RUNNING HEAD: Perceptual grouping in infants

# A longitudinal study of perceptual grouping by proximity, luminance and shape in infants at two, four and six months

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## Abstract

Grouping by luminance and shape similarity has previously been demonstrated in neonates and at 4 months, respectively. By contrast, grouping by proximity has hitherto not been investigated in infancy. This is also the first study to chart the developmental emergence of perceptual grouping longitudinally. Sixty-one infants were presented with a matrix of local stimuli grouped horizontally or vertically by luminance, shape or proximity at 2, 4, and 6 months. Infants were exposed to each set of stimuli for three presentation durations. Grouping was demonstrated for luminance similarity at the earliest testing age, 2 months, by shape similarity at 4 months, but was not observed for grouping by proximity. Grouping by shape similarity showed a distinctive pattern of grouping ability across exposure durations, which reflected familiarity preferences followed by novelty preferences. This remained stable across age. No link was found between the emergence of perceptual grouping ability and the exposure duration required to elicit grouping. We conclude by stressing the importance of longitudinal studies of infant development in furthering our understanding of human cognition, rather than relying on assumptions from the adult endstate.

Keywords: Infant development, perception, preferential looking

## Introduction

Perceptual grouping was first introduced by Gestalt psychologists and is described as the process by which local elements within a visual scene are grouped together into an organised whole (e.g., Kohler, 1929; Wertheimer, 1923). Perceptual grouping occurs according to a set of Gestalt grouping principles such as grouping by proximity, similarity (e.g. luminance, shape, or colour similarity), good continuation and closure (Wertheimer, 1923). Two further principles have also recently been added: common region and uniform connectedness (Palmer & Rock, 1994). The function of perceptual grouping is to form objects for object recognition, to direct selective attention, and to increase efficiency in processing (see Gillam, 2001). It is thus a vital aspect of perceptual organisation.

Perceptual grouping was once thought to be a single mechanism that operated automatically when an object was attended to (e.g. Kohler, 1929). However, more recent investigations of infant and adult participants have demonstrated that perceptual grouping is not operated by a single mechanism. For infants, the ability to perform perceptual grouping emerges at different developmental time points for each grouping principle (e.g., Quinn et al. 2002). For adults, the perception of grouping is dependent on presentation duration, which again differs for each grouping principle (e.g., Ben-Av & Sagi, 1995).

The development of perceptual grouping from infant startstate to the adult endstate has received little attention. Enns & Girgus (1985) compared the effects of perceptual grouping on perceptual judgement from 5 years to adulthood and demonstrated a reduced spatial distortion effect with age. Kimchi et al. (2005) also investigated development from 5 years to adulthood. They reported different developmental trajectories when local elements were few and large compared to small and many. This shows further evidence that perceptual grouping is operated by a number of mechanisms. Developmental comparison across perceptual grouping types is not evident in the literature either cross-sectionally or longitudinally. The present study investigates perceptual grouping longitudinally from the first 2 to 6 months of life, in an effort to capture the emergence and early development of perceptual grouping.

A method common to both the infant and adult literature is to present the participant with a matrix of elements that can be grouped either horizontally or vertically. In studies with infants, grouping is then assessed through preferential looking. For example, Quinn et al. (1993) presented 3 month-old infants with a matrix of squares in a 4 by 4 formation, which were grouped by luminance similarity (squares were dark or light) into columns or rows. After familiarisation to the luminance stimulus, Quinn and colleagues presented infants with two stimuli depicting vertical and horizontal stripes, respectively. Infants displayed a novelty preference for the horizontal stripes after familiarisation to stimuli organised by luminance into columns, and a preference for vertical stripes after familiarisation to rows. This demonstrates that luminance grouping is present at 3 months. Using similar stimuli, Farroni et al. (2000) have since shown that grouping by luminance similarity is present in neonates. It appears, therefore, that this form of grouping may be a process operating at birth.

Studies of luminance similarity have been supplemented by studies of shape similarity. Quinn et al. (2002) presented infants with arrays of X and O elements, which could be grouped horizontally or vertically by shape similarity. To our knowledge, this is the only study that has used more than one presentation duration. Infants saw stimuli for six (Experiment 1) or twelve (Experiment 3) 15-second presentations. In all other respects, the methodology was the same as that used in Quinn et al. (1993). Results showed that, regardless of presentation time, infants aged 2-4 months showed no sensitivity to grouping by shape, but a novelty preference indicated that this type of grouping ability had emerged in a group of 6 to 7 month old infants. Quinn & Bhatt (2005) further investigated grouping by shape similarity in 3- to 4-month-old infants. In Experiment 1 infants were familiarised to either H and I elements or square and diamond elements for six periods of 15 seconds. In Experiment 2, infants were familiarised to three stimulus sets (H-I, square-diamond and X-O) for two 15 second periods each (a total of 6 periods). In Experiment 2, but not Experiment 1, infants showed evidence of grouping at 3 to 4 months. Quinn & Bhatt (2005) suggest that infants are able to group by shape similarity at 3 to 4 months provided that they are exposed to various examples.

The above evidence indicates that Gestalt principles become functional over different developmental time courses and in turn that Gestalt grouping is accomplished by different mechanisms. In the adult literature, variations in the processing time required for each grouping type are also thought to provide evidence for different grouping mechanisms (Chen, 1986). For example, Chen (1986) demonstrated that grouping by proximity occurred at shorter presentation durations than grouping by orientation similarity, and that grouping by closure occurred earlier than grouping by orientation similarity. Ben-Av and Sagi (1995) also reported differences in processing time across grouping types. They found that proximity grouping occurred before grouping by either luminance or shape similarity, and that there was no difference between the two types of similarity grouping, luminance and shape. Chen (1986) suggested that differences in processing time are indicative of the level of computational complexity, i.e., that processing time increases with computational complexity.

