Modeling Infant Visual Preference as Perceptual Oscillation

Benjamin Balas  
Psychology Department  
North Dakota State University  
Fargo, ND 58102-6050  
Email: benjamin.balas@ndsu.edu

Lisa Oakes  
Center for Mind and Brain  
University of California, Davis  
Davis, California  
95618  
e-mail: lmoakes@ucdavis.edu

Abstract—Infants’ visual recognition abilities are typically studied using variations of preferential looking paradigms. In this broad class of tasks, the extent to which infants discriminate between, categorize, and recognize complex images is determined by which of two test images they prefer to look at. This preference is usually expressed by calculating the proportion of total looking time allocated to a target stimulus (e.g., the stimulus that is more novel) on each trial. Although this coarse description of infant looking behavior has been sufficient to reveal a wide range of important effects, it also potentially obscures great deal of important visual behavior. As a result, we know less about changes in infant looking over learning and development than we would if visual behavior were measured in other ways. We argue that deeper understanding of learning and development of infants’ visual behavior requires appreciation of the dynamics of that behavior: During any individual trial, infants look back and forth between stimuli several times. These oscillations between stimuli may reflect aspects of visual processing that have been heretofore overlooked. We suggest that modeling the distribution of look durations made across trials provides a rich description of looking behavior that makes it possible to approach preferential looking as a form of perceptual oscillation, and may provide additional understanding into learning and development. Here we show how fitting the parameters of a gamma distribution to infants’ look durations in a face recognition task allows us to see effects that are not evident when simpler descriptors are used and discuss how this approach supports the interpretation of infant behavioral data in the context of neural models of visual competition.

Index Terms—visual development, preferential looking, perceptual oscillation, modeling

I. INTRODUCTION

The visual system develops rapidly during the first year of life and infant observers’ capacity to process complex visual patterns including faces, objects, and textures changes as a function of maturation and visual experience. The extent to which infants can recognize or discriminate between complex patterns is typically inferred by their performance in some sort of preferential looking task. In these tasks, infants’ preference for one test image over another is the dependent variable that is used to decide if the infant exhibited behavior consistent with discrimination, recognition, etc. There are many instances of such tasks: In a visual preference task, infants typically are presented with two images on each trial and their preference for one image over another is assessed without any manipulation of their recent visual experience in the laboratory. By contrast, a visual paired-comparison (VPC) [1] task relies on a manipulation of recent visual history that is meant to induce a preference for one test image over the other. In these tasks, infants are familiarized with a stimulus for a pre-determined amount of time, after which they are presented with that same image (or one much like it) paired with a novel stimulus. The initial familiarization period is meant to make the novel stimulus more salient, leading to a preference for that image. We note, however, that in some situations infants may also show a familiarity preference rather than a novelty preference [2] but in either case lack of a preference in VPC tasks is often interpreted as an inability to discriminate between the two test images. Besides these two commonly used tasks, there are many elaborations on these basic designs that are meant to reveal the properties of other visual processes like categorization, identification, and aesthetic preference. The application of these empirical methods has revealed a great deal about the nature of infant visual recognition. For example, preferential looking methods have been successfully used to investigate the role of visual experience in the development of face recognition. One such phenomenon is that perceivers—infant and adults—are more sensitive to differences between faces of their own race than they are to differences between faces of other races. The development of this so-called “other race” effect in infancy has been characterized using visual preference [3], VPC tasks [4,5], and categorization tasks [6].

Though visual preference is a powerful methodological tool for understanding infants’ visual capabilities, we suggest that the typical approaches to the analyses of the data from these tasks are limited in important ways. By far, the most commonly used descriptor of infant visual behavior in preferential looking tasks is the proportion of looking time spent on the target stimulus. For example, in a
standard visual preference task, when presented with two images side by side, a single infant may exhibit a 60% preference for the preferred image—that is, over the course of an entire trial (or series of trials), 60% of the time this infant spent looking at either image was spent looking at the preferred one. Though this single descriptor has been enough to capture many features of infant visual processing, it also severely obscures the dynamic nature of infant visual behavior during these tasks and thus may limit our ability to see some properties of visual discrimination and recognition.

