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The Influence of Two Spatially Distinct Primers and Attribute Priming on Motion Induction

JOCELYN FAUBERT,* MICHAEL VON GRÜNAU†

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In a series of experiments, we demonstrate the effects of two spatially distinct primers on *motion induction* (MI) and the influence of attribute characteristics on the resulting collision site. MI means that a primer such as a spot produces a motion sensation in a subsequently presented geometrical pattern such as a line or a rectangle. This pattern will appear to grow out of the spot. In the present paper we report that when two different locations of the visual field are activated simultaneously by presenting two spots prior to a bar between these spots, there is a motion sensation of two bars growing away from the spots and colliding in the centre ***(split priming effect).*** Attribute characteristics can have profound effects on this illusion. When two differently coloured isoluminant spots are presented and the subsequent bar is composed of either one of these colours, the induced motion is away from the spot of identical colour. We call this effect ***attribute priming.*** Manipulating the delay between the spot presentations (SOA) showed that timing had a strong effect on split priming, but very little on attribute priming. For split priming experiments with dichoptic presentations, we show that at shorter SOAs there is a dominant effect of the primer which is presented to the same eye as the bar, as opposed to the usual dominance of the later primer. For longer SOAs, however, the temporal sequence of the primers also plays a role in motion induction. Further, we report that geometrical arrangements can strongly influence the direction of perceived motion when more than a single primer is used. Generally, in motion induction with two primers, unlike what is found with a single primer, there appears to be a dominance of low-level effects such as geometry, attributes, and eye of presentation. For dichoptic presentations, however, this can be overcome for longer SOAs. The differences between the single and split priming paradigms are discussed in terms of the differential contribution of bottom-up and top-down processes.

Motion   Motion induction   Attention   Split priming   Attribute priming   Illusory motion   Attributes

INTRODUCTION

When a spot followed by a bar produces a motion sensation within the bar, this has been called the illusory line motion effect (Hikosaka, Miyauchi & Shimojo, 1993a, b) or motion induction (von Grünau & Faubert, 1994). Similar motion sensations have been reported many years ago by the German Gestalt psychologists and were labelled as gamma motion by Kenkel (1913). This refers to the apparent expansion from the centre to the outside when a bar is presented. An interesting extension of gamma motion was presented by Kanizsa (1951, 1979), where the perceived movement was polarized in one direction, away from an adjacent stimulus that was present prior to showing the bar. Hikosaka *et al.* (1993a, b), however, were the first to clearly attribute this type of motion sensation to attentional processes. They have argued that this effect is possible under cross-modal conditions implying that higher-level (perhaps attentional) elements are involved. In a recent study (von Grunau & Faubert, 1994), we showed that motion induction (MI) was readily visible when the spot and the bar stimuli were defined with respect to the background by one of a variety of attributes, such as luminance, colour, stereodepth, texture and motion. We reported that all attribute combinations produced MI, but that the strength of the perceived motion varied and depended more on the attribute defining the bar, than the attribute defining the spot.

The roles of high-level (top-down) and low-level (bottom-up) processing in this effect is not clear at this time. The present study addressed the following questions: (1) how does priming of two spatially distinct positions (split priming) influence our perception of the bar stimulus in the MI paradigm? (2) What is the role of physical attributes such as colour and luminance in the MI illusion with two spatially distinct primers (Attribute priming)? (3) What is the relative location within the visual system of the priming effects?

*École d'optometrie, Universite de Montréal, 3750 Jean-Brillant, C.P. 6128, succursale "Centre-Ville", Montreal, Quebec, Canada H3C 3J7 *Email* jocelyn.faubert@umontreal.ca

†Department of Psychology, Concordia University, Montréal, Quebec, Canada HSG 1M8.

In the following paragraphs we will discuss the outcome of pilot experiments and the underlying logic leading us to the three experiments conducted in this study.

Split priming

In the simple MI paradigm used previously by Hikosaka *et al.* (1993a, b) and ourselves (von Grünau & Faubert, 1994), a spot was presented just prior to a bar, and the obtained motion sensation was away from the primed area, presumably due to local facilitation of the bar near the spot (Hikosaka *et al.*, 1993a, b; Stelmach & Herdman, 1991; Stelmach, Herdman & McNeil, 1994). Assuming that we present two spots prior to a bar [see Fig. 1(a)], three possible outcomes can be derived from this situation, each resulting in different motion percepts with regards to the bar.

One possibility is that the resulting facilitation from the spots *cannot* be activated simultaneously at two separate locations of the visual field and only a shift from one location to the next is possible. The resulting motion sensation would be identical to that of the original MI paradigm, and motion would be perceived away from the only spot producing facilitation [see Fig. 1(b)]. Another possible outcome is demonstrated in Fig. 1(c). If some form of spreading between the two primers occurs, the entire region of the bar stimulus would be facilitated and, thus, no motion towards or away from the spots should be perceived. A third possibility holds that facilitation can be achieved