In addition, Kurylo (1997) compared two forms of spatial grouping abilities, proximity and good continuation, in adults and demonstrated faster grouping in the former than the latter. Along a similar vein to Chen (1986), Kurylo suggested that although both types of grouping rely on spatial awareness, grouping by alignment may be computationally more intensive than grouping by proximity.

It is clear that both the infant and adult literature provide evidence that Gestalt grouping is not driven by one mechanism. What is not clear is whether the commonality stops there or whether emergence and presentation duration index a common underlying factor, such as cognitive efficiency. It is possible that there is a relationship between presentation duration and the emergence of perceptual grouping in infancy. We refer to this as the ‘efficiency’ hypothesis. Note that, to support this hypothesis, the pattern of presentation durations that elicit each grouping type should not mirror that observed in adulthood, but should mirror the pattern of emergence, i.e., the earlier emerging forms of grouping, once emerged, should be evident at relatively shorter presentation durations than the later emerging forms of grouping. It would be erroneous to ignore the actual process of development over time by simply assuming that the pattern of performance observed at an adult end-state is present and fixed from birth.

If, on the other hand, the differences in perceptual grouping observed in infancy and in adulthood reflect different variables, then those grouping principles which emerge earlier in development should not necessarily be processed at relatively short presentation durations. An alternative prediction is that during the process of development, there is an optimum or threshold presentation duration at and beyond which low-level visual processing, such as perceptual grouping, is most likely to be elicited (which might or might not vary with development), and that only once the developmental process is complete does a second factor come into play. This second factor relates to differences in presentation duration across types of perceptual grouping. We refer to this as the ‘constancy’ hypothesis.

In summary, for adults, the dominance of one grouping type over another is dependent on presentation duration (e.g., Ben-Av & Sagi, 1995) and for infants, not all forms of perceptual grouping are innate or present from birth (e.g., Quinn et al. 2002). In the present study, emergence and exposure duration are employed as complimentary measures of perceptual processing, which is one of the first to bring the adult and infant literatures together.

We aim to determine at what point in development, an infant’s cognitive system is suitably efficient to perform perceptual grouping. Once emerged, any differences in the processing time across Gestalt principles will be observed. This will be tracked developmentally in infants at 2, 4 and 6 months. It is our view that the brain is a dynamic structure which becomes specialised through the gradual process of development (see discussions in Karmiloff-Smith, 1998, 2002). Thus, processing time is an ideal measure with which to track this process. It has the potential to provide a measure of development which is far more sensitive than previous studies of perceptual grouping in infancy.

To our knowledge, grouping by proximity has hitherto not been investigated in infancy. Therefore, proximity grouping is investigated in the present study as well as further investigation of similarity grouping by shape and by luminance. Based on previous investigations with infants, it is predicted that grouping by luminance similarity, but not by shape similarity, will be available at 2 months and that grouping by shape similarity will be available by 6 months. Predictions cannot be made for the emergence of proximity grouping. Emergence and processing time will be evaluated to determine whether they measure the same or different factors relating to perceptual grouping mechanisms. The efficiency hypothesis predicts that the order in which grouping abilities emerge will relate to presentation duration at later points in development. That is, once emerged, earlier emerging grouping types will require less processing time than later emerging grouping types. Processing time might also reduce with development. The constancy hypothesis predicts no relationship between the order of emergence and the processing time required for perceptual grouping to occur, and no developmental changes in processing time while the ability to use perceptual grouping is still emerging.

## Method

### *Participants*

Sixty-one full-term infants were recruited from the Royal Berkshire Hospital maternity wards in Reading, Berkshire, UK. Testing took place at two, four and six months of age. The attrition rate was reasonable, with a minimum of 42 infants being tested at subsequent testing ages. Due to fussiness, not all infants completed all three grouping experiments. Similarly, not all infants completed all three presentation durations within a single grouping type. Some data were also eliminated due to the infant showing a side bias, a bias to either the vertical or horizontal test stripes at baseline, or general disinterest (less than 15% of the available time spent looking at the test stripes). Participant numbers for each of the three grouping types (infants who completed at least one presentation duration) at each testing age are shown in Table 1.

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Table 1 about here

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*Stimuli*

Stimuli were globally equated for luminance (all had an overall luminance of 50 to 55 cd/m$^2$). There were three familiarisation stimuli, one for each of three grouping types (shape, luminance, proximity) as shown in Figure 1. Each familiarisation stimulus was a matrix of local elements which subtended a visual angle of 16.5 degrees squared and displayed 16 stimuli in a 4-by-4 formation, with the exception of the proximity matrix which displayed 24 stimuli in a 4-by-6 formation. Circle and square stimuli were employed to similar extents overall; luminance stimuli were circles, proximity stimuli were squares, and shape stimuli were squares and circles. Local elements subtended a visual angle of 2.4 degrees squared.

The test stimuli subtended a visual angle of 16.5 degrees squared and displayed four dark and three light stripes, each with an angle of 16.5 by 4.1 (Figure 2). The dishabituation stimulus was a red circle on a black background, the circle subtending a visual angle of 15 degrees across the diameter.

Figures 1 and 2 about here

*Design and Procedure*

Infants were placed in a car seat within a booth. They viewed stimuli, back-projected onto a screen, which was 50cm in front of them. For each grouping type, a baseline trial preceded three experimental trials. The baseline trial established a baseline preference to two test stimuli presented to the left and right respectively. One test stimulus depicted vertical stripes and the other depicted horizontal stripes (Figure 2). These were presented for ten seconds, followed by a left-right reversal for a further ten seconds. After the baseline trial, participants took part in three experimental trials of the same grouping type, presented in a fixed order. Each consisted of presentation of the familiarisation stimulus (Figure 1: a matrix of local elements, which could be grouped vertically into columns or horizontally into rows), followed by presentation of the test stimuli using the same procedure as at baseline. Thus, after baseline preference testing, infants' preferences for horizontal versus vertical stripes were tested three times in the following order: once after a single 10-second presentation of the familiarisation stimulus (prehabituation condition), once after habituation to the familiarisation stimulus had occurred (habituation condition), and finally after re-habituation to, and a further two 10-second presentations of, the familiarisation stimulus (habituationplus condition). Infants were then dishabituated by presenting an attention grabbing, novel, coloured stimulus of a red circle on a black background. This procedure was then repeated for the remaining grouping types until the infant had been assessed for all three grouping types. The order of presentation of each grouping type was counterbalanced across participants.