**Figure 1** – Schematic depictions of looking behavior by two infants who have the same proportion of their looking time to the preferred stimulus (60%, in red). Red and blue bars in each rectangle represent the amount of time spent on each of two images (i.e., the duration of individual looks to the two stimuli) over the course of a single trial. Though both infants spend 60% of their time looking at the image represented by the color red, the second infant (bottom) alternates between the two images while the first (top) does not. This is a simple example of dynamic behavior that is not captured by traditional analyses.

Consider the infant just described who was assigned a preference score of 60%. Although this score indicates that this infant looked more at—and thus preferred—the preferred item, this score alone tells us little about how the infant achieved this preference. Perhaps this infant examined one of the test images for an unbroken 6-second period and then looked at the second image for an unbroken 4-second period. These two looks together yield a 60% preference for the first item. However, there are other looking patterns that might have resulted in exactly the same 60% preference. Imagine that the infant alternating rapidly between the two images, each time dwelling a bit longer on one than the other. The bottom half of Figure 1 might represent the infant alternating looks to the two images, first exhibiting 4 1-s looks, then a 2-s look, and then a 4-s look. Overall, the infant looked 4-s to the first image (2 1-s looks then a 2-s look, represented in blue) and 6-s at the second image (2 1-s looks and a 4-s look), but the pattern of looking seems to reflect different processes than the first pattern described, and illustrated in the top half of Figure 1. The point is that although these infants have the same proportion of looking time to the preferred stimulus, they also clearly have vastly different behavioral patterns—“sticky” fixation to each stimulus in the first case and rapid alternation in the second case. Examining only the visual preference would lead to the conclusion that infants’ responding in the two situations was the same. Evaluating the dynamics of infants’ looking, in contrast, reveals differences, and those differences may reflect differences in processing that emerge with age, learning, experience, or some other factor. Thus, determining a means of analyzing infant visual preference such that richer aspects of looking behavior like this can be measured and compared across conditions may reveal important aspects of infant vision that we have heretofore been largely unable to see. The challenge is to identify a principled means of capturing the richness of dynamic infant looking, ideally with analytic techniques that relate easily to the putative cognitive and neural processes that support the visual functions we are interested in.

