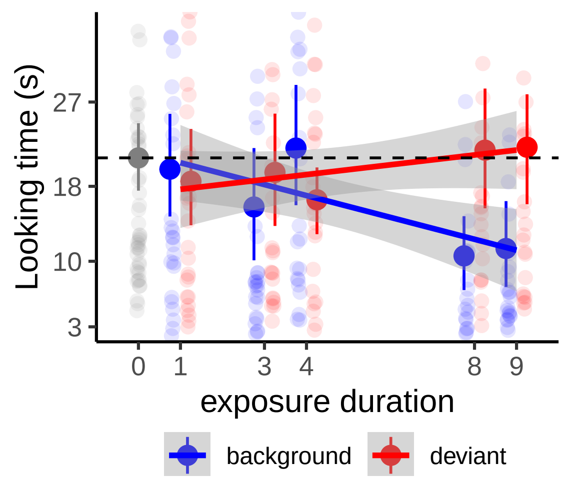

Figure 3: Looking time to background and deviant test events as a function of exposure duration. We found evidence of habituation and novelty prefences, but not familiarity preferences. Y-axis is log-transformed to reflect the transformation of looking time in mixed effects models. The gray point at exposure duration 0 and the corresponding dashed reference line show baseline looking time without prior exposure.

Discussion

We developed new looking time paradigms for preschoolers and infants that tested the relationship between exposure duration and the duration of attention within individual participants. Using these paradigms, we found evidence for habituation and novelty preferences across all ages tested. In contrast, despite prematurely interrupting familiarization to induce partial encoding, we failed to find attentional preferences for familiar stimuli in either preschoolers or infants. Limited exposure in the current paradigms did not lead to familiarity preferences. Our failure to find familiarity preferences, in a within-subjects design targeting partial encoding, should suggest caution when inferring familiarity preferences post-hoc in similar experiments.

The presence of habituation and novelty preferences along with the absence of familiarity preferences were consistent across age groups (and similar to previous results in adults), suggesting developmental continuity of the dynamics of attention in this paradigm. For simple visual events presented sequentially, the decision of how long to look at a stimulus, and when to look away, can therefore be explained by a simple information gain model, like the one presented in Cao et

Predictor	Coefficient	Std error	t	df	p value
(Intercept)	2.99	0.11	27.20	175.84	< 0.001
Exposure duration	-5.01	0.95	-5.25	269.60	< 0.001
Squared exposure duration	0.09	0.91	0.098	266.09	0.922
Novelty	0.22	0.09	2.44	269.98	0.016
Block number	-0.16	0.02	-6.55	269.04	< 0.001
Exposure duration : **Novelty**	6.92	1.65	4.20	271.34	< 0.001
Squared exposure duration : **Novelty**	-0.23	1.68	-0.16	270.34	0.874

Table 1: Mixed effects model results testing for a non-linearity in infant looking time.

al. (2022), across the lifespan.

The absence of familiarity preferences in our results 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 which aims to test the predictions made by Hunter & Ames (1988) may give insight into this possibility (Kosie et al., 2023).

Second, evoking familiarity preferences may depend on the presentation mode of stimuli: In our studies participants saw one stimulus, familiar or novel, at a time. By contrast, 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 to each is recorded (Roder, Bushnell, & Sasseville, 2000; Rose et al., 1982; Thiessen & Saffran, 2003). Familiarity preferences could arise due to the *recognition* of a familiar stimulus among other stimuli, in which case the current paradigm would not be suited to detect them (though see Gustafsson et al., 2021).

Third, affective processes might drive familiarity preferences. The "mere exposure effect" is widely documented in social psychology: brief exposure to a particular stimulus can be sufficient to induce positive affect associated with that stimulus (Montoya, Horton, Vevea, Citkowicz, & Lauber, 2017; Zajonc, 1968). Therefore, it is possible that familiarity preferences arise in infants when the familiar stimulus evokes positive affect. Including measurements that more directly tap into liking, such as reaching or pointing (Powell, 2022; Woo, Tan, & Hamlin, 2022), and relating them to looking time, may help identify the contribution of affect in familiarity preferences.

Finally, and most importantly, the learning problem that people are solving 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 in their native language, infants show persistent preferences for familiar stimuli throughout the first year (Bergmann & Cristia, 2016). In contrast, when tested on statistical learning of novel words, infants show consistent preferences 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 accounts of how the learning problem influences optimal attention. Dubey & Griffiths (2020) give an example of such a formal account by showing that when past and present events are correlated, rational agents, under some assumptions, develop a tendency to attend to familiar stimuli to prepare for the most likely future events, while in uncorrelated environments, novelty preferences are optimal. 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 a phase of attending to familiar stimuli.

Conclusion

In conclusion, we found robust evidence for habituation and novelty preferences in preschoolers and infants. In the same paradigms, we found no evidence for familiarity preferences, despite attempting to impose partial encoding through a new experimental paradigm in which we manipulate exposure duration within-subjects. Our findings suggest that familiarity preferences do not necessarily arise after limited exposure to stimuli, so post-hoc inferences of familiarity preferences in infant looking time data should be made with care. We conclude that developmental psychology needs formal models to make specific predictions for the conditions under which infants will, and will not, show familiarity preferences, that can then be rigorously tested in experiments.

References

Aslin, R. N. (2007). What's in a look? *Developmental Science*, *10*(1), 48–53.