Habituation was determined using a standard 50% decrement habituation procedure (Horowitz, Paden, Bhana & Self, 1972). During habituation trials, the experimenter pressed a button to record the duration of each fixation on the familiarisation stimulus. Thus, in the habituation trials, the infant was judged to have habituated when, from the fourth presentation onwards, looking time to three consecutive 10-second presentations of a stimulus had reduced to 50% of that infant's looking time on the first three 10-second presentations. In the habituationplus condition, the infant was judged to have re-habituated when looking time to three consecutive 10-second presentations of a stimulus had reduced to 50% of that infant's looking time on the first three 10-second presentations of the habituation trial.

The testing session took no longer than twenty minutes. Breaks were given between grouping types if the child became agitated or upset. Grouping organisation into rows and columns was counterbalanced such that a single participant viewed the first and third grouping type organised in one dimension (50% of participants viewed rows first and 50% viewed columns first) and the second grouping type organised in the opposing dimension.

## *Results*

The primary observer was naïve to whether a familiarity or novelty preference was anticipated. A second observer coded a random 10% of the data at each of the testing ages. Inter-rater reliability was consistently good (see Seigal & Castellan, 1988): Cohen's Kappa: 2 months, mean (s.d.) = 0.82 (0.12); 4 months, mean (s.d.) = 0.84 (0.10); 6 months, mean (s.d.) = 0.85 (0.02).

### *Exposure duration*

As presentation durations were infant controlled using a habituation procedure, the cumulative exposure time to each stimulus type was calculated in seconds (see Table 2). One-way ANOVAs were carried out for the habituation and habituationplus conditions for each testing age, with grouping type as a between participant variable (3 levels: luminance, shape, proximity). Habituation and habituationplus exposure times did not differ across grouping types ($p>.05$). Thus, all grouping types took approximately the same length of time for infants to habituate to.

Exposure duration was also analysed longitudinally. In order to maximise participant numbers, exposure duration was averaged across grouping type for each age group for habituation and habituationplus conditions separately (exposure duration at the prehabituation condition was fixed at 10 seconds). ANOVAs were calculated for each condition, with one between participant factor of age (3 levels: 2, 4, and 6 months). This demonstrated a main effect of age at both the habituation and habituationplus conditions due to reduced exposure duration with increasing age (reported as a linear contrast: habituation, $F(1, 36)=13.76$, $p=.001$, partial $\eta^2=.28$; habituationplus, $F(1, 35)=16.64$, $p<.001$, partial $\eta^2=.32$).

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Table 2 about here

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*Perceptual grouping*

Preferences to horizontal and vertical stripes were measured using a difference score between the longest look to the novel and to the familiar stripes. Longest look is defined as the longest duration of uninterrupted looking made by the infant to each stimulus (e.g. Houston-Price, Plunkett & Harris, 2005). The difference score was calculated by subtracting the longest look (msec) to the familiar stripes from the longest look to the novel stripes (msec) for each of the two ten second presentations. The average of these two scores was employed. Thus, for each individual, a single score was obtained for performance at baseline, prehabituation, habituation and habituationplus. Longest look difference scores are shown in Figures 3, 4 and 5, where a positive difference score indicates a novelty preference and a negative score indicates a familiarity preference.

Each grouping type was analysed separately using paired t-tests between the baseline and the test condition (prehabituation, habituation or habituationplus). Positive and negative t-values represent novelty and familiarity preferences respectively. As no predictions were made regarding novelty or familiarity, all p-values reported are for a two-tailed hypothesis.

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Figures 3, 4 and 5 about here

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*Grouping at 2 months*

There was a familiarity preference for grouping by luminance similarity in the habituation condition ($t(44)=2.12$, $p=.04$). Grouping by luminance was not significant in the prehabituation or the habituationplus conditions ($p>.05$ for all).

There was no evidence of grouping by shape similarity or by proximity at 2 months ($p$>.05 for all)

*Grouping at 4months*

At 4 months, grouping by luminance was not evident ($p$>.05 for all). Grouping by shape similarity was evident in the habituationplus condition, demonstrated as a novelty preference ($t$ (34) =-2.01, $p$=.04). Grouping by shape was not evident in the prehabituation or habituation conditions ($p$>.05 for all). Grouping by proximity was not evident ($p$>.05 for all).

*Grouping at 6 months*

At 6 months, the evidence for grouping by luminance was marginal, observed as a familiarity preference in the habituationplus condition ($t$ (33) =-1.85, $p$=.07). There was also marginal evidence of grouping by shape in the habituation condition, this time shown as a familiarity preference ($t$ (33) =1.90, $p$=.07). There was no evidence of grouping by proximity ($p$>.05 for all).

*The development of perceptual grouping: longitudinal analysis*

Perceptual grouping performance was analysed longitudinally for each grouping type. The number of infants that contributed to a full data set across all three testing ages was 20 for the luminance task, 14 for the shape task and 16 for the proximity task. Longest look data for each of the three test conditions were converted into z-scores based on the mean and standard deviation of baseline performance for that testing age. Positive and negative z-scores represent novelty and familiarity preferences respectively.

