An Investigation of Visual-Field Effects in Infant Response to Colour
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BACKGROUND

For most adult brains, there are clear indications that the responsibility for attending to, encoding and storing information from the visual field is distributed asymmetrically across the two cerebral hemispheres (Davidson & Hugdahl, 1995; Hellige, 1993). The present investigation is broadly concerned with the developmental origins of one fundamental aspect of such asymmetry, namely the response to the dimension of colour.

Colour is a particularly salient feature of the visual world for infants and figures prominently in early attention to and memory for visual stimuli (Catherwood, Skoien, Green, & Holt, 1996; Dannemiller, 1998; Teller & Bornstein, 1987). It was thus considered to be important to explore the way in which the infant brain may distribute responsibility for responding to coloured stimuli.

For adults, any evidence of hemispheric asymmetry in response to colour tends to favour the RH (right-hemisphere) or LVF (left visual field). For example, there is evidence of a RH (LVF) advantage in colour discrimination, as long as verbal processing can be eliminated (Pennal, 1977) and there is ERP evidence of preferential activation of the right temporal cortex during the retrieval of colour information (Rossler, Heil, & Henninghausen, 1995). Moreover, colour after-effects (McCullough Effect) are known to be stronger in the LVF (RH) (Meyer, 1976). However, before the present investigation, there had been no appraisal of whether infants display any such hemispheric asymmetry in the response to colour. The project therefore addressed a significant omission in the research base regarding infant response to a fundamental dimension of the visual world.

OBJECTIVES

The aim of the present investigation was to assess if there were visual field biases (taken to be reflective of hemispheric processing asymmetries) in infant response to colour in terms of (1.) visual “attention” (detection and orientation) and (2.) memory (storage and retrieval). It was the intention to explore both these aspects in order to assess whether any preliminary biases in initial response to a coloured stimulus were preserved or sustained in memory processing.

The particular objectives were to conduct two experiments to ascertain (respectively) if infants displayed (1.) preferential orientation to and (2.) preferential recognition for colours presented in the LVF relative to those in the RVF, indicating a RH advantage in the response to colour, of the kind observed for adults.
The outcomes were not as expected, but both studies have yielded potentially valuable and publishable data. Moreover, an additional experiment (Experiment 1x) has been completed in order to provide further insights into the findings for Experiment 1.

METHODS and RESULTS

EXPERIMENT 1:

Rationale and Design:

The aim in this experiment was to assess whether infants orient more readily (rapidly) to coloured stimuli in the LVF relative to the RVF, indicating more effective processing of colour information in the RH relative to the LH. The basic paradigm was to firstly centre the infant’s fixation and then present target stimuli in the lateral visual field. Infants were presented with 8 trial “blocks”, each involving presentation of a central stimulus followed by exposure of a lateral stimulus: on four trials to the left and four to the right of the central fixation point (random order). As a control measure, for each infant, half of the stimuli in each visual field were achromatic (white) and half were chromatic (blue or green or yellow or red, with equal numbers of infants assigned to each colour). This manipulation would permit an evaluation of whether any visual field asymmetries were specific to coloured stimuli or were more generic. In addition, one further variation involved presenting the target stimuli in either the upper quadrant of the visual field as opposed to the midline (between-subjects condition) in order to appraise the relevance of the stimulus location to any visual field asymmetries. The latency of infant fixation to the lateral stimuli would be measured, with a view to comparing response times to the stimuli in each visual field.

Sample. The final sample of 24 infants had a mean age of 22 weeks (range: 16-28) and no known family history of colour vision abnormalities. Infants were randomly assigned to the colour conditions.