We suggest that one possible solution to the problem of capturing the dynamics of infants’ visual behavior may be to apply tools and techniques from the binocular rivalry literature. Binocular rivalry refers to a form of perceptual oscillation in which observers are simultaneously presented with two images, one to each eye (often achieved using red-green anaglyphs or a stereoscope). The subjective percept resulting from this stimulus configuration is an ongoing oscillation between the two images: Each image “dominates” perception for an interval before being replaced by the other image, and so on. The ongoing oscillation between the two images is reasonably well-described by a simple model of mutual inhibition (Figure 2). In such a model, the input from each eye competes with the input from the other via inhibitory connections and the changing strength of these inhibitory connections relative to the excitatory connections that drive conscious perception determines which image the observer will see over time. Critically for our purposes, the binocular rivalry literature has long relied on rich quantitative descriptions of the dynamics of dominance and suppression that relate behavioral data to a neural model of visual competition. Specifically, Levelt [7] introduced the use of the gamma distribution (see Eqn. 1) as a tool for describing the distribution of percept durations in binocular rivalry tasks. Aside from the fact that it tends to offer a reasonable fit to empirical data (though see Brascamp [8] for a critical evaluation of this point), the gamma distribution also offers a useful neural model for understanding how perceptual oscillations work: A hypothetical “Poisson clock” that generates random ticks will also generate gamma-distributed latencies, suggesting that rivalry (and other oscillations) may depend on some abstract neural “events” that occur randomly. This implies that observers’ oscillations between subjective percepts can be described in terms of the accumulation of “ticks” (or neural spikes) necessary for the suppressed stimulus to become dominant. The parameters k and λ (typically referred to as the shape and scale parameters, respectively) in the expression above thus describe the underlying properties of the neural process that putatively governs the oscillation between two percepts. Single-unit recordings from non-human primates [9] are broadly consistent with this account, suggesting that this relationship between the hypothetical “Poisson clock,” real neural events, and subjective experience is meaningful. In the case of binocular rivalry and other bistable percepts [10], gamma distributions thus offer a way to model a process whereby stimuli compete for conscious awareness.
We suggest that it may be fruitful to consider infant visual preference in similar terms. It is of course not strictly accurate to say that infants “suppress” the image they are not looking at in a standard visual preference experiment – presumably they have a subjective experience of the image in their peripheral vision. Nonetheless, we argue that visual preference tasks are similar to other forms of perceptual oscillation insofar as two stimuli compete for a limited resource, leading to alternation between two or more states. Considering a standard schematic model of binocular rivalry (Figure 2), we suggest that the basic architecture of visual preference may largely resemble that of other forms of perceptual rivalry. Although we obviously cannot speak so directly to the underlying neural structures supporting visual preference, the dynamics of visual preference may nonetheless exhibit many of the same statistical properties and invite comparison across conditions on those terms. In the current experiment, we therefore examined infants’ performance in a VPC face recognition task using both standard measures of preference and the parameters of a gamma distribution fit to the look durations observed during extended trials.

Figure 2 - A schematic model of binocular rivalry, which we suggest may be useful for understanding infant visual preference. Stimuli compete to drive down-stream activity by mutually inhibiting one another, leading to oscillating suppression of one stimulus in binocular rivalry and possibly leading to preference for one image over another in preferential looking paradigms.

Our specific goal in this investigation was to determine the extent to which effects of visual experience over familiarity with faces during the course of an experimental session would be evident using traditional preference measures and gamma-distribution parameters. To that end, we presented infants with a series of VPC test trials in which a familiar face was depicted with a different novel face on each trial. Thus, over the course of the trials infants behavior reflects their increasing familiarity with and recognition of the familiar face and their preference (or lack of preference) for the novel face. The visual preference data recorded during these trials were subsequently analyzed using standard single-number descriptors of visual behavior (proportion looking time to the novel face) and the parameters of gamma distributions fit to individual subjects’ data. Briefly, we found that while standard measures of visual preference failed to reveal any learning, the parameters of the gamma distributions fit to the data did reveal such effects. Specifically, we find not only that gamma distributions reveal effects obscured by novelty preference scores, but that the profile of effects we observe suggest dissociable aspects of visual learning that change the dynamics of looking behavior as experience accumulates.

II. METHODS

Participants
Our final sample included 36 6-month-old (M = 182.00 days SD = 7.74; 20 girls) and 24 10-month-old (M = 307.83 days, SD = 7.04; 10 girls) infants from the greater Sacramento Valley region of Northern California. All infants had Caucasian parents. All infants were healthy, typically developing infants born at term with no history of vision problems.

Stimuli
We used 29 images of Asian women’s faces, obtained from a variety of face datasets. All women in a front-facing pose, expressing a positive neutral expression, without jewelry or head adornments (e.g., hats, scarves).

