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Kotsoni, E. and Csibra, Gergely and Mareschal, Denis and Johnson, M.H. (2006) Common-onset visual masking in infancy: behavioral and electrophysiological evidence. *Journal of Cognitive Neuroscience* 18 (6), pp. 966-973. ISSN 0898-929X.

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Common-onset Visual Masking in Infancy: Behavioral and Electrophysiological Evidence

Eleni Kotsoni, Denis Mareschal, Gergely Csibra, and Mark H. Johnson

Abstract

■ Common-onset visual masking (COVM) occurs when a mask and a target have common onset but delayed offset, with the mask persisting beyond the duration of the target [Di Lollo, V., Enns, J. T., & Rensink, R. A. Competition for consciousness among visual events: The psychophysics of reentrant visual events. *Journal of Experimental Psychology: General*, 129, 481–507, 2000]. We report the first behavioral and electrophysiological evidence of COVM in infants. An initial behavioral study included a familiarization phase during which a visual pattern (the target) surrounded by four black dots (the mask) was flashed 15 times to the infant. In the “unmasked” condition, the mask disappeared with the target. In the “masked” condition, the mask remained on the screen after deletion of the target for a further 93 msec. During

the test phase, the familiar target pattern was paired with a new pattern. Infants in the unmasked condition showed a significant familiarity preference, suggesting that they had encoded the target during familiarization, whereas those in the masked condition showed no preference, suggesting that they had not encoded the target during familiarization. In the second experiment, high-density event-related potentials were used to investigate the electrophysiological pattern of activity that accompanies COVM. Six-month-old infants viewed both masked and unmasked conditions. Electrophysiological data indicated that over posterior channels the masked condition elicited a larger amplitude positive wave around 300 msec after stimulus onset than trials in the unmasked condition. ■

INTRODUCTION

Visual object recognition clearly involves a complex interaction of bottom-up and top-down processing (Lamme & Roelfsema, 2000; Lamme, Supèr, & Spekreijse 1998). What is far less clear is the age at which top-down processing begins to influence the percept that an infant experiences (e.g., Csibra, 2001). In this article we examine whether there is any behavioral and electrophysiological evidence of top-down visual processing in 6-month-olds. To assess the presence of top-down processing we examine whether 6-month-olds are susceptible to common-onset visual masking (Di Lollo, Bischof, & Dixon, 1993).

In general, visual masking refers to the reduction of visibility of one object (the target) when it is followed by another object (the mask) nearby in space or time. Masking has been widely used to study a broad range of visual processes in adults (Breitmeyer, 1984; for reviews, see Breitmeyer & Ogmen, 2000; Enns & Di Lollo, 2000). Common-onset visual masking (COVM; Di Lollo, Enns, & Rensink, 2000; Enns & Di Lollo, 1997; Di Lollo, Bischof, & Dixon, 1993) refers to one particular masking paradigm where both the target and the mask come into view simultaneously. For example, the mask might consist of

four black dots that surround but do not touch the target. Di Lollo, Enns, & Rensink (2000), Enns and Di Lollo (1997), and Di Lollo, Bischof, and Dixon (1993) found that when adult participants were presented with a brief display consisting of several potential targets of which one was surrounded by four black dots, followed by a second display that contained only the four dots, the surrounded target was effectively masked. In addition, masking increased the more attention was distributed among many potential targets.

Di Lollo, Enns, and Rensink (2000) argued that this form of masking was difficult to explain without the notion of visual reentrance. *Visual reentrance* refers to the interactive loop of processing between forward and backward visual projections. They argue that the first wave of feed-forward or bottom-up processing of the visual input may not be sufficient for identification. Therefore, identification is aided by feedback (or top-down) projections. This process involves searching for a match between a descending code representing a perceptual hypothesis and an ongoing pattern of low-level activity. The matching of information at higher and lower areas allows a percept to be achieved, ensuring that information is consistent between both levels. However, if the target item is deleted and only the four-dot mask is left on the target location, the ongoing activity at the lower level would then consist of an image

of the mask alone and a decaying image of the target. This creates a mismatch between the ongoing (bottom-up) pattern of low-level activity and the reentrant (top-down) perceptual hypothesis that included both the target and the mask, leading to confusion and disruption of the target's identification. Thus, the presence of COVM in infants would provide converging evidence that top-down, reentrant processing was at play in the infant's visual processing.