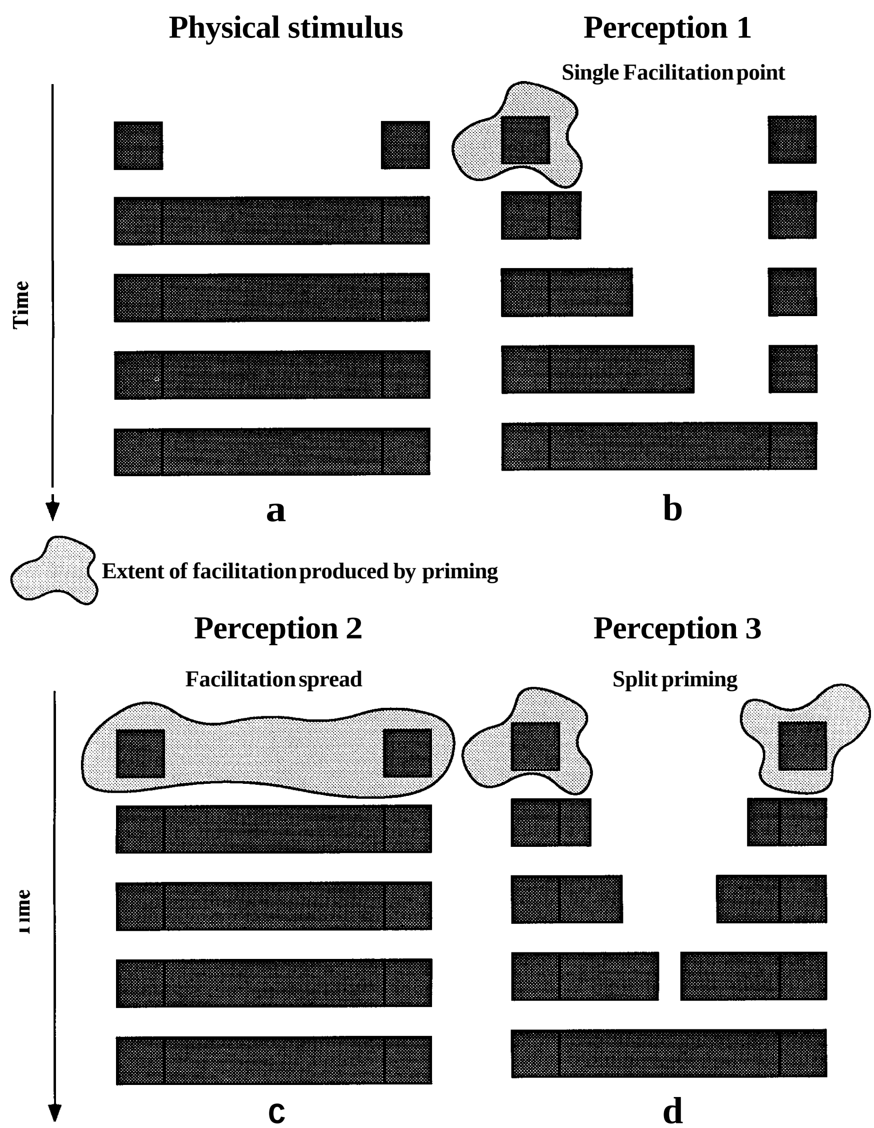

FIGURE 1. Schematic representation of the stimulus sequence and the perceptual results which could be obtained from different hypotheses about priming facilitation. The vertical axis describes the progression of time as well as the vertical stimulus dimension, and the horizontal axis depicts the horizontal extent of the stimuli. Two spots are presented first and remain on throughout the experimental sequence. Following a short delay after the onset of the spots, a bar is presented and remains on. (a) The actual physical stimulus presented. (b) The perceptual experience hypothesized for the actual physical stimulus if priming facilitation remains in one spot or simply shifts location. (c) The perceptual experience hypothesized for the actual physical stimulus if priming facilitation spreads between the two primers. (d) The perceptual experience hypothesized for the actual physical stimulus if priming facilitation is present at the two primer locations simultaneously. This experience is what the observers generally report. We call this effect *split priming.*

in more than one location at a time, leading to the perception illustrated in Fig. 1(d). If we assume that processing near the primers will be accelerated (Hikosaka *et al.,* 1993a, b) the bar should seem to appear initially near the two spots and then more and more towards the centre. This would result in the perception of two bars growing away from the spots and towards each other, finally colliding in the centre. This latter possibility is what is being perceived when the bar is shown in such a context (Faubert & von Grunau, 1992a). It seems therefore that facilitation produced by primers is not restricted to one location of the visual field at any one time. In fact, we have observed that many primers followed by adjacent bars will all produce simultaneous movement sensations in the bars, implying that some low-level parallel facilitation system is involved. In Expt 1, we examined how delays between two priming spots can alter the collision point within the bar.

Attribute priming

A second aim of this study was to evaluate the effect of attribute characteristics, such as colour and luminance, on split-priming in the context of MI. Based on our previous experiments (von Griinau & Faubert, 1994), we would predict that each one of a pair of isoluminant priming spots of different colours would have comparable motion effects on the bar. This is because those data showed only a small influence of the spot attribute as long as the bar was readily visible. In the previous method with a single spot, however, there was no direct way of determining the relative strengths of attributes on MI. In the context of split priming, it is possible to present, for example, two different colours as priming spots simultaneously and have them "compete" for effects on the bar. In the case of a green spot and a red spot presented simultaneously, we would presume that initially both areas in the vicinity of the spots would be facilitated by the spatially distinct primers. What would happen if the subsequently presented bar was either red or green? In an earlier study (Faubert & von Griinau, 1992a), we had found that the bar would grow out of the correspondingly coloured spot as readily as it did in the single spot MI experiments. An illustration of this effect is shown in Fig. 2. For example, if a green and a red spot were presented followed by a red bar, the bar would grow out of the spot without collision. It appears that, although local facilitation is equal at both primed positions, its strength is nonetheless biased by the colour concordance of the subsequently presented bar. We call this effect *attribute priming*. In Expt 2, we examined colour and luminance in attribute priming with and without delays between the two priming spots.

Temporal factors

The introduction of a delay [stimulus onset asynchrony (SOA)] between the presentation of the first spot and the presentation of the second spot, can be considered another way of determining the relative effectiveness of the facilitation produced by two spatially distinct primers in the MI context. This is shown schematically in Fig. 3. When both spots are presented simultaneously, collision has been found to occur near the centre of the bar, presumably due to equivalent facilitation produced by the two spots. If the facilitation decays with time, we would expect a shift in the position of the collision away from the centre toward the position of the first spot.

It may also be possible to counteract the directional bias caused by attribute priming by changing SOA values, thus balancing the effect of the timing delay against the effect of attribute priming. For instance, if the first spot was green, the second spot presented after a certain delay was red, and the bar (with the usual delay) was green, standard attribute priming would cause motion to be perceived as away from the green spot. A long enough SOA, on the other hand, would cause motion to be perceived as away from the red spot. The results generally show that the collision position can easily be shifted in the split priming paradigm by introducing SOAs, but attribute priming under the present conditions turns out to be very resistant to timing changes.