We are interested in both an effect of presentation condition, and how this might interact with age. Thus for each grouping type, ANOVA was carried out with age (three levels: 2, 4 and 6 months) and presentation condition (three levels:

prehabituation, habituation and habituationplus) as within participant factors. This revealed no significant main effects of presentation condition (luminance: $F(2, 38)=1.78$, $p=.18$, partial $\eta^2=.09$; shape: $F(2, 26)=2.07$, $p=.15$, partial $\eta^2=.1$; proximity, $F<1$) , or significant interactions between age and presentation condition (luminance: $F(4, 76)=1.45$, $p=.28$, partial $\eta^2=.07$; shape: $F(2, 26)=2.07$, $p=.15$, partial $\eta^2=.14$; proximity, $F<1$).

*The development of perceptual grouping: cross-sectional analysis*

Analysis was also carried out where testing age was treated as a between participant variable. This avoids the drop in Ns for each age group, observed in the longitudinal analysis. ANOVA revealed a main effect of presentation condition for shape ($F(2, 230)=5.28$, $p=.01$, partial $\eta^2=.04$) due to significantly lower z-scores for the habituation condition than for the prehabituation and habituationplus conditions ($p<.05$ for all). There was no main effect of presentation condition for grouping by luminance ($F(2, 228)=2.22$, $p=.11$, partial $\eta^2=.02$) or by proximity ($F<1$). There were no significant interactions between presentation condition and age ($F<1$ for all).

## *Discussion*

The current experiment investigated grouping by luminance similarity, shape similarity and proximity longitudinally in infants aged 2, 4 and 6 months. Results showed that grouping by luminance similarity is available by two months, whilst grouping by shape similarity is available at 4 months. Grouping by luminance similarity has already been observed in neonates (Farroni et al., 2000). Our finding is, therefore, in line with predictions. Quinn & Bhatt (2005) demonstrated grouping by shape similarity at 3 to 4 months, but only when infants were familiarised to a variety of stimuli. This is, therefore, the first study to demonstrate grouping by shape similarity as young as 4 months when one type of grouping stimulus is presented.

Grouping by proximity was not evident in infants at 2, 4, or 6 months. It is possible that this type of grouping emerges beyond 6 months of age. In this study, the proximity stimuli were designed in a way that maintained consistency across grouping types. That is, the visual angle of the elements was the same across all three grouping types, and the number of elements in the least proximal dimension in the proximity condition (i.e. 4 elements) was the same as the number of elements in both vertical and horizontal dimensions for the luminance and shape similarity conditions. Despite this consistency across grouping types, it is possible that grouping was not equally salient across the stimuli (see Kaldy, Blaser & Leslie, 2006), and that the proximity stimuli failed to capture the ability to group by proximity. A number of variables could be manipulated in future studies to determine this. For example, one could manipulate the ratio of elements in the more proximal dimension compared to the less proximal dimension, or the size of the elements relative to the spacing between the elements could be varied. The three grouping types could also be calibrated for salience. As there are no other studies of grouping by proximity in infants, the present findings can inform future investigations.

Quinn et al. (2002) and Quinn & Bhatt (2005) demonstrated that infants aged 3-4 months did not show grouping by shape similarity when presented with a single stimulus type, but did show grouping when presented with a variety of grouping stimuli. The present study indicated that infants aged 4 months can group by shape similarity, when presented with squares and circles. This difference across studies could relate to differences in the salience of perceptual grouping stimuli employed. Further investigation could determine the relative salience of different types of shape similarity. Related to this, it is even possible that, although 2 month olds cannot group by squares and circles, and 2-4 or 3-4 month olds can't group by the stimuli employed by Quinn and colleagues, that the ability to group by shape similarity might emerge at an even younger age than 4 months, but that no-one has yet employed sufficiently salient stimuli.

Quinn et al. (2002) used X-O stimuli and Quinn & Bhatt used X-O, H-I and square-diamond stimuli. One could argue that each of these is confounded by other grouping types. The X-O stimuli differed both by shape similarity and by closure (circles: closed stimuli, crosses: open stimuli), and the H-I and square-diamond stimuli were identical in form, but differed in orientation. This argument is also true of the present stimuli; whilst the visual angle across the diameter of the squares and circle were equivalent, the area of the squares was larger than the area of the circles. It is possible that differences in the emergence of grouping by closure, orientation and size dictated infants' grouping ability rather than the intended grouping type. This could explain why our stimuli were singly more able to elicit grouping in young infants, perhaps both grouping by shape and size similarity have emerged by 4 months, but grouping by closure and orientation have not. The potential impact of confounding grouping types can also explain why Quinn and Bhatt (2006) showed grouping after exposure to a variety on stimuli, as infants were then able to observe the commonalities across these stimulus types, i.e. shape similarity. Grouping by shape similarity is difficult to isolate. For example, if the stimuli in the present study were equated by size, the diameters of each shape would no longer be equal, thus affecting the relative proximity between each element type. In future, studies could measure the influence of confounding variables by examining the effect of grouping of each confounding variable, such as orientation or size, in isolation (where possible).

A second explanation for the difference in results between studies could be accounted for by the slight age difference between the infants employed in the present study (4 months) and those of Quinn and colleagues (3-4 months). Perhaps the period between 3 and 4 months represents the critical period for the emergence of grouping by shape similarity. Further investigation could elucidate these possibilities.

Perceptual grouping performance was observed as the exposure duration to the familiarisation stimulus increased across three presentation durations: a single ten-second presentation (prehabituation condition), habituation (habituation condition), and re-habituation and a further two ten-second presentations (habituationplus condition). The order of presentation of the three grouping types was counterbalanced across participants and no order effects were observed, indicating no observable fatigue across infants during the testing session. Grouping was elicited from the habituation and habituationplus conditions, but not the prehabituation condition. This suggests that the prehabituation duration was insufficient for infants to discriminate between the individual elements, or that despite being able to discriminate, the exposure duration wasn’t long enough to group the elements.