Procedure
In each experimental session, infants initially were presented with a single, brief familiarization trial with one item presented simultaneously on two screens side-by-side. This item was presented until infants accumulated 5 s of looking total to the two images. Next, we presented infants with a series of 28 trials in which that familiar face was presented with a different novel face on each trial; the left-right position of the novel face was counterbalanced across trials. Each trial continued until the infant accumulated 5 s of looking to the two faces combined. Trials were separated by an attention-getting stimulus, a looming circle accompanied by a whistle, which was presented until infants fixated it. When the experimenter judged that the infant was fixating this attention-getter, and thus was generally attentive to the screen, he or she depressed a key on the computer keyboard that ended the attention-getter and initiated the presentation of the experimental stimuli. During each trial, the observer recorded infants’ looking to the two images by pressing one key when the infant was looking at the left stimulus and a different key when the infant was looking at the right stimulus. Looks away from the stimulus were also recorded, but we have not included an analysis of this data here. From the left/right looking data, we derived several measures, all of which were calculated within each of four 7-trial blocks:

1. A traditional novelty preference measure, indicating at which points (if any) infants’ preference for the novel item differed from chance. This score is the percent of the 5 s of accumulated looking on each trial that infants devoted to
looking at the novel face. Traditionally, this measure would be taken as evidence about how long it took infants to learn or form a memory of the face.

2. The **scale parameter** of the gamma distribution represents (theoretically) the rate of information accrual, or the efficiency of information gathering. Higher scale scores correspond to taking longer to accumulate sufficient information to trigger the perceptual “events” that lead to a switch. We hypothesized that increased visual experience would lead to a decrease in the scale parameter, reflecting faster and/or more efficient visual processing. We therefore expected to see scale values decrease over the course of multiple experimental blocks (reflecting increasing efficiency as experience accumulates during the task).

3. The **shape parameter** of the gamma distribution represents (theoretically) the amount of information necessary for a switch to occur. Higher shape scores correspond to infants requiring more information (more perceptual “events”) before glancing from one item to the other. Similar to our reasoning regarding the scale parameter, we anticipated that we would see shape values decrease over the course of experimental blocks, reflecting increased efficiency for the stimuli in the experimental session as experience accumulates in the laboratory setting.

![Figure 3](image.png)

**Figure 3** – An example of a gamma distribution fit to the fixation data obtained from a single infant in a visual preference task. The distribution is parametrized via a shape term and a scale term, which we use as descriptors of looking behavior alongside traditional novelty preference.

III. Results

We computed standard measures of visual preference for each infant in each block of 7 trials by aggregating novelty preference across look durations. Gamma distribution parameters were estimated using the `gamfit.m` function in the Matlab Statistics Toolbox, yielding a shape and scale parameter for each set of look durations recorded during a 7-trial block (see Figure 3 for an example of an estimated distribution). Infants were excluded (N=9) on the basis of a poor gamma fit if the optimization procedure failed to converge, yielded values that were non-numerical because of poorly conditioned data, or if the values of the shape and scale parameters were many orders of magnitude larger than those obtained from other participants. We emphasize that these infants were only excluded from this analysis because we could not obtain meaningful gamma distribution parameters from their data and wished to compare outcomes using infants whose data allowed us to compute all 3 descriptors. The proper way to handle such cases is an important question for this analysis (and others based on distribution fitting). This is not a new issue, however, since infants are frequently excluded from studies using traditional measures because of pervasive “side-bias” which we argue represents a similar case of ill-conditioned data serving as the basis for exclusion.

We conducted separate Analyses of Variance (ANOVA) for each of our 3 dependent measures. These ANOVAs included trial block as the within-subject factor and age as the between-subjects factor. Novelty preference scores are bounded values (they cannot exceed 1 or be less than 0), which means that the use of ANOVA is potentially problematic. This is a common means of analyzing novelty preference scores however, so we have included this analysis here.

**A. Novelty preference**

The ANOVA on novelty preference yielded no significant effects or interactions (Figure 4, Panel A). This suggests that as a group infants failed to show robust and significant changes in their preference for the novel over the course of the session, and thus provide no clear evidence of having learned the familiar face. Indeed, inspection of the novelty preference scores shows that those scores were near .50 (or chance levels) throughout the session, with the exception that the 10-month-old infants had somewhat higher novelty preference scores in block 2 and 3. But, the pattern across blocks was not significant, nor were the differences between the age groups. Thus, based on this traditional measure, we would conclude that there was little change in learning and no differences in infants’ responding as a function of experience. This is contrary to what one might expect given that novelty preferences are often measurable in VPC tasks, but the robustness of VPC effects is not universal. It is thus not intrinsically surprising that we observed the pattern of novelty preferences that we report above.