Dichoptic presentations

In an attempt to identify the relative location within the visual system where the split priming effect occurs, we have conducted a third experiment using dichoptic presentations. In this case, the two primers were always presented to different eyes while the bar was presented to only one of the eyes. If the processing of the split priming effect occurs at or beyond the binocular fusion site, the way in which the two spots and the bar are presented among the two eyes should have no bearing on the results, and the temporal sequence of the primers alone should predict the position of the collision site, as illustrated in Fig. 3. On the other hand, if the split priming effect is processed prior to the binocular junction, the collision site should be influenced by the eye of presentation. In such a case, the collision site should be biased away from the location of the spot presented to the eye which also received the bar. The results show that eye of presentation is important at shorter SOAs (at and below 150 msec) but that for longer SOAs the temporal sequence of the primers influences the motion illusion.

EXPERIMENT 1

In this experiment we tested the effect of a delay (SOA) between the two spatially distinct primers in the split priming paradigm as described above.

Methods

Subjects

Three subjects were tested (JF, MvG and SD). All have normal or corrected-to-normal visual acuity (Snellen

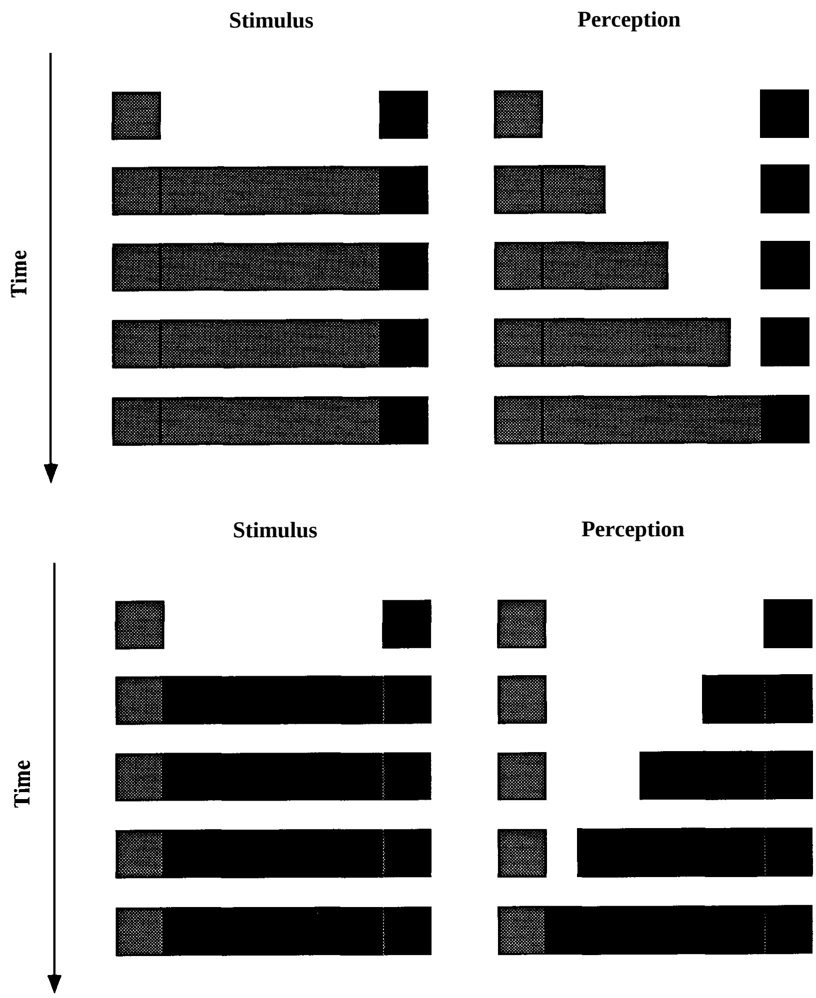

FIGURE 2. Physical representation and actual perceptual experience when attributes of the primers differ. The vertical axis describes the progression of time as well as the vertical stimulus dimension, and the horizontal axis depicts the horizontal extent of the stimuli. Two spots are presented first and remain on throughout the experimental sequence. Following a short delay after the onset of the spots, a bar is presented and remains on. When the spots are different and the bar has the same characteristic as one of the spots, the experience is of a bar growing away from the spot with the same attribute instead of the usual central collision perceived when the attributes are the same. We call this effect *attribute priming*.

6/6) and are experienced psychophysical observers. SD was naive as to the hypothesis of this experiment.

Apparatus and procedure

The experiments were conducted on a Macintosh IIfx computer with an Apple High Resolution RGB Monitor. The inducing spot was a square with 1.5 deg sides, and the bar was a rectangle of 1.5 x 7.5 deg. They appeared in the middle of the screen with a fixation cross centred 7 deg below them. The delay between the last presented spot and the bar was fixed at 300 msec. The observers watched this display from a distance of 57 cm, keeping their eyes on the fixation cross. The spots were identical in luminance and colour and were either presented at different times or the spots were presented simultaneously in the control condition (see Fig. 3). Once presented, both the first and second spot were left on until the end of the trial. Typically, 60 trials were recorded per condition for each observer. SOAs between the two spots of 0, 90, 150, 300 and 600 msec were used. In each trial, the observer had to indicate where the collision had occurred by dragging a cursor controlled by a mouse and positioning it adjacent to the perceived collision point. This response was recorded by the computer as a position on a numeric scale. Once the response was recorded, the next trial was initiated. The numeric scale varied from -1, which was the extreme left position of the scale representing the left edge of the bar at the edge of the left spot, and $+1$, which was the extreme right edge of the bar. Thus, a response to a centre collision would be recorded as a value of 0. The spots and the bar areas always consisted of a homogeneous luminance and colour. The isoluminance and luminance polarity conditions were tested separately. In the colour trials, the colours used for the spots and bars were red ($u' = 0.425$, $v' = 0.530$) or green ($u' = 0.122$, $v' = 0.564$) on an isoluminant yellow background. The isoluminance points for each colour combination used were determined for each observer by flicker photometry just prior to the experiment. The same spatial positions were used for flicker photometry as in the testing condition. In the luminance polarity