We presented two possible predictions for patterns of data regarding presentation duration. First, the efficiency hypothesis states that the emergence of grouping ability and presentation duration represent a common factor. Once established, those grouping patterns that emerge first should be evident at relatively shorter presentation durations than those that emerge later. Second, the constancy hypothesis suggests that there is a threshold presentation duration from which perceptual grouping is evident and that this threshold remains constant until the developmental process is complete. As grouping by proximity was not evident by 6 months, our hypotheses are assessed in relation to grouping by luminance similarity and by shape similarity only.

Consistent with previous studies, the results demonstrate that grouping by luminance similarity emerges before grouping by shape similarity. Following the efficiency hypothesis, one would therefore predict that, once emerged, grouping by luminance similarity would be evident at a shorter presentation duration than grouping by shape similarity. The efficiency hypothesis is not supported at any testing age. Both grouping types have emerged by four months. However, at this testing age grouping by luminance similarity is no longer evident. At 6 months both grouping by luminance similarity and by shape similarity are marginally evident. However, luminance similarity, which emerges earlier than shape similarity, is evident at a longer presentation duration than shape similarity.

In both the longitudinal and cross sectional developmental analyses, presentation condition failed to interact with age, which shows further evidence against the efficiency hypothesis. At first blush, this appears to support the constancy hypothesis. However, the profile of presentation conditions was flat for grouping by luminance similarity. Whilst this could reflect a constant pattern of grouping with age, significant evidence of grouping is not consistently evident across age or across presentation conditions, and so is most likely to point towards the fact that grouping was not always evident. Nevertheless, grouping by shape similarity showed a V-shaped pattern across presentation conditions: z-scores were significantly lower for the habituation condition (a relative familiarity effect) than for the prehabituation and habituationplus conditions (relative novelty preferences). This was also observed as a significant novelty preference in the habituationplus condition at 4 months, and a marginal familiarity preference in the habituation condition at 6 months. As performance was not consistently different from baseline, we must emphasise that, although this pattern indicates familiarity and novelty preference relative to one another, familiarity and novelty preferences are not consistently shown, relative to baseline. It does, however, at least for the cross sectional analysis, reflect a distinctive pattern of grouping performance which remains constant with age. One could argue that this supports a constancy hypothesis. However, this argument would be stronger had the pattern consisted of significant familiarity and novelty preferences for each age group.

Evidence for both familiarity and novelty preferences in relation to one grouping type can be considered in light of Hunter and Ames' (1988) model of infant preferences. This explains that familiarity preferences occur when information is part processed and so the infant is still interested in attending to it. Once processed, the infant shows habituation, and the presentation of a novel stimulus causes dishabituation and hence attention to the novel stimulus. Thus, over repeated exposure, an infant will first show a familiarity preference, which is then followed by a novelty preference. The evidence for both familiarity and novelty preferences in this study, might also explain why grouping was not always observed in consecutive presentation conditions. It is possible that infants were in a period between showing a familiarity or novelty preference or that some infants were still attending to the familiar test stimulus while others had moved onto the novel stimulus, and the two effects cancelled each other out (see Houston-Price & Nakai, 2004).

In light of Hunter and Ames (1988), it is surprising that a familiarity effect is observed in the current experiment after habituation to the familiarisation stimuli. Indeed, previous, similar studies report novelty preferences only (e.g. Farroni et al., 2002; Quinn et al., 1993). This could suggest that infants were not fully habituated. However, as we used a standard habituation procedure (Horowitz et al., 1972), we can be confident that are criteria for habituation (50% decrement of looking time) was sufficient. In the present study, the test stripes were not identical to the familiarisation stimuli. This additional processing requirement might have induced a preference to look at the ‘familiar’ test stripes in the habituation condition due to a need to consolidate the perceptual link between the familiarisation stimulus and the familiar test stripes.

One of the paradigms employed by Quinn et al. (Experiment 1, 2002) and Farroni et al. (Experiments 2 & 3, 2000) was similar to that employed here, where the familiarisation stimuli and test stimuli are different. However, they report novelty preferences. In the Quinn et al. (2002) study, this can be accounted for by long presentation durations that exceeded habituation, which would have allowed infants to pass through familiarity to a novelty preference. However, Farroni et al’s. (2000) novelty preferences were observed after habituation, and so contrast to the familiarity preferences observed in the present study. One could argue that this reflects the low visual acuity of newborns, and that they perceive the familiarisation and test stimuli as identical. Their data, however, rule out this possibility (see Experiment 1, Farroni et al., 2000). Our explanation for the familiarity effects observed in the present study is therefore given with caution. Nevertheless, from the pattern of preferences, we can conclude that for grouping by shape similarity, the relative pattern of performance across presentation time has some consistency with the pattern predicted by Hunter and Ames’ (1988) model of infant preferences.

Comparison of grouping at different testing ages reveals that it is not always the case that once grouping has emerged, it is then evident at subsequent testing ages.

This might be explained in part by a transition between familiar and novelty preferences, as discussed above. One might also argue that, as the effects of grouping by luminance similarity and by shape similarity at 6 months are marginal, that this reflects a loss of statistical power on account of infant attrition. However, as attrition was not particularly high, with an N of 42 at 6 months, a lack of power is not supported. Furthermore, the pattern observed for grouping by luminance is not consistent with a lack of power; grouping by luminance similarity is evident at 2 months, but not at 4 months, and then is observed again, albeit marginally, at 6 months. This suggests that a developmental change occurs at 4 months, which affects the ability to group by luminance similarity. Possible candidates include the maturation of the visual primary cortex or changes in visually guided behaviour (see Johnson, 1990). However, neither of these predict an effect specific to luminance similarity and, intuitively, as luminance similarity is available in neonates and can therefore be considered to be innate (Farroni et al., 2000), one could argue that it is a stronger grouping ability, which would predict that this form of grouping is *less* affected by changes to related functions. As such, the notion that developmental change at 4 months affects the ability to group by luminance similarity is not discussed further.

