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

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Abstract

From birth, humans constantly make decisions about what to look at and for how long. A classical framework of information-seeking in development proposes encoding as a key driver of attentional preferences - in early stages of encoding, infants and young children will prefer to engage with a familiar stimulus in order to complete their representation, while at later stages of encoding they will preferentially attend to novel stimuli. While this framework is often invoked in the interpretation of looking times studies, it has not been explicitly validated with large developmental samples. Here, we test these predictions using new looking time paradigms which manipulate exposure durations to different stimuli within-subjects. While we find robust evidence for habituation and novelty prefences across development, limiting exposure to visual concepts did not result in familiarity preferences in any age group. Our findings suggest that partial exposure may not generically lead to familiarity preferences, and that post-hoc rationalizations of observed familiarity preferences should be made with care. We argue that developmental psychology needs formal frameworks that link the learning problem faced by subjects to their attentional preferences, so that such frameworks can be applied predictively, rather than post-hoc.

Keywords: developmental psychology; familiarity preferences; habituation; learning; attention

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, when 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 (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 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 ('dishabituation'). However, in contrast to Hunter & Ames (1988)'s framework, these formal models generally 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 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, 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 value 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, 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 duration. We conducted experiments with preschoolers and infants 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 new within-participants measurement paradigm. This set of experiments allows us to directly investigate whether a familiarity preference arises 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 a familiarity preference 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 preference may explain the lack of familiarity preference observed in adults (Cao et al., 2022; Gustafsson, Francoeur, Blanchette, & Sirois, 2021). It is possible that adults can process so fast that even brief exposure is sufficient for completing the stimuli encoding.

We therefore tested young children on an experimental paradigm that has captured habituation and novelty preference in adults (Fig. 1: left panel, Cao et al., 2022). According to Hunter & Ames (1988), younger subjects may 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 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 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 (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).

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 could move on to the next trial by pressing the space bar. Each block consisted of six trials. Usually, the same creature was 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.

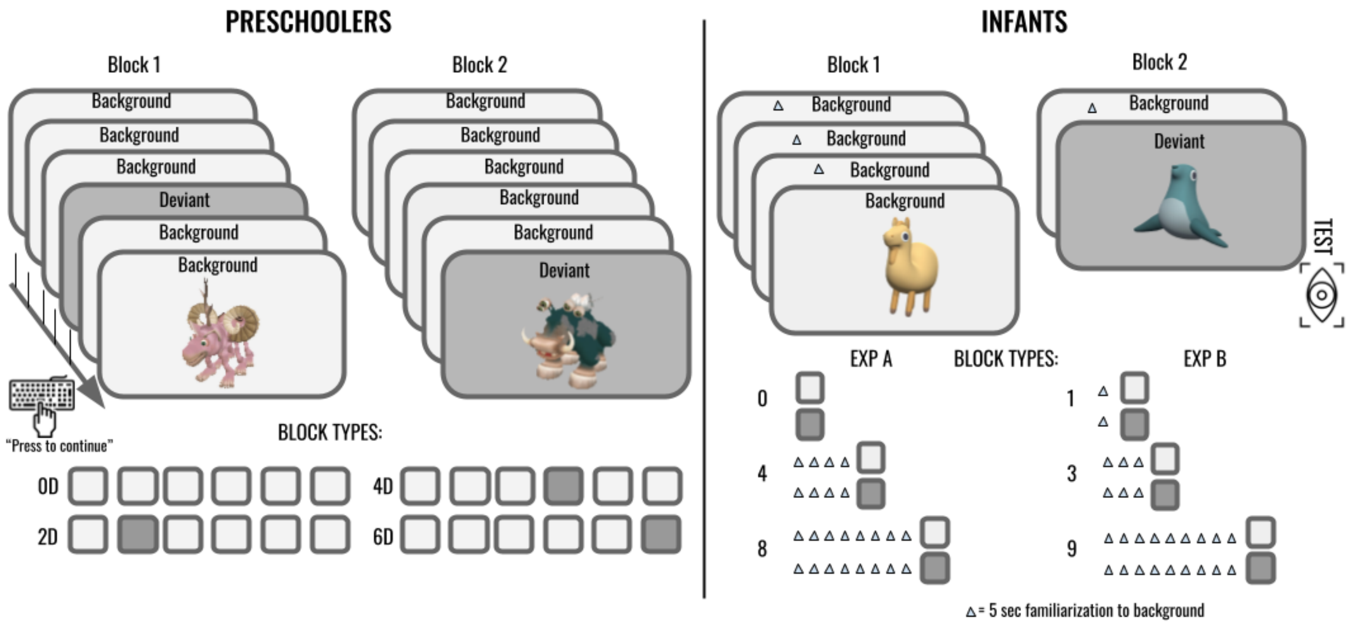

Figure 1: Experimental design of preschooler and infant experiments. There were four main differences: 1) Preschoolers responded with button presses, infants through lookaways, 2) preschoolers saw background trials after deviants, whereas deviants always appeared at the end in the infant experiments, 3) in 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.

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

Results

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 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 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 may be 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 ($\beta = 0.41$, $SE = 0.03$, $t = 12.24$, $p < 0.01$).

In summary, this experiment captured habituation and novelty preferences in preschoolers, replicating the patterns seen in a previous adult sample (Cao et al., 2022). In contrast, we did not find any evidence of 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 test with an even younger population (or more complex stimuli). 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.