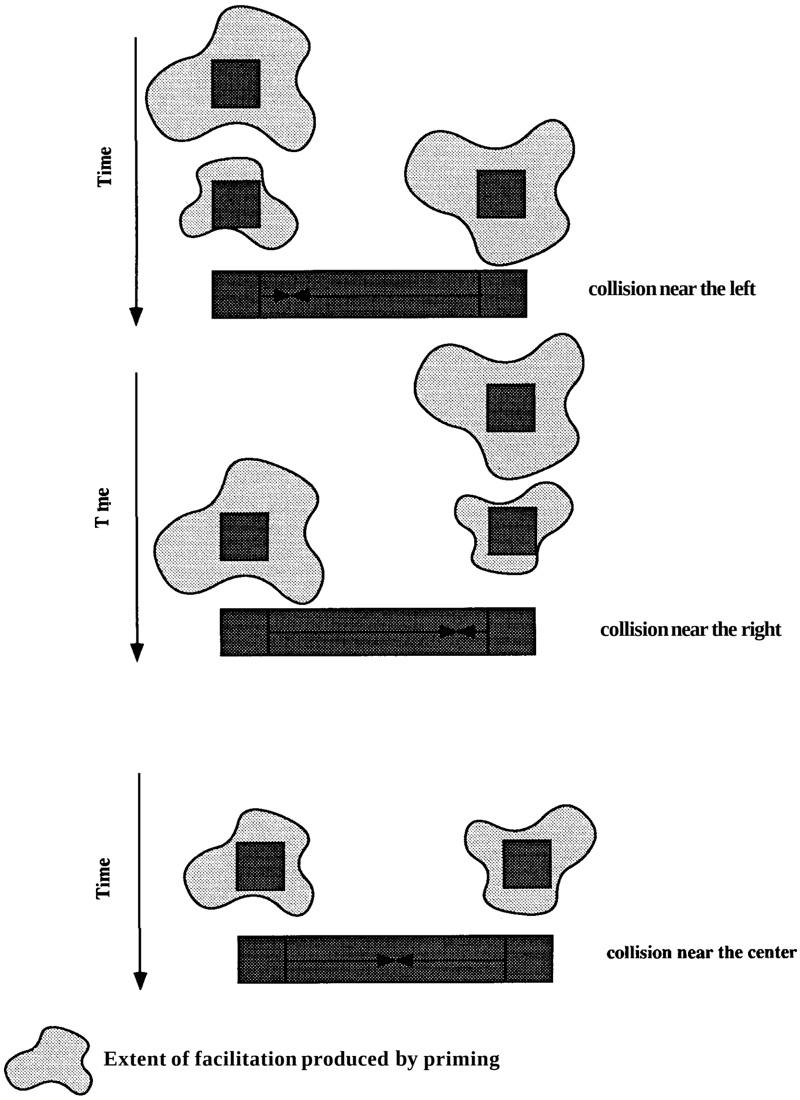

FIGURE 3. Schematic representation of the hypothesized priming facilitation effects if the primer activation decays with time. The grey areas represent hypothesized priming facilitation strength. The opposing arrows in the bar show the presumed collision location based on relative weights of the spots due to the timing sequence. Once the spots are presented they always remain on. These patterns represent well the results obtained in the study.

trials, one luminance condition was slightly brighter than the $10 cd/m^2$ background ($12 cd/m^2$) and one was slightly darker than the background ($8.34 cd/m^2$) yielding identical contrast values. All other independent variable conditions (first and second spot location, SOA, colour and luminance polarity), were randomized.

Results and Discussion

The results for both the isoluminant coloured targets (red or green) and the luminance polarity targets are shown in Fig. 4. They are graphed separately for the three observers and are presented as the mean collision site on the y-axis and the different SOA conditions on the x-axis. Two curves are shown in each graph, one representing the expected rightward motion (i.e. when the last presented spot was on the left) and the other the expected leftward motion (i.e. when the last presented spot was on the right). Only one point is shown at zero SOA representing the control conditions.

Results for all three subjects show clear trends in the expected directions for both the colour and luminance defined stimuli. As expected for the zero SOA condition, the collision site was generally near the middle of the bar positioned between the two primers. When a delay was introduced between the first and second spots, the apparent collision point shifted increasingly toward the first spot with increasing SOA. This behaviour can be understood within the simple timing model presented in Fig. 3. The SOA allows a decay of the facilitation strength of the first spot, so that the second spot comes to dominate more and more, pushing the collision point towards the first spot.

EXPERIMENT 2

In this experiment we determined the effect of the temporal sequence of the primers in the attribute priming condition, as described in the Introduction.