We conclude that during infancy, the present study does not show a link between the emergence of perceptual grouping and the presentation duration required to elicit it. Thus, in contrast to adults, in infancy, presentation duration does not seem to reflect computational load. It appears that it is only once the developmental process is complete, that the mechanisms responsible for different types of perceptual grouping are reflected in differences in the exposure duration required to elicit perceptual grouping. Our results also demonstrate that adult patterns of performance are not present and fixed from birth. In adulthood, proximity is processed before luminance and shape similarity, whilst processing times for luminance and shape similarity are equivalent (Ben-Av & Sagi, 1995). In contrast, this study has shown a discrepancy between perceptual grouping by luminance and shape similarity in both emergence and processing time in infancy, and a late emergence for grouping by proximity.

To summarise, we have shown in the present longitudinal study evidence for grouping by luminance similarity and shape similarity, but not proximity, within the first 6 months of life. Once grouping has emerged, for grouping by shape similarity and possibly luminance similarity, the exposure duration required does not change with development, but shows some evidence of remaining stable across developmental time. Previous research on adults has shown that there are different mechanisms underlying perceptual grouping. In infancy, this is demonstrated by differences in the age at which grouping types emerge. In adulthood, this is shown by differences in the exposure duration required for perceptual grouping to occur. This study provides additional evidence that perceptual grouping is operated by a number of mechanisms, indicated by the different patterns of familiarity and novelty preferences across presentation durations, for grouping by shape similarity compared to luminance similarity. Our results demonstrate that exposure duration in infancy is not linked to emergence. This again highlights the importance of longitudinal studies of infancy that do not take the adult endstate as reflecting the point of departure in human development.

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Table 1: Participant details

| CA (days): mean (S.D.) | Task | Infants excluded due to: | | | | Final N |
|---|---|---|---|---|---|---|
| | | fussiness | side bias | stripe preference at baseline | looking time < 15% | |
| 58.98 (3.69) (N=61) | Luminance | 10 | 0 | 6 | 0 | 45 |
| | Shape | 7 | 5 | 2 | 2 | 45 |
| | Proximity | 12 | 2 | 3 | 1 | 44 |
| 121.94 (3.91) (N=49) | Luminance | 7 | 0 | 3 | 2 | 37 |
| | Shape | 7 | 0 | 6 | 1 | 35 |
| | Proximity | 10 | 0 | 3 | 2 | 34 |
| 186.17 (4.72) (N=42) | Luminance | 4 | 0 | 1 | 2 | 35 |
| | Shape | 3 | 1 | 3 | 1 | 34 |
| | Proximity | 3 | 0 | 4 | 1 | 35 |

Table 2: Cumulative exposure duration (seconds): Mean (s.d.)

| | | Presentation duration | | |
|---|---|---|---|---|
| Grouping type | Testing age (months) | Prehabituation | Habituation | Habituationplus |
| Luminance | 2 | 10(0) | 90.96 (36.90) | 152.11 (40.16) |
| | 4 | 10(0) | 76.19(13.43) | 135.00 (20.75) |
| | 6 | 10(0) | 71.58(7.89) | 124.86(11.46) |
| Shape | 2 | 10(0) | 81.15(28.94) | 147.31 (49.63) |
| | 4 | 10(0) | 75.48(14.85) | 137.69(26.70) |
| | 6 | 10(0) | 72.43(8.63) | 124.59(16.93) |
| Proximity | 2 | 10(0) | 80.60(29.10) | 137.80 (34.18) |
| | 4 | 10(0) | 73.08(11.04) | 132.31(15.64) |
| | 6 | 10(0) | 71.03(12.52) | 122.41(9.51) |

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Figure captions

Figure 1: Grouping stimuli

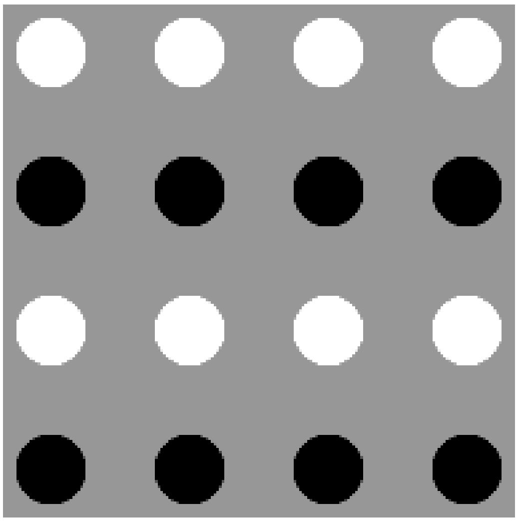
Figure 2: Test stimuli

Figure 3: Longest look data for grouping by luminance at 2, 4, and 6 months

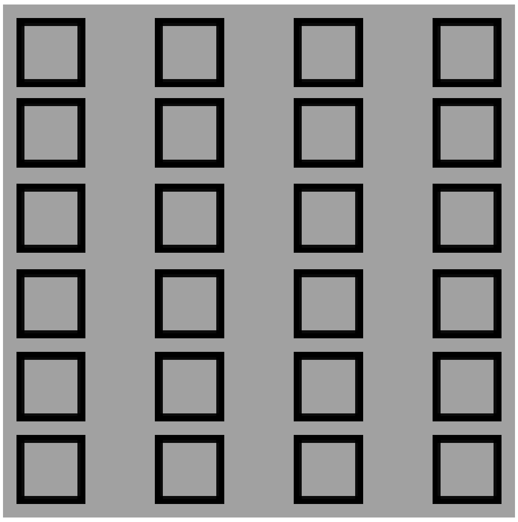
Figure 4: Longest look data for grouping by shape at 2, 4, and 6 months