However, we can evaluate infants’ learning in each block by comparing novelty preference scores to chance (.50). If infants’ can discriminate between the familiar and novel face, they should significantly prefer the novel face, and their novelty preference score should differ from chance. No scores for the 6-month-old infants were different from chance, confirming the conclusion from the ANOVA that these infants provided little evidence of learning. At 10 months, novelty preference scores for blocks 2 and 3 were marginally significant or significantly greater than chance, \( t(23) = 2.99, p = .06 \) for block 2 and \( t(23) = 2.27, p = .03 \) for block 3, indicating that in these two blocks infants did differentiate the novel and familiar faces. Because the pattern did not differ from that of the 6-month-old infants, and the changes over time did not reflect significant differences in preference, the evidence of learning by 10-month-old infants is modest.
Although the ANOVA did not yield significant effects, we did compare the novelty preference scores across blocks for each age for consistency across the three measures reported here. At 6 months, there was no significant change between blocks. At 10 months, the increase from block 1 to block 2 was significant ($p = .05$), and the decrease from blocks 2 and 3 to block 4 was marginally significant ($p = .06$). Thus, at this age there appears to be rapid learning followed by (perhaps) a decrease in interest, but the conclusions we can draw from novelty preference scores about changes in infants’ looking behavior are limited to whether or not they discriminate between the novel and familiar faces.

**B. Gamma distribution: Scale parameter**

The ANOVA on the scale parameter yielded a significant main effect of block, $F(3, 174) = 4.84, p = .003$, partial eta squared = .08. As is clear in Figure 4 (panel B), across blocks, the scale parameter increased suggesting that over time infants took longer to accumulate sufficient information to trigger a switch. This effect seems counter to our prediction that the scale parameter would decrease with experience, as infants became able to acquire information more quickly over the session and learning. However, our task context may have not allowed us the sensitivity to observe such an effect. Specifically, in this task infants’ were required to accumulate 5 s of looking on every trial—even after they (perhaps) had learned the face and were no longer interested in general. Indeed, we observed that over the blocks the amount of off-task time accumulated increased significantly. This issue needs to be addressed in future investigations.

The ANOVA also revealed a significant block by age group interaction, $F(3, 174) = 2.87, p = .04$, partial eta squared = .05. Comparisons of the scale score for each block revealed no change in the scale score across blocks for 6-month-old infants, but that the scale score for 10-month-old infants significantly increased from block 1 to blocks 3 and 4 and from block 2 to block 4. This difference, coupled with the fact that 10-month-old infants’ novelty preference scores were significant in the middle of the session, provide further evidence that the scale score is disproportionately influenced by general lack of interest in the task, at least as it was conducted here.

**C. Gamma distribution: Shape parameter**

The ANOVA on the shape parameter revealed a main effect of block, $F(3, 174) = 2.74, p = .05$, partial eta squared = .05. Across blocks, the shape parameter decreased (see Figure 4, panel C). Recall that the shape parameter is thought to reflect how much information infants need to accumulate before initiating a shift. This decrease in shape, therefore, suggests that with increased familiarity with a face, less information is needed to initiate a shift, and there was increased efficiency of processing across the session. No other main effects or interactions reached significance, indicating that this pattern did not differ significantly for 6- and 10-month-old infants. However, inspection of Panel C suggests that the effect was more robust for 10-month-old infants than for 6-month-old infants. Indeed, comparisons of the shape score across blocks revealed no significant differences at 6 months, but at 10 months the shape score on blocks 1 and 2 were significantly greater than that score on block 4 ($ps < .04$). Although these results are speculative given the lack of a significant interaction in the ANOVA, they are generally consistent with the other analyses and suggest that in contrast to the 6-month-old infants, the 10-month-old infants showed systematically changes in their looking behavior as they learned about the familiar face.