Stimuli and apparatus. The stimuli were computer-generated and presented on a 33cm colour monitor. All stimuli were shown on a black ground (known to improve detection of peripheral stimuli in infants: Maurer & Lewis, 1991) The central stimulus was a facial shape 6cm in diameter. This was presented in the same colour as the following lateral stimulus on each occasion (e.g., if the lateral stimulus was white, then the central face was white but if the lateral stimulus was blue, then the face was also blue). The lateral stimulus was a 5cm star presented 2cm to the left or right of the perimeter of the face shape in either white or one of the 4 colours (saturated blue, green, yellow or red) matched for adult levels in apparent brightness to the white stimulus. The star subtended a visual angle of approx. 5°44′ with the centre located approx. 8°35′ in the periphery of the visual field (past evidence indicates that 6-month-olds can detect a 3° stimulus out to 90° in the temporal periphery: Maurer & Lewis, 1991).

Procedure. Infants were presented with 8 pairs of trials (as explained above: see Rationale and Design). Each of these pairs of trials consisted of a centring trial on which the facial
stimulus was exposed until the infant was clearly fixating it. Then the lateral stimulus was presented until the infant showed clear visual orientation or after 5 seconds had elapsed.

**Results:**

The video tapes were coded (by two independent observers with mean correspondence in scores being: $r = 0.86$) for the time taken by the infant to orient to the lateral star stimuli on each presentation (latency from offset of centring stimulus to clear fixation of the lateral stimulus). These times (seconds) were analysed in a $2 \times 2 \times 2$ ANOVA (target location: upper sector vs. midline $\times$ target colour: coloured vs. white $\times$ visual field of target: LVF vs. RVF). There are significant main effects for target colour and for visual field, but there is also an interaction of these factors approaching significance: $F(1,22) = 3.210, p = .08$.

Further analysis of this interaction indicates that contrary to the findings for adult response to colour, there is no evidence of visual field asymmetry in the infant response to the coloured targets. However, there is evidence of asymmetry in the response to the achromatic targets, with a RVF (LH) advantage in the reaction to the achromatic targets. (See Figure 1.)

The visual field equality for colour indicates that for these infants both hemispheres of the brain were involved comparably in processing this dimension. It may well be that any asymmetry in this regard does not emerge until later in the development of the functional organization of the brain and this outcome may relate to the salience of colour in infant response to the visual world. However, the outcome indicating asymmetry in response to the achromatic targets indicates that such asymmetry may emerge for other visual dimensions. The response in this case reflects an apparent RH tardiness (relative to the LH response to the achromatic targets and also relative to the response for both hemispheres to the coloured targets). This outcome seemed deserving of further exploration.

One possible explanation is that the RH was delayed in response to the achromatic targets because of engagement with prior processing responsibility. It is conceivable that the facial characteristics of the centring stimulus were more prominent or salient for the achromatic trial blocks than for the coloured blocks (for which the colour of the centring stimulus may have been a more dominant feature). If so, then the RH may have been disadvantaged in responding to the lateral targets in the achromatic trials due to a preoccupation with processing the central facial stimulus. There is ample evidence for infants (Deruelle & de Schonen, 1991) and adults (Allison, McCarthy, Nobre, Puce, & Belger, 1994) that the RH has greater facility than the LH for processing facial patterns in a holistic or configurational way and hence may be more engaged by such patterns in early processing intervals. If this occurred in the present case, then the RH may have essentially been “busy” with processing of the achromatic facial centring stimulus and hence taken longer to disengage and respond to the lateral target. After considerable discussion with colleagues (e.g., at the European Developmental Conference, Greece, 1999), it was decided to conduct an additional experiment to determine the role of the centring stimulus in these results. This approach was adopted to enhance the value and power of the results for Experiment 1. This resulted in Experiment 1x as described below.
EXPERIMENT 1:
This was essentially a replication of Experiment 1 with a sample of 12 infants of comparable age—except that in this case, the centring stimulus for each trial block was an inverted face (the same face as for Experiment 1 except in inverted orientation). (In this experiment, only upper sector targets were employed since the target location in the upper or midline positions was not relevant in Experiment 1.) For both adults (Allison et al., 1994) and infants (Slater & Butterworth, 1997), the inversion of a face disrupts the processing of the configurational information and hence should reduce or remove any RH advantage or bias towards the centring stimulus. If this was the critical factor in explaining the RH tardiness for the achromatic trials in Experiment 1 then there should be an improvement in RH (LVF) response to the targets in this experiment. This is precisely the outcome. An ANOVA comparing the reaction times to the lateral stimuli with the inverted centring stimulus shows no evidence of visual field differences: $F(1,11) = 2.081, p = .16$.