There has been very little prior work examining any kind of visual masking in infants. A notable exception is the work of Lasky and Spiro (1983). They used tachistoscopic presentation of stimuli followed by a mask as a methodology for investigating visual processing in 5-month-old infants. A visual pattern was presented for 100 msec followed by a mask at four different intervals (0, 250, 500, and 2000 msec). This sequence was repeated 45 times followed by a 15-sec-long preference test. Results indicated that only infants in the longest intervals between the target and the mask condition showed a significant novelty preference, suggesting that 5-month-old infants may require a long period of uninterrupted processing following the offset of a briefly presented stimulus before they are able to recognize it.

Similarly, Catherwood (1994) and Catherwood, Skoien, Green, and Holt (1996) have used a backward masking paradigm to study the early encoding of color and shape in visual stimuli and shape. Five-month-old infants were presented with 18 very brief exposures (250 msec) of a colored shape followed 1000 msec later by a mask. Recognition of the familiar stimulus was then assessed by pairing the stimulus with a novel shape or color stimulus. At this speed of presentation, 5-month-old infants demonstrated recognition of color but not shape by looking longer at a stimulus with a new color but looking equally long at both stimuli when they differed only in shape. Additional data showed that the use of a longer delay (2000 msec), presumably giving infants more time to encode the stimulus, resulted in infants' being able to recognize both novel color and shape. Thus, it seems that from at least 5 months of age, infants are susceptible to some forms of masking. If Di Lollo and colleagues (2000) are correct, a susceptibility to COVM would indicate that infants object recognition involves reentrant processing. One way to test his hypothesis is to measure electrophysiological activity as the infants are engaged in a task involving COVM.

We now report two experiments investigating COVM in 6-month-olds. In Experiment 1 we combine the standard COVM experimental paradigm with a familiarization and visual preference methodology. Infants are familiarized to a target either in the presence or in the absence of a mask. The reasoning here is that if masking of the target has occurred, then infants should not show a visual preference in a subsequent novelty preference test. In contrast, if masking has not occurred, then infants should discriminate between the familiar and a novel stimulus.

In Experiment 2, we investigated the electrophysiological responses that accompany COVM in 6-month-olds. Following the rationale of the behavioral study, targets in the delayed offset condition are expected to elicit different event-related potential (ERP) waveforms than stimuli in the simultaneous offset condition because the latter may be more familiar than the former. In other work exploring the electrophysiological signature of COVM in adults, we found significant effects of masking beginning around 200 msec poststimulus onset in the posterior regions (Kotsoni, Csibra, Mareschal, & Johnson, submitted). We therefore anticipate the presence of similar effects in our infant participants.

EXPERIMENT 1

Participants

Forty 6-month-old infants (18 boys and 22 girls, with a mean age of 180.5 days, $SD = 8.5$ days) participated in the study. An additional 28 infants were tested but were excluded from further analysis due to experimenter error ($n = 2$), fussiness ($n = 15$), or because the infants did not attend sufficiently to the test event during testing ($n = 11$). According to parental reports, all infants were healthy, full-term, and of normal birth weight. Infants were recruited through local parent groups, hospitals, baby shops, or magazine advertisements. Finally, all infants were tested individually in our laboratory in the presence of at least one parent who had provided informed written consent.

Apparatus and Stimuli

Infants sat in a car seat, in a darkened experimental room, facing a 42-in. flat screen (with a 1024×768 resolution at 75-Hz) placed at eye level at a distance of approximately 110 cm away. The actual size of the screen area used during the present study was 65×50 cm. A video camera was mounted above the flat screen peeping through the opening of a black curtain, allowing the experimenter to monitor the infant's eye fixations and record the session. The experimenter, along with the parent(s), was in the same room behind a dark-gray screen that separated the area where the infant was seated from the area where the experimenter was monitoring the whole study.