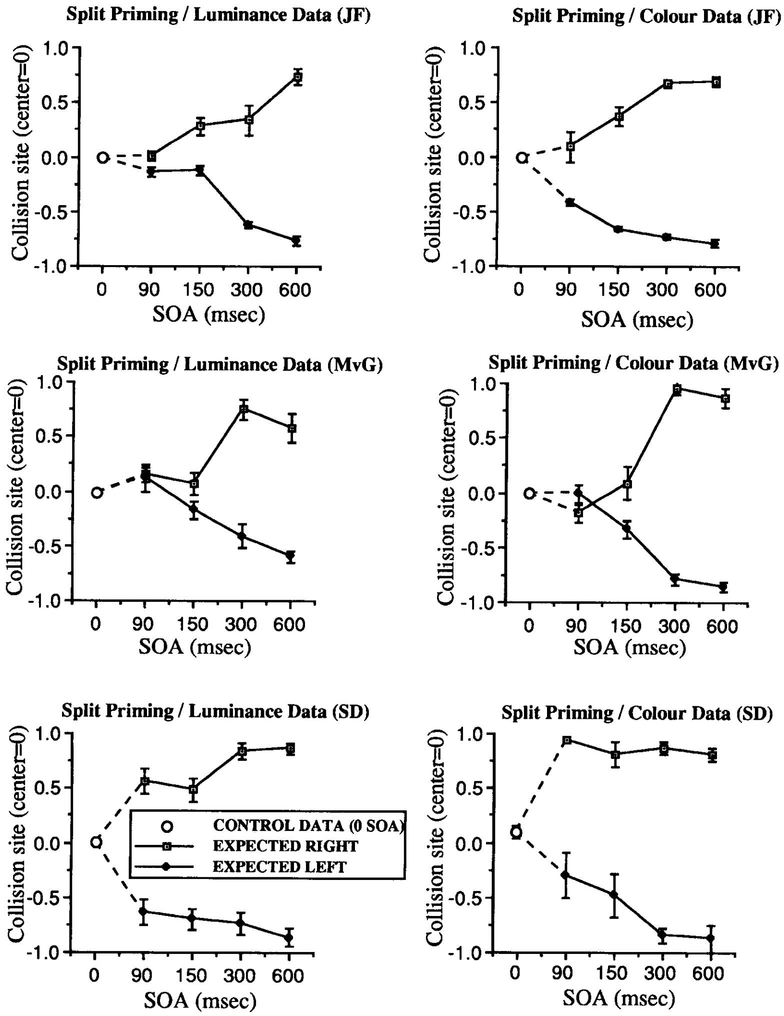

FIGURE 4. Split priming data obtained for three subjects. The values are presented as the mean collision site on the y-axis and the different SOA conditions on the x-axis. Two curves are presented in each graph one representing the expected rightward motion (i.e. when the last presented spot was on the left) and the other the expected leftward motion (i.e. when the last presented spot was on the right). Only one point is shown at zero SOA representing the control conditions. A value of 0 on the y-axis represents a central collision, a negative value represents a collision site to the left of centre and a positive value represents a collision site to the right of centre on a scale from -1 to $+1$.

Methods

Subjects

Two of the three subjects in Expt 1 participated in this experiment (JF and MvG) and a third subject (LB) also participated.

Apparatus and procedure

Similar conditions were used in this experiment as in Expt 1, except that the spots differed in colour or luminance and the line attribute was identical to that of one of the spots. SOAs of 0, 150, 300, 600 and 1200 msec were used. The colours and luminances used were the same as in Expt 1. The isoluminance and luminance conditions were tested separately. All other independent variables (first and second spot location, SOA, colour of spots and bar, or luminance polarity of spots and bar) were randomized. The same task as before was used, i.e. the subject positioned a cursor next to the collision point on the screen.

Results and Discussion

Figure 5 shows the results obtained in the attribute priming paradigm for the luminance and colour data. The collision site is again graphed as a function of SOA. Expected right and left motion direction due to attribute priming are shown schematically at the bottom.

Generally, these findings show that attribute priming under these conditions was very strong and dominated the motion perception within the bar. The different SOAs had almost no effect on the perceived direction of motion. No difference could be observed between the colour and luminance stimuli. These results are strikingly different from the results obtained with a single primer (von Grünau & Faubert, 1994). In the single priming condition we previously found that when two different colours such as a red and green were used for the bar and spot, the motion illusion was readily perceived when the bar and spot were of the same colour or when they were of different colours. This

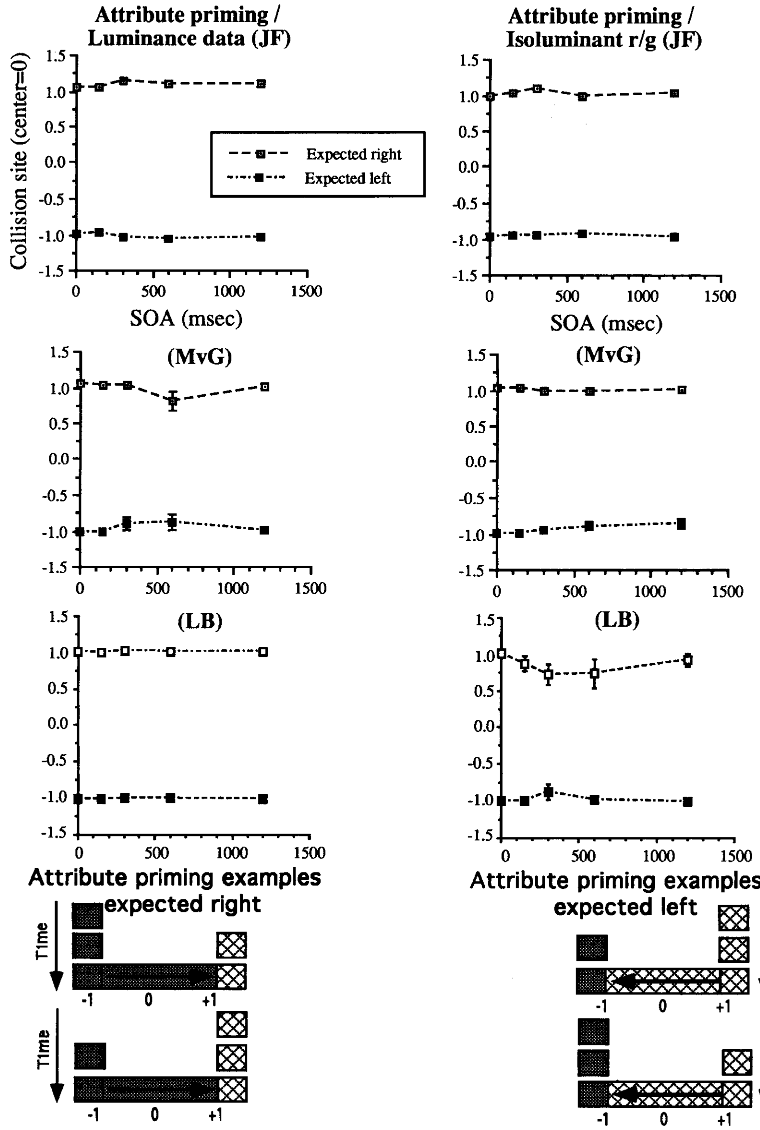

FIGURE 5. Attribute priming data for colour and luminance conditions obtained for three subjects. The values are presented as the mean collision site on the y-axis and the different SOA conditions on the x-axis. Two curves are given in each graph, one representing the expected rightward motion (i.e. when the primer presented on the left and the bar had the same attribute) and the other the expected leftward motion (i.e. when the primer presented on the right and the bar had the same attribute). Scale defined as in Fig. 4.

demonstrates the possibility that the nature of motion induction differs greatly for the split priming and single priming paradigm. In the former case, the influence of stimulus characteristics is much more profound suggesting the importance of bottom-up processes.