**IV. DISCUSSION**

These data demonstrate that by using a gamma distribution to characterize the dynamic nature of full distribution of look durations, we gain increased sensitivity to
measure behavioral effects and potentially gain insight into candidate mechanisms supporting those changes in looking behavior. If we had analyzed only the traditional measure of novelty preference, we would have concluded that there was weak evidence of developmental differences in learning—these score suggest that 10-month-old infants learn the familiar face rapidly, and 6-month-old infants failed to learn the familiar face in this session. However, these conclusions would be speculative because they were not supported by the ANOVA analyses, and are indicated only by a few key comparisons. Moreover, the conclusions we can draw about changes in visual behavior as a function of learning in this task are limited. We conclude that 10-month-old infants showed evidence of learning in block 2, and then they exhibit an ambiguous null preference—that is, they did not continue to differentiate the familiar from the novel (despite the fact that a different novel face was presented on each trial). Thus, this null preference is ambiguous. In general, when this type of visual preference task has been used in the past, testing ended when infants showed evidence of learning [11].

Our analyses of the gamma distribution parameters provide a richer understanding of the changes in infants’ looking behavior during their learning of this visual stimulus. Unlike the novelty preference measure, both the scale and shape scores changed significantly over blocks, and the changes were more pronounced and evident in the older infants. Thus, we observed infants’ learning in the changing values of parameters used to describe the full distribution of look durations observed during blocks of trials. Both the shape and scale parameter values changed over block, and these changes seemed to be more robust in the 10-month-old infants. Thus, older infants’ dynamic behavior seemed to change during the session. The first thing we can therefore say about the use of distribution-fitting in this instance is that it made it possible to see behavioral effects (in this case learning during the experimental session) that were not evident (or were only modestly evident) via traditional measures. This underscores the utility of using parametric models of behavior when we have reasonable prior expectations about the underlying shape of the data we are likely to collect. Independent to some extent of the particular distribution we choose to use, using the expected form of the data to guide the choice of descriptors we apply in our analysis is very likely to give us more expressive power to see interesting effects. In this sense, our result is commensurate with prior results demonstrating the utility of more sophisticated descriptors of fixation data [12,13] that can in some cases both provide insight into the behavior of infants considered as a group, as well as support meaningful analysis of individual infants’ behavior.

Besides this very basic conclusion about our analysis, we can make tentative inferences about the nature of learning in this task that follow from our assumptions about the underlying mechanisms that generate behavioral data consistent with a gamma distribution. That is, beyond simply saying that the parameters we estimate from a gamma-distribution are more sensitive, those parameters also allow us to make statements about the mechanisms behind changes in visual behavior over learning. Specifically, if we accept the assumption of an underlying clock-like mechanism that generates “events” that contribute to stimulus dominance (in this case, looks to one image over another), then the changes we observed in the shape and scale parameters over the course of experimental blocks correspond to changes in how perceptual oscillation depends on properties of that clock. The scale parameter of the gamma distribution reflects the rate at which perceptual events occur, and so the observed increase in scale as a function of experimental block suggests that during the experimental session infants require more time to accrue enough information to trigger whatever “event” supports oscillation. This slower rate of information accrual may be a by-product of boredom rather than learning per se, since we would typically associate learning with increased efficiency and rapid, fluent processing of visual stimuli. This conclusion is supported by the observation that these scale changes were more pronounced in the 10-month-old infants, and seemed to occur after they had learned the face (as evidenced by a significant novelty preference score). Thus, features of the task may have elicited more “off-task” behavior from the older infants once they had learned the face. Future research will address this possibility. By contrast, the changes we observed in the shape parameter are more consistent with this characterization of learning. We observed decreasing shape values as a function of experimental block. The shape parameter reflects the number of perceptual events required to trigger a perceptual oscillation, so decreasing shape values over time suggest that infants require fewer events over the course of a session to change their fixation from one face to the other. Again, this was more pronounced in the 10-month-old infants who showed the clearest evidence of learning.