The target stimuli consisted of two orange "gingerbread men" (Figure 1). A column of either four green squares with black contours or four green diamonds with black contours was embedded within each one. Each gingerbread man subtended a visual angle of 8.9° wide and 12° high. The mask consisted of four black squares ($0.7^\circ \times 0.7^\circ$) that surrounded but did not touch the gingerbread man placed at a distance of 2.5° eccentricity from the target. During familiarization, one of the gingerbread men and the mask were repeatedly

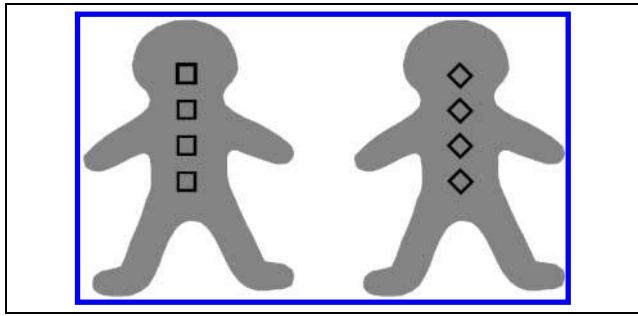


Figure 1. Stimuli used in Experiments 1 and 2. The gingerbread man's body was bright orange and its buttons were bright green with a black border.

presented in the center of the screen against a white background. During the test trials, the familiar gingerbread man was presented simultaneously with the novel gingerbread man, one in each half of the monitor, 36 cm to the left and right of the center of the screen.

Procedure

Twenty infants were randomly allocated to one of two familiarization conditions. In both conditions, the infant's attention was first drawn to the center of the monitor by spiraling animations and sounds. When the infant was looking at the center of the monitor, the experimenter pressed a key that started a familiarization sequence. This consisted of flashes of the target gingerbread man and a mask consisting of four black squares that surrounded it but did not touch it. In the *simultaneous offset* condition, the gingerbread man and the mask both disappeared after 200 msec. In the *delayed offset* condition, the gingerbread man disappeared first (after 200 msec) and the mask disappeared a further 93 msec after deletion of the gingerbread man (i.e., after 293 msec had elapsed). This sequence was repeated continuously for a total of 15 flashes. If the infant looked away, spiraling animations and sounds were used to redirect the infant's attention back to the center of the screen. Once the infant was recentered, the flashing sequence was resumed.

The familiarization phase was immediately followed by a test phase during which two gingerbread men were presented simultaneously, one in each half of the display screen, and with no surrounding mask. This was followed by a second test trial in which the location of the novel and familiar stimuli were reversed. The initial left-right location of the novel gingerbread man was counterbalanced across infants. Looking time toward the computer monitor was scored online by pressing a computer key. The test trial was ended when the infant had accumulated 10 sec of total looking. If necessary, the infant was reoriented toward the monitor with spiraling animations and sounds before starting the second test trial.

The infant's face was recorded during the whole session, and looking times were scored off-line. Only stimulus flashes that were looked at without any blinking or looking away for the whole 200 or 293 msec were counted as valid. The experimenter counted how many valid flashes each infant had seen and how long the infant had looked at each of the test stimuli during both test trials.

Results

During the familiarization phase, infants in the simultaneous offset condition looked at an average of 12.25 flashes and those in the delayed offset condition looked at an average of 12.75 flashes. This difference was not significant, $t(38) = -1.11, p < .28$. Moreover, all infants in both conditions looked at a minimum of 10 flashes. The corresponding average total looking time during familiarization was 2450 and 2550 msec, respectively.

Preference scores were computed for each infant by dividing the duration of looking toward the novel stimulus by the total amount of looking toward either of the two test stimuli. There was a significant familiarity preference in the simultaneous offset condition, preference score = 56%, $SD = 8.3, t(19)_{vs. 50\%} = 2.95, p < .008$, but not in the delayed offset condition, preference score = 51%, $SD = 6.2, t(19)_{vs. 50\%} = 0.94, p > .35$. Moreover, the familiarity preference was significantly greater in the simultaneous offset than in the delayed offset conditions, $t(38) = 1.80, p < .05$, one-tailed, and this effect was also confirmed by a Mann-Whitney U test ($z = 2.0, p < .05$). In the simultaneous offset condition, 16 out of 20 infants exhibited a familiarity preference ($p < .02$ by a sign test), whereas in the delayed offset condition 10 infants showed a familiarity preference and 10 showed a novelty preference. Moreover, the proportion of infants showing a familiarity preference differed between the two conditions, $\chi^2(1) = 3.96, p < .05$. Finally, there was no correlation (measured by Pearson's method) between the number of flashes the infants looked at and their subsequent novelty preference in either the simultaneous offset ($r = .12$) or delayed offset ($r = -.05$) conditions.