Figure 5: Longest look data for grouping by proximity at 2, 4, and 6 months

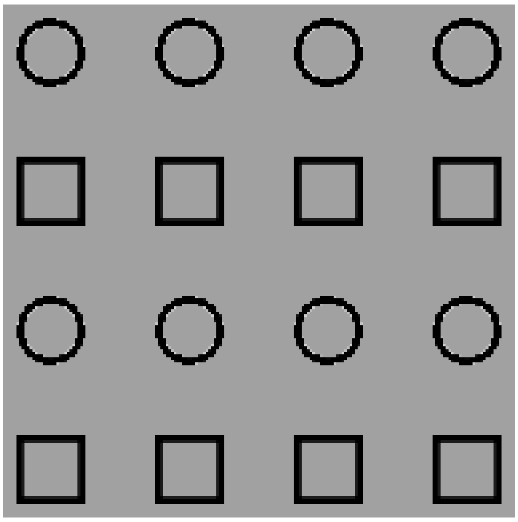
Figure 1



Horizontal grouping by luminance



Vertical grouping by proximity



Horizontal grouping by shape

Figure 2

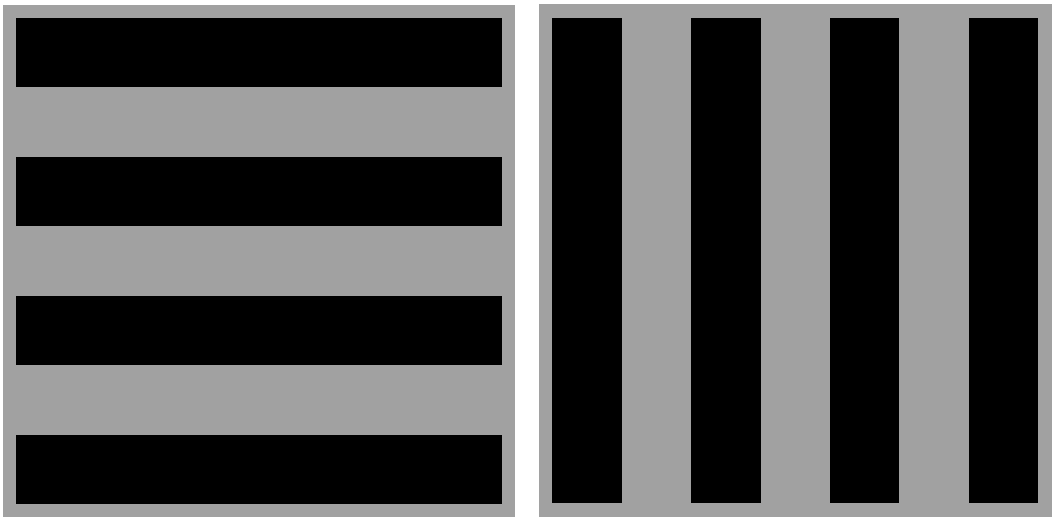
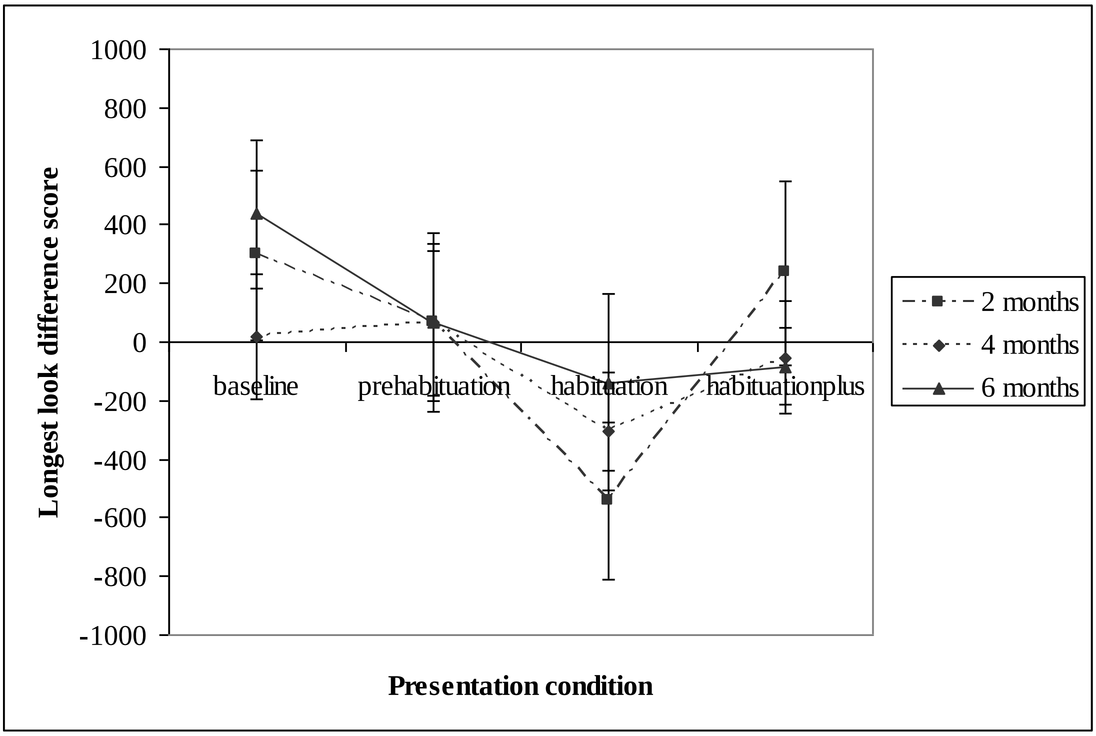