EXPERIMENT 3

In an attempt to determine whether such processing occurs at or before the binocular fusion site we assessed the split priming paradigm in the context of dichoptic presentations.

Methods

Subjects

The same subjects who participated in Expt 2 also participated in this experiment.

Apparatus and procedure

Similar conditions were used in this experiment as in Expt 1, except that the spots and the bar were presented dichoptically using red/green glasses. The luminances of the colours were carefully adjusted so that nothing was visible through the red filter when a red spot or bar was presented, and nothing was visible through the green filter when a green spot or bar was presented on the yellow background. One eye was presented with a spot and the other eye was presented with a primer and the bar. The spatial position of the primer, the timing sequence of the spots, and the eye selected for presentation of either a single spot or both a spot and the bar, were all randomly selected in a given trial. SOAs of 0, 90, 150, 300 and 600 msec were used. The response task was the same as in the previous experiments where the subject has to identify the collision site by dragging a cursor on the screen to the perceived collision location.

Results and Discussion

Figures 6 and 7 show the results obtained for the three subjects in this experiment. Collision site is graphed as a function of the SOA between the two spots.

In Fig. 6 we graph the data obtained when the bar was presented to the same eye as the second spot. For the sake of simplicity, and because the results were similar when motion was perceived in either direction, we have reversed the polarity of the leftward direction, as illustrated in the figure, and averaged the two sets of data. In this case, a positive value always represents movement away from the second spot. The results from two of the three observers demonstrate, as expected, that the different SOAs bias the perceived motion direction to be mostly away from the second spot. Under these conditions motion is dominated by the second spot, and since this spot and the bar appeared in the same eye, the results are similar to the single spot MI data when the stimuli are presented to both eyes simultaneously. The data from the third subject shows that the eye-of-origin is very important with short SOAs. However, with increasing SOAs the initial primer also had an influence on the perceived motion. She described a sensation of two transparent bars moving in opposite directions over one another. In this case she could not evaluate the relative strength of the motion sensations originating from either end. Rather, she would indicate a central collision which explains why for SOAs of 150 msec and higher her collision site values approached zero. Although, the first two observers also perceived transparent lines on occasion, they were able to evaluate the stronger motion sensation and estimate a collision site which represented the relative weights of the two motion sensations moving in opposite directions.

In Fig. 7 we illustrate the results obtained when the first spot and the bar were shown to the same eye. In this case the curves for both perceived directions

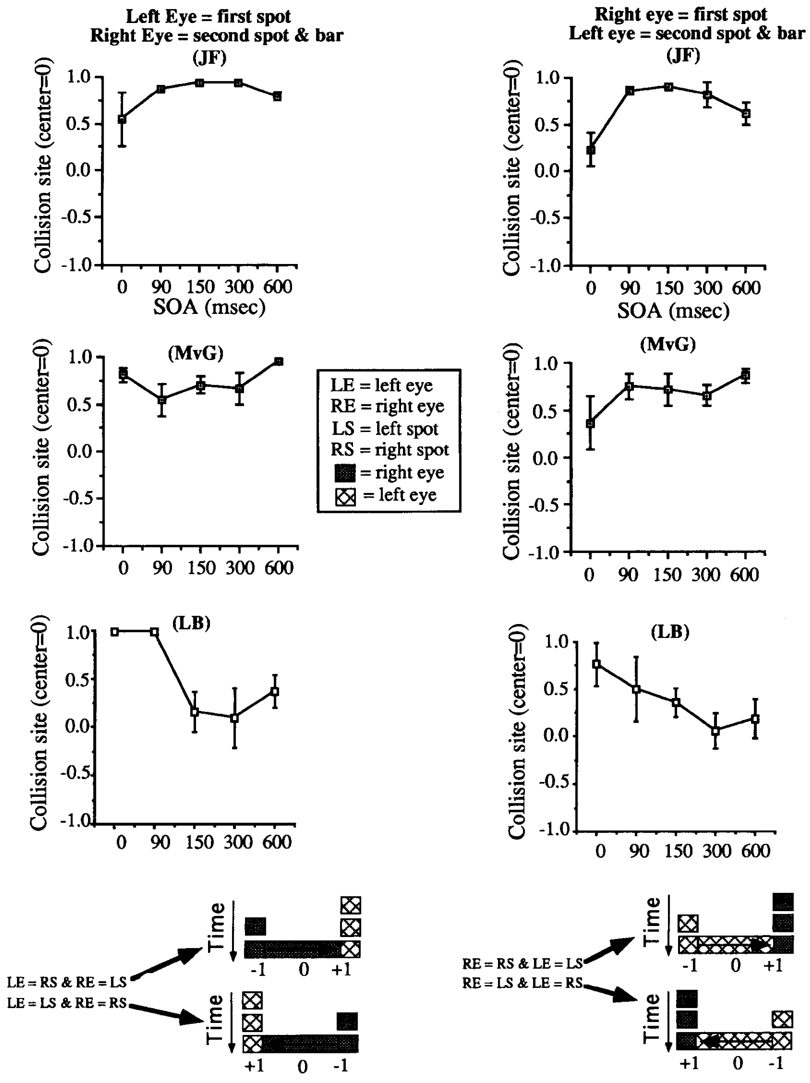

FIGURE 6. Dichoptic presentation data when the second spot and the bar are shown to the same eye. The values are given as the mean collision site on the y-axis the different SOA conditions on the x-axis. For the sake of simplicity, and because the results were similar when motion was perceived in either direction, we have reserved the polarity of the leftward direction and averaged the two sets of data. In this case, a positive value always represents movement away from the second spot.