Discussion

Infants in the common offset (unmasked) condition showed a preference between the novel and the familiar gingerbread man in a subsequent test. In contrast, infants in the delayed offset (masked) condition did not show preferential discrimination. In the unmasked condition, infants showed a familiarity preference on test instead of the more commonly reported novelty preference. Familiarity preferences indicate discrimination and are not uncommon when infants have not

had sufficient time to fully encode a stimulus (Sirois & Mareschal, 2002; Roder, Bushnell, & Sasseville, 2000; Hunter & Ames, 1988). As infants gradually encode a stimulus over repeated presentations, they will show a familiarity preference during the initial stages of encoding, and only later switch to a novelty preference once they have fully habituated to the stimulus. The presence of a novelty preference in the unmasked condition suggests that infants have sufficiently encoded the stimulus to recognize it on test but that they have not yet fully processed the stimulus or habituated to it.

Although it is theoretically possible that the null preference in the masked group is the result of more familiarity with the stimulus than that in the unmasked condition (but not enough familiarity for a novelty preference to have emerged), this seems unlikely for several reasons. First, the time infants spent encoding the stimuli during familiarization did not differ between conditions. Second, even if there were differential levels of encoding, the trailing mask could only make the masked condition more complex than the unmasked stimulus, and as more complex stimuli take longer exposures to encode, this would predict a stronger familiarity preference in the masked than the unmasked condition. We found the opposite pattern of looking times. Finally, similar masking procedures in adults prevent, rather than facilitate, encoding of the masked stimulus (Kotsoni et al., submitted; Di Lollo, Enns, & Rensink, 2000). It seems unlikely that the trailing mask had an opposite effect on perceptual processing in adults and infants.

These results are consistent with the interpretation that infants in the delayed offset condition experienced some degree of masking that prohibited them from being familiarized to the shape of the buttons on the gingerbread man. In contrast, the infants in the common offset condition did not experience any masking and therefore encoded the buttons and subsequently showed a discriminatory response on testing. This provides initial evidence that 6-month-olds are susceptible to COVM. In Experiment 2, we examine whether there are any electrophysiological markers of common-onset masking in similar-aged infants.

EXPERIMENT 2

The purpose of this experiment was to identify electrophysiological markers of reentrant processing associated with common-onset visual masking in 6-month-olds. Our reasoning was that differences in the familiarity of the stimuli due to the presence or absence of the mask may be reflected as differences in their neural processing. There is already some ERP evidence of reentrant processing during visual processing in adults. For example, Curran, Tucker, Kutas, and Posner (1993) examined

visual ERPs during a visual word reading task. They reported that following N1 (the first negative deflection following stimulus onset), a separate posterior positive pattern emerged (termed as the “P1 reprise”) that seemed to repeat the topography of P1. According to the authors, the scalp distribution of this effect was similar to the P1 and seemed unlikely that it reflected stimulus offset. Rather, the P1 reprise was suggested to reflect the reactivation of early cortical visual areas under the influence of top-down feedback.

Similar effects have been reported in infants. Johnson and de Haan (2001) compared the spatiotemporal characteristics of electrocortical activation during the early stages of face processing by 6-month-old infants and adults. In this work, both age groups passively viewed a series of color pictures of upright and inverted human faces. Results indicated that early latency ERP components, such as P1, did not differ much between infants and adults. However, in both age groups, there appeared to be dynamic movement of voltage change consistent with migration of information along the ventral visual pathway. This was then followed by a reactivation of overlapping visual areas similar to the adult P1 reprise. In infants, this reactivation phase appeared to be greater than that seen in adults, possibly due to a greater mismatch between input and top-down information. Because the reentrant mismatch associated with common-onset visual masking is expected to occur in early visual cortical areas (see Di Lollo, Enns, & Rensink, 2000) we might expect to find such an effect over the posterior regions of the cortex.

Finally, in work examining the electrophysiological signature of COVM in adults, we found significant modulations of P2 in the masking condition (Kotsoni et al., submitted). We found larger P2 amplitudes when participants viewed delayed offset stimuli as compared to common offset stimuli. Moreover, this effect was consistent with the hypothesis that the neural processes behind the posterior P2 component represent reactivation of primary and secondary visual cortices by feedback from other higher visual areas.