Figure 3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Longest look difference score
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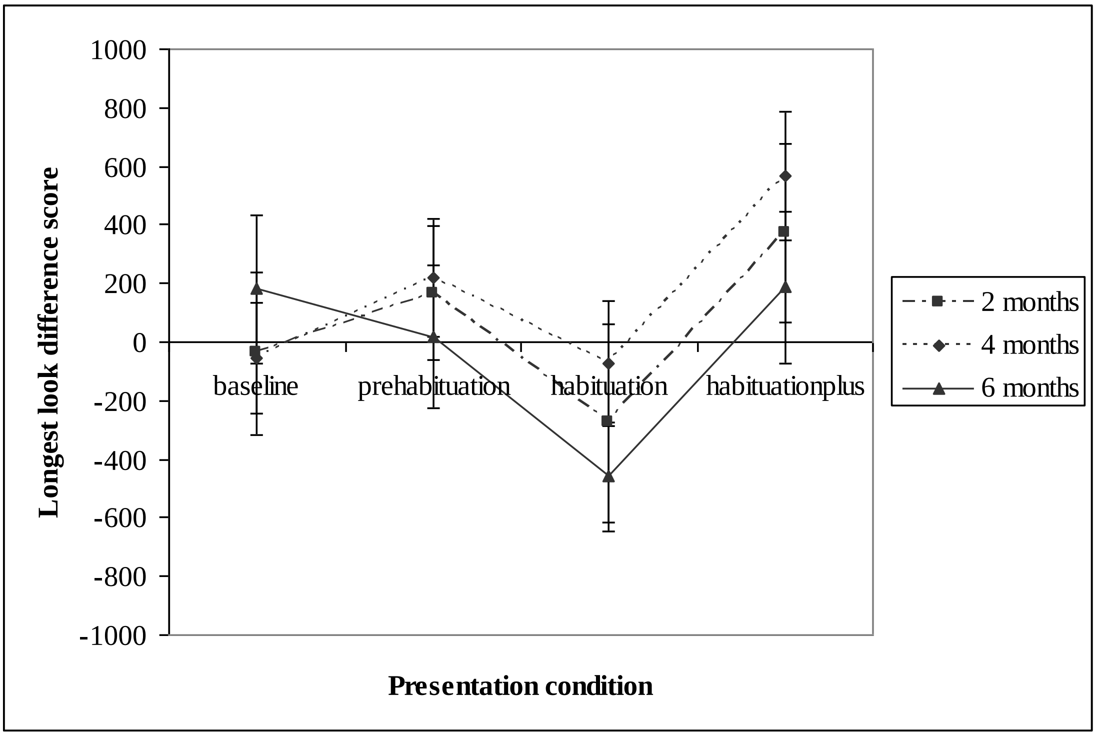
prehabituation
habituation
habituationplus
Presentation condition
2 months
4 months
6 months

Figure 4



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Longest look difference score
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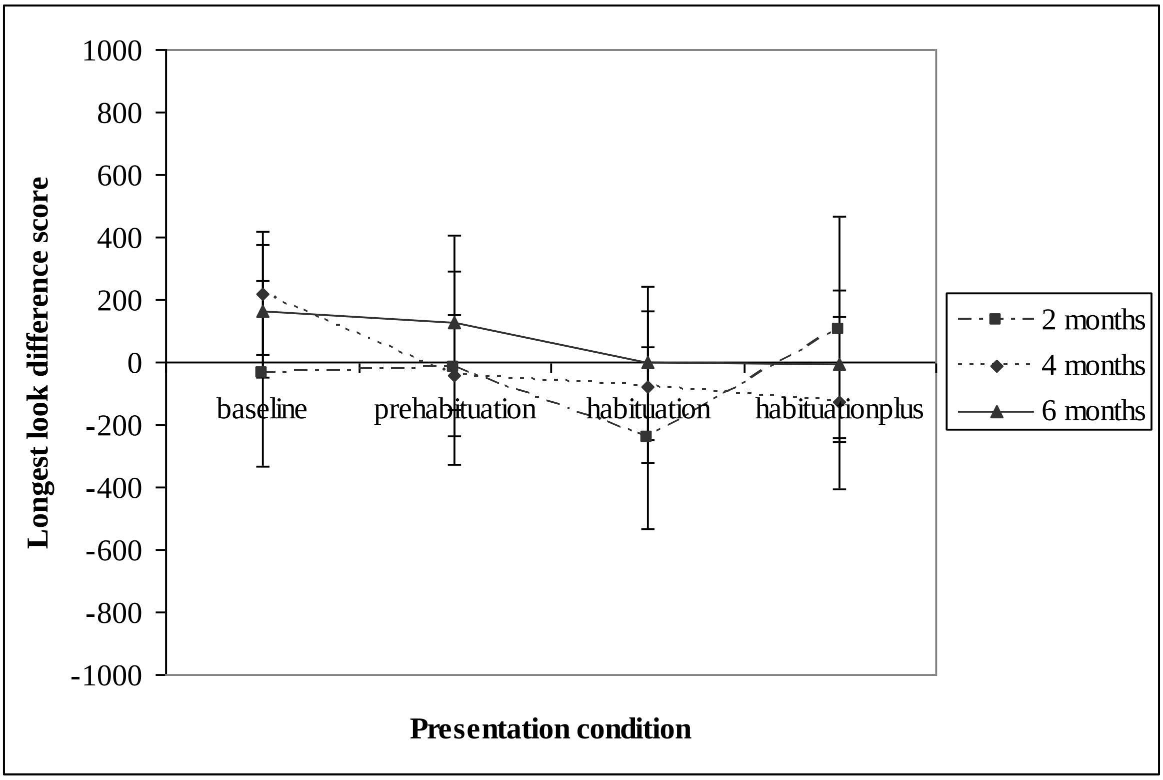
prehabituation
habituation
habituationplus
Presentation condition
2 months
4 months
6 months

Figure 5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Longest look difference score
baseline
prehabituation
habituation
habituationplus
Presentation condition
2 months
4 months
6 months