EXPERIMENT 2:
Rationale and Design:
The aim in this experiment was to determine if infants displayed visual field (hemispheric) asymmetry in memory for the colour of a stimulus. As noted above, adults demonstrate a greater RH involvement in colour memory (e.g., Rossler, et al., 1995) and it was the intention of this experiment to assess if this was also the case for infants.

The essential paradigm involved familiarizing infants to a pair of different-coloured shapes presented simultaneously in the left and right visual fields (respectively). Infant fixation was firstly centred and then the lateral display was exposed for a duration that circumvented lateral fixation, thereby resulting in the projection of the lateral stimuli to the contralateral hemisphere (LVF to RH and RVF to LH). The same lateral stimuli in the same locations were used over the familiarization phase.

Then the infants were presented with two trials aimed at assessing recognition for the colours of the two lateral stimuli. On these trials the lateral stimuli were paired respectively with a novel-coloured stimulus (in the familiar shape) and the extent of any “preference for” this novel stimulus was measured in terms of relative fixation on the respective trials. In this
procedure, a greater-than-chance novelty preference is taken as an index of recognition for the familiar item. The aim then was to ascertain if the infants showed a greater novelty preference on the recognition tests involving the familiar LVF colours (processed by the RH in the first instance) than the RVF colours (processed by the LH).

Sample. The final sample comprised 36 infants (equal numbers of females and males) with a mean age of 20.9 weeks (SD: 4.3; range: 13 to 29 weeks). Assignment to the colours used in the experiment was random.

Stimuli and apparatus. Stimuli were computer-generated and presented on a colour monitor in a similar arrangement as for the first experiment. A flashing black-and-white bullseye pattern was used as a centring stimulus and the stimuli presented in the lateral visual fields were star shapes. Past evidence suggests that infants of about 6 months of age are able to detect a 3° stimulus at 90° eccentricity (Maurer & Lewis, 1979) and so the present lateral stimuli should have been potentially detectable for the infants in the study. The stars were presented in red, yellow or blue, with the dominant wavelengths being respectively, 607nm, 583nm and 468nm (estimated from chromaticity coordinates measured with a Topcom BM-7 luminance colorimeter and plotted on C.I.E. charts: Hardy, 1936). Previous evidence suggests that infants of the age range in the sample should be able to discriminate the selected colours (Teller & Bornstein, 1987).

Procedure. The infants were tested in a similar context to that for Experiment 1. During the familiarization phase of the experiment, there were 20 trial pairs, each comprised of the centring stimulus followed by a lateral display. When the infant was clearly fixating the centring stimulus, the lateral display was presented (and the central display simultaneously terminated). Each lateral display involved the simultaneous presentation of two star-shapes in different colours - one colour in the LVF and the other in the RVF, with the colours maintained in the same lateral locations across the familiarization trials for any one infant. The colours, colour combinations and colour-location combinations were all counterbalanced across the sample.

Each lateral display was exposed for 250 msec, with this duration selected to circumvent lateral fixations, since even in adults saccadic eye movements are considered to require an interval in excess of 250 msec.

The test phase was presented immediately after the final familiarization trial. The centring stimulus was presented until the infant was judged to be clearly fixating it and then the first of two paired-comparison displays (LVF and RVF recognition tests) was presented for 5 seconds. Each of these displays paired one of the familiar lateral stimuli (from LVF or RVF) with a novel stimulus, the latter being the familiar shape in a novel colour (same novel colour used on both such tests for any one infant). This process was repeated for the second test block. The colours of the familiar and novel test stimuli were also counterbalanced over the sample, with each colour appearing equally often as the familiar and novel stimulus. The left-right location of the novel and familiar stimuli on the test trials was alternated across test trials for each infant, with the order of the test trials counterbalanced over the sample.