Participants

Fourteen 6-month-old infants (7 boys and 7 girls, mean age 178.71 days, $SD = 8.45$ days) participated in the study. An additional 32 infants were tested but were excluded from the final analysis due to experimenter error ($n = 2$), fussiness ($n = 5$), because the infants did not attend sufficiently to the test event ($n = 10$), or because not enough valid ERP trials were collected ($n = 15$). As before, according to parental reports all infants were healthy, full-term, and of normal birth weight. Infants were recruited through local parent groups, hospitals, baby shops, or magazine advertisements. Finally, all infants were tested individually in our

laboratory in the presence of at least one parent, who had provided informed written consent.

Apparatus and Stimuli

High-density ERPs were recorded by using a Geodesic Sensor Net (Tucker, 1993) consisting of 62 silver–silver chloride electrodes evenly distributed across the scalp. After the sensor net was positioned on the infant's head, each infant was placed on their carer's lap, approximately 100 cm away from a 21-in. computer monitor in an acoustically and electrically shielded and dimly lit room. A video camera was mounted below and behind the monitor peeping through the opening of a black screen, allowing the experimenter to monitor the infant's behavior and to record the session. The experimenter was in an adjacent room from which the whole study was monitored and was in continuous contact with the infant and his or her carer in the testing room.

The stimuli were identical to those used in the previous experiment and consisted of two gingerbread men, with an embedded column of either four squares or four diamonds (Figure 1). In particular, the visual angles subtended by the stimuli were the same as in the previous experiment. As in the familiarization trials in the previous experiment, a mask consisting of four black squares surrounded one of the gingerbread men.

Procedure

At the beginning of the session the infant's attention was drawn to the center of the monitor by spiraling animations and sounds, similar to those used in the previous experiment. Whenever the infants were looking at the monitor, the experimenter pressed a key that started a sequence of flashes that consisted of a gingerbread man with either an embedded column of squares or diamonds and surrounded by a mask of four black squares. If the infant looked away, this sequence was replaced by the spiraling animations and sounds until the infant's attention was drawn again back to the screen. One of the two columns of geometrical shapes always appeared in the *simultaneous offset* condition (i.e., in which the gingerbread man appeared and disappeared with the mask after 200 msec), whereas the other column of shapes always appeared in the *delayed offset* condition (i.e., in which the gingerbread man appeared simultaneously with the mask, but the mask remained on the screen for an additional 93 msec after deletion of the gingerbread man).

Each infant viewed examples of both simultaneous and delayed offset conditions. The sequence of flashes was randomized and intermixed, whereas the choice of the geometrical shape for either condition was counterbalanced across infants. Half of the infants were presented with the column of squares in the simulta-

neous offset condition and the column of diamonds in the delayed offset condition and the other half with the opposite arrangement. The infants passively viewed the stimuli sequence for as long as they were willing. This ranged from a minimum of 46 to a maximum of 204 flashes.

Data Acquisition and Analysis

All signals were recorded referenced to the vertex, with a band pass of 0.1 to 100 Hz. The electroencephalogram (EEG) was sampled every 4 msec (250 Hz) throughout each trial. For each trial, the EEG was segmented to create an epoch from 200 msec before stimulus onset to 700 msec after stimulus onset. Data were then edited off-line for artifacts. Within any given trial, the activity at a sensor was excluded if it went off-scale, if the sensor was not making good contact, or if its activity did not appear to correspond to brain activity. The entire trial was excluded if more than six of the sensors had been excluded or if there were eyeblinks or movement artifacts. Data were then baseline corrected for a period of 100 msec before stimulus onset. Following that, a separate average was created for each individual across trials for each condition. Finally the data were re-referenced to the average reference (Johnson et al., 2001).

The infant's eye movements were also coded off-line from the videotape to exclude trials where the infant did not fixate at the center of the screen or when blinking occurred during stimulation. Infants who were included in the final sample for analysis contributed at least 10 trials, and an average of 28 trials, per condition.