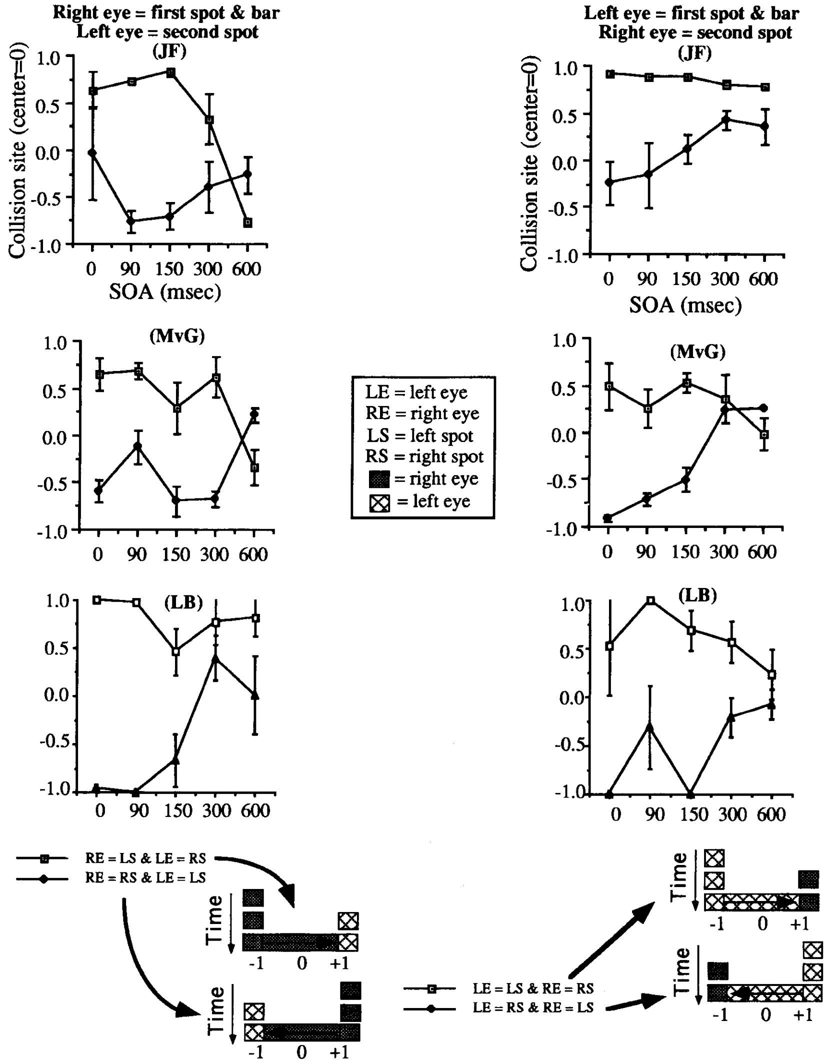

FIGURE 7. Dichoptic presentation data when the first spot and the bar are shown to the same eye. The values are presented as the mean collision site on the y-axis and the different SOA conditions on the x-axis. In this case we show curves for both perceived directions separately to demonstrate the interaction obtained for the different SOA conditions. The cartoons in the figure show the expected motion direction, in the form of arrows, if the motion induction effect in this context would be processed at levels below the binocular fusion site, i.e. if the motion induction effect was only driven monocularly and not by the temporal relation between the spots. The scale is defined as in Fig. 4.

are shown separately to demonstrate the interaction obtained for the different SOA conditions. The cartoons in the figure show the expected motion direction, in the form of arrows, if the motion induction effect in this context was determined by the spot that was presented in the same eye as the bar (the first spot here). In other words, the motion induction effect would not be determined by the spot presented later, as was the case in binocular split priming (see Fig. 4). For short SOAs, this was the dominant outcome: the collision site was located mainly nearer to the second spot. For longer SOAs, however, the location of the collision moved more toward the first spot. This indicates that under those temporal conditions, MI was strongly influenced by the second spot, regardless of the fact that this spot was presented to a different eye than the bar. This interaction is most evident with SOAs longer than 150 msec.

These results imply that, under split priming conditions, the perceived motion direction is generally determined by monocular processes, but that at longer SOAs some process situated at a different level comes to dominate in an increasing fashion. This lends support to the notion that both early and late processes are involved in MI.

GENERAL DISCUSSION

In the experiments reported in this study, we first tested whether simultaneous activation sites in the visual field were possible in the context of the MI paradigm. That is, is it possible to elicit different motion directions simultaneously in MI as a result of priming more than one area of the visual field? Three possible outcomes were proposed (see Fig. 1). The results clearly show that when there are no attribute differences between the primers and the bar, motion sensation in the bar is perceived away from both primers simultaneously, thus producing the percept of a central collision. In the first experiment we further tested whether the hypothesized underlying facilitation is time-dependent as proposed by other researchers for single primers (Hikosaka *et al.,* 1993a, b). The results were clear in this regard: SOA was found to have a profound effect on the collision site with the more recent primer having the stronger effect.

In Expt 2 we determined whether attribute correspondence could influence the collision site in the split priming paradigm. Based on the results of previous studies where only a single primer was used (von Grunau & Faubert, 1994) we would expect that a difference in attribute characteristics between the spots and the bar would have little influence on the collision site. The present results are very different from the single spot data. The attribute differences of colour or luminance had profound effects on split priming motion induction. The similarity of attribute (i.e. same colour or luminance polarity) between the bar and one of the spots totally determined the direction of the perceived motion. Motion was always biased away from the spot having the same colour or luminance as the bar. This was true even for very long SOAs. This suggests a substantial difference between the single and split priming paradigms. In the former case, there is some evidence that the level of processing is not restricted to early motion analysers and that attribute differences between the single spot and the bar play a minor role (von Grunau & Faubert, 1994). Here the introduction of a second spot makes attribute correspondence a major factor. The attribute priming effect does not appear to be limited to colour and luminance polarity because we have observed that this effect is also visible with texture differences. Further, research will determine whether there are any attribute interactions within the attribute priming effect.

In the third experiment we assessed further, by means of dichoptic presentations, at what level the motion illusion obtained in split priming could be produced. According to the results of the second experiment, we would expect the processing to be mainly stimulus based (bottom-up) rather than top-down. Therefore, eye of presentation should be a decisive factor in predicting motion direction in addition to the temporal sequence of the primers. The results of Expt 3 show this to be true, and to depend on the length of the SOA. Only for SOAs longer than 150 msec did the temporal sequence of the primers influence the collision site to a substantial degree. This influence, however, was not complete, i.e. the collision site was shifted from a position near the second spot across the centre of the bar to the other side near the first spot, but this shift was never total. Based on these results, we conclude that the split priming motion induction effect is primarily a bottom-up process, usually taking place early in the visual system. We cannot exclude, however, that higher processing levels can be involved, particularly for longer SOAs.