We thus are able to tentatively separate two aspects of experience/learning as they occur during an extended experimental session: (1) Increased exposure to experimental stimuli leads to habituation/boredom, which impacts the scale parameter of the underlying gamma distribution. (2) Increased fluency with the experimental stimuli over time decreases the number of abstract “events” infants need to switch their gaze, leading to changes in the shape parameter of the distribution. Distribution fitting thus gives us insights into the mechanisms of learning and makes it possible to identify the contribution of distinct sub-processes that may each reflect familiarity acquired during an experimental session. Importantly, this theoretical framework suggests a mechanism by which looking behavior changes over the course of familiarity. That is, analyzing these parameters adds to our understanding of why infants’ looking changes with familiarity and allows us to make predictions about what factors would influence each factor. Therefore, this approach has the potential to allow us deeper insight into mechanisms that do (or do not) change over development that contribute to difference in learning of visual stimuli.

Although our analytic approach has a great deal of potential for describing visual preference data in a manner that may reveal important aspects of learning, there are also some important theoretical questions to consider. In particular, the theoretical link between the gamma distribution parameters and underlying clock-like mechanisms depends on an analogy between neural data (where perceptual events are actual spikes) and behavioral data remains speculative. What are the “perceptual events” that govern perceptual oscillation in this setting? Is the “Poisson clock” interpretation of the shape and
scale parameters the best way to describe looking behavior and the processes it depends on? We obviously cannot make strong statements about neural firing given that we are only measuring looking behavior, but what is the right mechanistic description to apply? We have talked about the data here in terms of a fairly loose analogy between the shape and scale parameters and the rate of information accrual, but the strongest case for using distribution-fitting methods would be made by establishing a firmer relationship between the estimated parameters and clearly specified mechanisms. This report is a first step towards that ambitious goal and we do not pretend to have the final word on this substantial open question. For now, we offer an initial demonstration that gamma distributions offer increased sensitivity (conferring a clear analytical benefit) and speculate that the theoretical link to perceptual oscillation may be useful, even though alternative models remain to be explored. Besides these substantial theoretical questions, there are also basic questions about these descriptors that would be useful for future work: What is the test-retest reliability of the shape and scale parameters? Are these parameters time-invariant (consistent over different temporal scales)? In general, are shape and scale values correlated?

Another important direction for further application of gamma distributions to infant preferential looking data is to examine the extent to which visual preference exhibits the same properties as other perceptual oscillations, most notably binocular rivalry. Binocular rivalry is of special importance because a range of BR phenomena can be accounted for by a small set of “laws” [14] which encapsulate several important aspects of how variation in stimulus properties (particularly stimulus strength) affect the dynamics of perceptual oscillation. If visual preference exhibits similar adherence to these lawful relationships, then discussing visual learning in terms of changes in visual salience or the fidelity of perceptual representations of the stimulus could potentially be incorporated into our interpretations of any effects we observe on the dynamics of looking behavior.

V. CONCLUSION

We have demonstrated that quantitative modeling of infant visual behavior during preferential looking tasks can reveal effects of visual experience that traditional descriptors do not capture. Like other forms of perceptual oscillation, visual preference in infancy can be usefully described by the parameters of a gamma distribution. This approach has both practical and theoretical value, because the application of the gamma distribution links preference to specific computational mechanisms of visual competition, making it possible to make inferences about the impact of experience (and other factors) on neural processes.

ACKNOWLEDGMENT

This research was supported in part by NEI grant EY-024375-01 awarded to BB and by NSF grant BCS 0951580, awarded to LMO.

REFERENCES