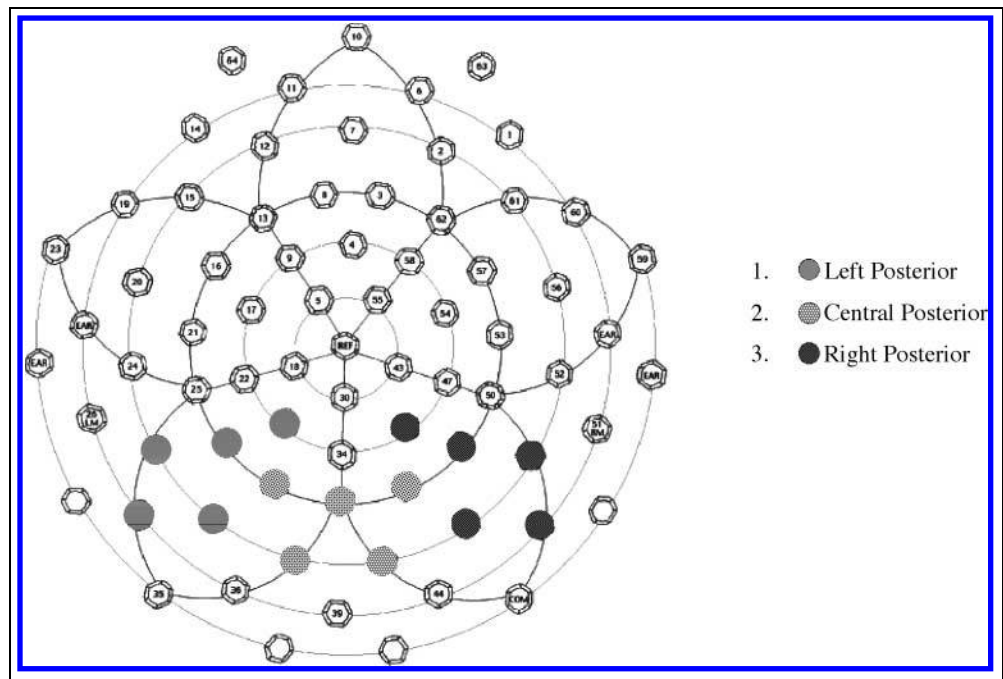
Based on the electrophysiological data obtained with adults in a COVM task (Kotsoni et al., submitted), our analysis of the current electrophysiological data focused on a single time window between 252 to 352 msec post-stimulus onset. This window was defined following visual inspection of the data and looking at the effect of the trailing mask duration on the difference files between the two conditions. To assess the significance of this effect within this time window, the electrodes over the posterior area of the scalp were grouped into three main channel groupings of five electrodes each (Figure 2).

Results

Distribution of Valid Trials by Condition

The number of valid ERP trials produced by each infant was entered in a $2 \times 2 \times 2$ repeated measures ANOVA with Condition (simultaneous or delayed offset) as the within-subject factors, Sex (male or female), and which Shape was used for the delayed offset condition (squares or diamonds) as the between-subjects factor was carried out. No significant main effects or interactions were found. More importantly, geometrical shape within the gingerbread men or sex did not significantly

Figure 2. Electrodes sites and their grouping for data analysis.



affect the number of trials the participants looked at during the study.

Electrophysiological Data

Figure 3 shows the mean amplitude of the electrophysiological signal in the left, central, and right channel groupings as a function of condition. The average voltage values in the 252- to 352-msec interval were initially analyzed in a $3 \times 2 \times 2$ mixed ANOVA with Channel Grouping (left, central, and right) and Condition (simultaneous or delayed offset) as the within-subject factors and Shape (square, diamond) of familiarization column as a between-subjects factor. This analysis revealed no effects of, or interactions with, the Shape factor, so the data arising from the two types of familiarization stimuli were combined and submitted to a new 3×2 ANOVA

with only Channel Grouping and Condition as within-subject factors. This analysis revealed a main effect of Channel Grouping, $F(2,12) = 25.21, p < .001$: the posterior right channel grouping elicited significantly more positive amplitudes than the other two channel groupings (Table 1).

Moreover, a main effect of condition was found to be significant, $F(2,12) = 5.83, p < .03$. More positive amplitudes were elicited by the delayed (masked) than the simultaneous offset (unmasked) condition. Figure 4 illustrates the distribution of this difference across a scalp map.