Baillargeon, R., Spelke, E. S., & Wasserman, S. (1985). Object permanence in five-month-old infants. *Cognition*, *20*(3), 191–208.

Bergmann, C., & Cristia, A. (2016). Development of infants' segmentation of words from native speech: A meta-analytic approach. *Developmental Science*, *19*(6), 901–917.

Black, A., & Bergmann, C. (2017). Quantifying infants' statistical word segmentation: A meta-analysis. In *39th annual meeting of the cognitive science society* (pp. 124–129). Cognitive Science Society.

Cao, A., Raz, G., Saxe, R., & Frank, M. C. (2022). Habituation reflects optimal exploration over noisy perceptual samples. *Topics in Cognitive Science*.

Cyr, M., & Shi, R. (2013). Development of abstract grammatical categorization in infants. *Child Development*, *84*(2), 617–629.

Dubey, R., & Griffiths, T. L. (2020). Reconciling novelty and complexity through a rational analysis of curiosity. *Psychological Review*, *127*(3), 455.

Dweck, C. S. (2017). From needs to goals and representations: Foundations for a unified theory of motivation, personality, and development. *Psychological Review*, *124*(6), 689.

Erel, Y., Shannon, K. A., Scott, K., Cao, P., Tan, X., Hart, P. K., ... Liu, S. (in press). iCatcher+: Robust and automated annotation of infant gaze from videos collected in the lab and online. *Advances in Methods and Practices in Psychological Sciences*.

Fantz, R. L. (1963). Pattern vision in newborn infants. *Science*, *140*(3564), 296–297.

Guest, O., & Martin, A. E. (2021). How computational modeling can force theory building in psychological science. *Perspectives on Psychological Science*, *16*(4), 789–802.

Gustafsson, E., Francoeur, C., Blanchette, I., & Sirois, S. (2021). Visual exploration in adults: Habituation, mere exposure, or optimal level of arousal? *Learning & Behavior*, 1–9.

Haith, M. M. (1980). *Rules that babies look by: The organization of newborn visual activity*. Lawrence Erlbaum Associates.

Hunter, M. A., & Ames, E. W. (1988). A multifactor model of infant preferences for novel and familiar stimuli. *Advances in Infancy Research*.

Hunter, M. A., Ames, E. W., & Koopman, R. (1983). Effects of stimulus complexity and familiarization time on infant preferences for novel and familiar stimuli. *Developmental Psychology*, *19*(3), 338.

Johnson, S. P., Fernandes, K. J., Frank, M. C., Kirkham, N., Marcus, G., Rabagliati, H., & Slemmer, J. A. (2009). Abstract rule learning for visual sequences in 8-and 11-month-olds. *Infancy*, *14*(1), 2–18.

Karni, G., Mattar, M. G., Emberson, L., & Daw, N. (2022). *A rational information gathering account of infant exploratory behavior. [Poster presentation]. RLDM*.

Kidd, C., Piantadosi, S. T., & Aslin, R. N. (2012). The goldilocks effect: Human infants allocate attention to visual sequences that are neither too simple nor too complex. *PloS One*, *7*(5), e36399.

Kosie, J., Zettersten, M., Abu-Zhaya, R., Amso, D., Babineau, M., Baumgartne, H., ... Berteletti, I. et al. (2023). ManyBabies 5: A large-scale investigation of the proposed shift from familiarity preference to novelty preference in infant looking time.

Montoya, R. M., Horton, R. S., Vevea, J. L., Citkowicz, M., & Lauber, E. A. (2017). A re-examination of the mere exposure effect: The influence of repeated exposure on recognition, familiarity, and liking. *Psychological Bulletin*, *143*(5), 459.

Powell, L. J. (2022). Adopted utility calculus: Origins of a concept of social affiliation. *Perspectives on Psychological Science*, *17*(5), 1215–1233.

Raz, G., & Saxe, R. (2020). Learning in infancy is active, endogenously motivated, and depends on the prefrontal cortices. *Annual Review of Developmental Psychology*, *2*, 247–268.

Roder, B. J., Bushnell, E. W., & Sasseville, A. M. (2000). Infants' preferences for familiarity and novelty during the course of visual processing. *Infancy*, *1*(4), 491–507.

Rose, S. A., Gottfried, A. W., Melloy-Carminar, P., & Bridger, W. H. (1982). Familiarity and novelty preferences in infant recognition memory: Implications for information processing. *Developmental Psychology*, *18*(5), 704.

Scott, K., & Schulz, L. (2017). Lookit (part 1): A new online platform for developmental research. *Open Mind*, *1*(1), 4–14.

Sirois, S., & Mareschal, D. (2002). Models of habituation in infancy. *Trends in Cognitive Sciences*, *6*(7), 293–298.

Smaldino, P. E. (2020). How to translate a verbal theory into a formal model. *Social Psychology*.

Thiessen, E. D., & Saffran, J. R. (2003). When cues collide: Use of stress and statistical cues to word boundaries by 7- to 9-month-old infants. *Developmental Psychology*, *39*(4), 706.

Woo, B. M., Tan, E., & Hamlin, J. K. (2022). Human morality is based on an early-emerging moral core. *Annual Review of Developmental Psychology*, *4*, 41–61.

Zajonc, R. B. (1968). Attitudinal effects of mere exposure. *Journal of Personality and Social Psychology*, *9*(2p2), 1.