Experiment 2

In the infant paradigm, infants are familiarized to six unique stimuli for different exposure durations within a single session in a blocked design (Fig. 1, right panel). This is in contrast to the standard infant familiarization/habituation

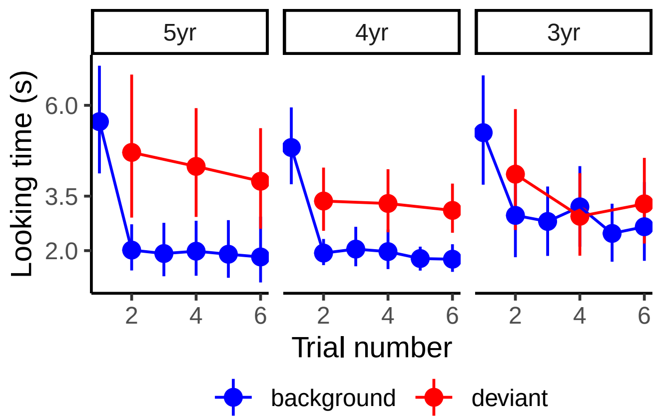

Figure 2: Looking times of preschoolers faceted by age showing habituation and dishabituation, but not familiarity preferences. Y-axis is log-transformed to reflect transformation of looking times in mixed effects models.

paradigm in which infants are familiarized to only one stimulus throughout an experiment, so effects of exposure duration must be estimated between groups of infants. By presenting individual infants with multiple blocks and varying exposure times, we directly measure the effect of prior exposure on looking times, 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 containg 0, 4 or 8 exposure events (Exp A; pre-registered here). The second experiment showed infants blocks containing 1, 3 or 9 exposure events (Exp B; pre-registered here).

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} = 9.5 months, 31 female). 5 participants were excluded completely due to fussiness. An additional 72 individual test trials (out of 360, 20% 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, 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 (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 moves in place for 3 seconds, and then the curtains close for 1 second. The number of exposure events (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 trial. 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 baby 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).

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 et al., in press). To obtain trial-wise looking times, we merged iCatcher+ annotations with trial timing information, thereby fully replacing manual coding of looking times.

Results

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 exposure duration, and its interaction with novelty.

We found that neither the main effect, nor the interaction of that quadratic term were significant (main effect: β = 0.63; *SE* = 0.89; t = 0.71; p = 0.48; interaction: β = 0.75; *SE* = 1.63; t = 0.46; p = 0.65), while the interaction of novelty with the linear term was significant (β = 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 (Fig. 3). 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 (β = -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 (β = 0.5; *SE* = 0.19; t = 2.7; p = 0.01) and 9 familiarizations (β = 0.63; *SE* = 0.16; t = 4.08; $p < 0.01$), as well as in the combined dataset (β = 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 (β = -0.05; *SE* = 0.19; t = -0.24; p = 0.81), 3 (β = 0.35; *SE* = 0.2; t = 1.72; p = 0.1) or 4 exposures (β = -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 familiarity preferences (β = 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).

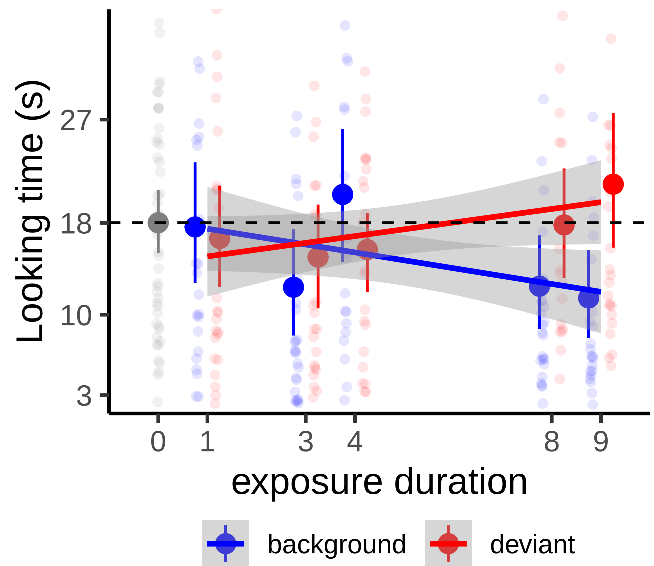

Figure 3: Looking times to background and deviant test trials as a function of exposure duration. We find evidence of habituation and novelty prefences, but not familiarity preferences. Y-axis is log-transformed to reflect transformation of looking times in mixed effects models. Grey data and dashed line show baseline looking times without familiarization.

Discussion

Overall, we developed a new looking time paradigm for infants and preschoolers which tests the relationship between exposure duration and the duration of attention, within-subjects. Using this paradigm, 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. Partial exposure did not lead to familiarity preferences.

Both the presence of habituation and novelty preferences and 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 al. (2022), across the lifespan.

Our failure to find familiarity preferences, in a relatively high-powered within-subjects design targeting partial encoding, should generate caution when inferring familiarity preferences, post-hoc, in similar experiments. Note, though, that 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 H&A 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 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 isolate the contribution of affect component 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 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 accounts of how the learning problem influences optimal attention. In environments in which past and present events are correlated, a tendency to attend to familiar events may arise to prepare for the most likely future events, while in uncorrelated environments, novelty preferences are optimal (under some assumptions, see Dubey & Griffiths, 2020). 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.

In conclusion, we find robust evidence for habituation and novelty preferences in preschoolers and infants. In the same paradigms, we find 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. Instead, 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.

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