Discussion

The electrophysiological data revealed systematic differences between the masked and unmasked trials. There

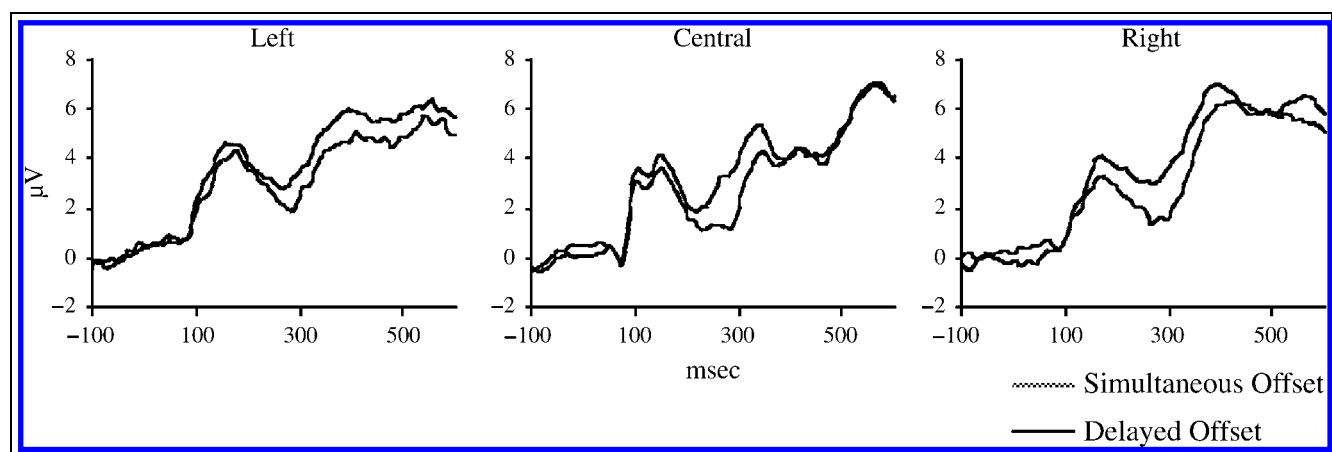


Figure 3. Grand-average ERPs for each channel grouping (left, central, and right) by test condition.

Table 1. Average ERP Amplitudes (Microvolts) by Channel Groupings in Experiment 2

Channel Grouping	Offset Condition	Minimum	Maximum	Mean	SD
Left	Simultaneous	-5.91	23.41	3.619	8.41
	Delayed	-4.11	31.01	5.919	8.91
Central	Simultaneous	-6.79	11.08	1.820	5.35
	Delayed	-9.52	23.35	3.476	8.01
Right	Simultaneous	-.42	20.75	8.463	6.34
	Delayed	1.18	34.60	13.351	9.33

were larger amplitudes in the masked than in the unmasked conditions. These results are consistent with additional work showing more positive amplitudes during masked conditions as compared to unmasked conditions, in adults engaged in standard COVM tasks (Kotsoni et al., submitted).

GENERAL DISCUSSION

The present experiments provide the first behavioral and electrophysiological investigation of common-onset visual masking in infants. Our data suggest that in the delayed offset condition, infants' visual encoding of the stimulus was disrupted. Indeed, although there was no significant difference between the numbers of flashes looked at in the two conditions in Experiment 1, a clear visual preference was exhibited only by infants in the simultaneous offset condition. In other words, although infants were exposed to the stimuli for the same amount of time during the familiarization phase across conditions, only those in the simultaneous offset (nonmasking) condition demonstrated recognition of the stimulus within the mask.

The outcome of the first experiment suggests that it is possible to familiarize 6-month-old infants to a relatively simple stimulus within an average looking time of 2.5 sec of successive flashes. This is consistent with previous studies showing that it is indeed possible to familiarize infants as young as 5 or 6 months of age (Catherwood et al., 1996; Catherwood, 1994; Lasky and Spiro, 1983; Fagan, 1974) with a relatively brief familiarization period (around 2 sec). Although these rates of familiarization are specific to the particular stimuli used, it is also worth noting that all of the previous studies report the need for a long uninterrupted delay following stimulus offset. This presumably provides the infants with adequate time for full visual encoding. Under such conditions, all of the earlier studies reported a novelty preference. The present study, however, provides the infants with an uninterrupted delay of only 1 sec following stimulus offset, targeting the earliest phases of stimulus encoding. Our aim was to modulate the formation of a stimulus repre-

sentation by means of common-onset visual masking. Therefore, it was crucial to present the stimuli long enough for the infants to initiate the formation of a representation, but briefly enough to avoid a full representation to be formed. Collectively, these data suggest that it is not only the duration of exposure to a stimulus that determines whether infants encode a stimulus but also some additional uninterrupted time beyond the stimulus exposure. In sum, common-onset visual masking appears to interfere with the early stages of visual encoding.