Results:
The fixation times on each of the two test trials were converted to percentage novelty preference scores (fixation to the novel stimulus as a percentage of total fixation time on the trial). These scores were then compared against 50% using t-tests in order to establish whether they reflected fixation preferences beyond chance levels.

Both the tests indicate response levels significantly different from chance, but in contrary directions: there is a marginally significant preference for the novel stimulus in the test of recognition for the RVF colour, but a robustly significant preference against the novel stimulus in the test for recognition for the LVF colour. In other words, there is a marginal preference for the novel colour on the RVF test, but a strong preference for the familiar colour on the LVF test. (See Figure 2 for representation of this pattern of results.)

A direct comparison of the scores for the two tests confirms that the novelty preference on the RVF test significantly exceeds that on the LVF test: t (35) = 3.699, p < .001 (2-tailed test).

![Figure 2. The Interaction of Visual Field with Test Stimulus: Experiment 2](image_url)

The results do not indicate RH advantage in memory for colour and on the contrary appear to demonstrate LH superiority. This could mean that memory for colour is largely handled by the LH in infants but becomes lateralized in the RH with subsequent development of the cerebral hemispheres -possibly because of competing demands on the LH with the acquisition of motor and/or language skills. This apparent difference in the locus of the bias for adults and infants is of interest because it highlights the potentially dynamic
nature of hemispheric asymmetry across the developmental spectrum, reflecting the possibility of ongoing negotiation for neural territory occurring with experience and maturation. Thus although the findings are contrary to those for adults, this outcome is valuable in indicating the possibility of developmental fluidity in hemispheric processing patterns.

However, it would not seem appropriate to portray the LH as having been the active agent and the RH as being passive or unresponsive during the familiarization to the coloured stimuli. Indeed the results for the RH are not consistent with this interpretation because they do not reflect a total absence of encoding for the familiar stimulus. This would be expected to produce chance levels of fixation whereas the “familiarity preference” for the RH is significantly stronger than chance.

Such familiarity preferences in infants of the age range in the present study are usually observed under impoverished encoding conditions involving either very brief or interrupted familiarization intervals. One interpretation of these findings (Rose, Gottfried, Mello-Carminier, & Bridger, 1982; Slater & Morison, 1991) is that under such conditions infants may achieve only partial or incomplete processing of the stimulus properties and hence may engage in further examination of the stimulus on subsequent exposures of longer duration (i.e., as on the recognition test trials in the present study). In other words, a familiarity preference may reflect partial recognition. The familiarity preference displayed for the LVF/RH colours in the present study may thus be reflective of partial or incomplete encoding of the stimulus colours. However, if this is the case, it remains to explain why there was not a similar effect for the LH which was also subject to brief exposures.

There could be alternative explanations for this discrepancy, but one possibility may be that the RH maintains a more diffuse mode of responsiveness to the sensory field, allowing temporary orientation and possibly rapid or premature habituation to stimulus change or novelty, without prolonged attentional focus (Heilman, 1995; Tucker & Williamson, 1984; Mangun et al., 1994). If this occurred in the current experiment, it may well mean that the RH initially responded to the presence of the lateral stimulus but then with repetition of this stimulus during the familiarization period, there may have been inhibition on any further processing to the extent that the RH habituated prematurely to the stimulus before encoding its colour. On the other hand, the LH may have been less restricted in this respect and hence encoded the stimulus colour more deeply and selectively. This possibility is being explored in a further experiment for which pilot work has already begun under the auspices of this grant. This new experiment will employ essentially the same paradigm as Experiment 2 but will compare two conditions- one in which the lateral stimuli are in the same location on each trial of the familiarization phase (as for Experiment 2) and one in which these stimuli move location randomly over these trials. The aim is to assess whether the RH may be more engaged by the variable stimulus than the constant stimulus.

A draft manuscript has been prepared for Experiment 2 (see attachment) and will be submitted to a major journal in the near future. (The results for the new experiment will be reported subsequently, with full acknowledgement of ESRC support.)

References

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