Having established the infant behavioral data for common-onset visual masking, the second experiment used high-density event-related brain potentials to investigate the ERP profile that accompanies common-onset visual masking. In this experiment, the more positive wave found for the masked trials may reflect the fact that the infants' representation of the target was disrupted. Although the peak of this effect occurred around 300 msec after stimulus onset, the effect of condition on latency appears to begin during initial stimulus processing. This early onset reflects the fact that during the course of the experiment the unmasked stimulus gradually becomes more familiar than the masked stimulus. This familiarity may be detected early in stimulus processing. The short latency of the effect allows us to rule out the effects of stimulus offset. This is important given that the trailing mask remained for 93 msec beyond the offset of the target in the masking condition.

The ERP effect we observed does not appear to map directly onto either a simple "stimulus familiarity" hypothesis or a P1 reprise (reentrant) hypothesis. In the former case, although the peak of the effect is around 300 msec, the component normally associated with familiarity in infants is usually evident at longer latencies

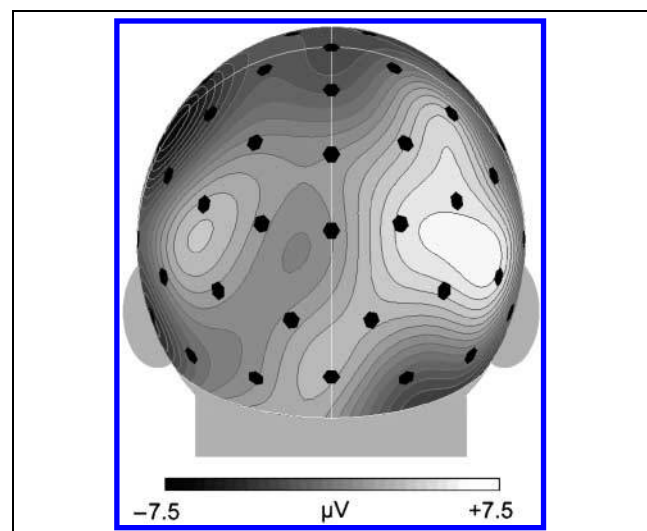


Figure 4. Grand-average difference ERP scalp map showing the effect of the trailing mask at 300 msec poststimulus onset.

(Nelson & Monk, 2001). However, as discussed above, familiarity with the stimulus is part of the explanation as the effect begins during initial stimulus processing. Reentrant processing cannot be the whole story either, because unlike in the adult case (Kotsoni et al., submitted) the effect is maximal around the N1 component rather than the P2 component. Instead, we suggest that the ERP effect we observed reflects an interaction between the local masking (feedback from higher areas) and familiarity. Specifically, the more familiar a stimulus is, the more readily it is extracted from the surrounding mask with the help of the feedback from higher areas. This explanation assumes that stimulus familiarity is processed by higher order areas (which do not directly “receive” the masked stimuli), and feedback from these areas makes stimulus processing in extrastriate areas become more efficient. This hypothesis is consistent with the adult behavioral evidence suggesting that familiarity with the stimulus improves detection (Di Lollo, Enns, & Rensink, 2000). Indeed, highly practiced adult participants require very short target presentations (e.g., 10 msec) to experience masking.

In relation to the theoretical background of common-onset visual masking and visual reentrance, the present data indicate that as infants are actively encoding and updating visual information, this process is disrupted by the trailing mask creating a mismatch between the ongoing lower level activity and a descending reentrant representation of the target. The posterior focus of the effect, as well as the fact that brain activity diverges before deletion of the target, supports the idea that this effect is associated with the formation of a visual representation of the target in relation to the presence or absence of the trailing mask.

Acknowledgments

We are very grateful to Agnes Volein and Leslie Tucker for helping with the collection of data. We acknowledge financial support from the European Commission RTN Grant HPRN-CT-2000-00065, European Commission Grant 516542 (NEST), and Medical Research Council Program Grant G97 15587.

Reprint requests should be sent to Denis Mareschal or Mark Johnson, Centre for Brain and Cognitive Development, School of Psychology, Birkbeck University of London, Malet Street, London WC1E 7HX, UK, or via e-mail: d.mareschal@bbk.ac.uk.

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