Differences between the split priming and single priming motion induction effects

The results of previous motion induction studies with a single primer had led us to believe that motion induction was effective regardless of the attribute characteristics (von Grunau & Faubert, 1994) and was subject to active attention (Hikosaka *et al.,* 1993a, b), suggesting some form of top-down processing. However, the results of our present experiments clearly show that split priming motion induction is generally a bottom-up process with some indication of top-down processing for longer SOAs. This difference between the single priming and split priming paradigms is also evident in the way in which geometrical arrangements influence motion induction. These observations are illustrated in Fig. 8 in the following way: in each case, spots are always presented simultaneously, followed by the bars, also presented simultaneously. The perceived motion direction and extent are indicated by the arrow(s) inside the bar(s). The effects shown in Fig. 8 were demonstrated with a number of observers (minimum of 10) and were reported unanimously by all of them.

In Fig. 8(a) a single spot is flanked on both sides by bars. A motion illusion is produced in both directions simultaneously. When two spots are presented, followed by bars on both sides and in the middle between the spots, motion is perceived in all directions away from the spots [Fig. 8(b)]. When, however, one of the outside bars is removed, the motion illusion becomes completely unidirectional [Fig. 8(c, d)]. There is no longer the perception of a collision in the centre bar. This constitutes another example where split priming motion induction is influenced by basic stimulus characteristics, in this case the geometry of the stimulus. Figure 8(e, f) shows other examples of observations made with the single and split priming motion induction paradigms. A direction change in the motion illusion is very difficult to observe with a single primer, but can be readily observed when two primers are used.

There are other experimental results which imply the role of low-level processes in motion induction. When many primers are presented simultaneously, followed by bars presented contiguous to the primers, motion is perceived in all the bars (our own observation and Stelmach, personal communication). This effect does not appear to be critically limited by the number of stimuli presented, suggesting low-level parallel processing. In this context, combining the MI paradigm with visual search for pop-out targets yielded results that suggested contributions of low-level, parallel processes as well as higher-level attentional processes to MI (von Grunau, Dube & Kwas, 1994). A further point stems from a study where the bar contained a luminance gradient (von Grunau, Faubert & Saikali, 1993). When such a bar was presented alone, a motion sensation was perceived away from the brighter end of the bar, presumably due to the

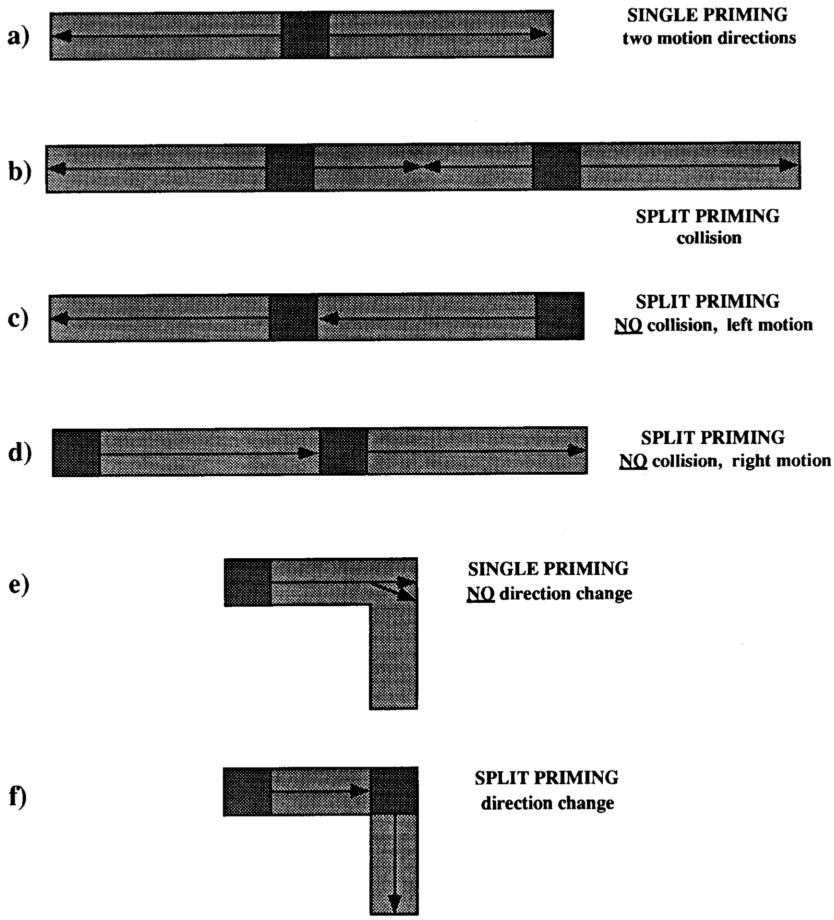

FIGURE 8. Schematic representation of observations indicating the influence of geometrical characteristics. In all cases, all spots and all bars are presented simultaneously with a delay between the spot(s) and the bar(s). Spots and bars had the same luminance and colour characteristics; differential shading is used to identify the stimuli. The direction and length of the arrows indicate the direction and extent of the perceived motion within the bar(s).

faster processing speed of the high-luminance end of the stimulus. When the bar was preceded by a single primer, the motion sensation due to motion induction could be modulated by the direction of the luminance gradient for primer-bar delays of up to 90 msec but not for longer SOAs. In a split priming paradigm, the motion direction was always determined by the luminance gradient regardless of the temporal sequence of the two primers.

SUMMARY AND CONCLUSIONS

Taking the above results into account, we may hypothesize that both the single priming and split priming motion induction effects incorporate both bottom-up and top-down processes. The results of the present experiments in particular show that when split priming is used, the motion sensation is generally driven by low-level effects such as attribute characteristics, the geometry of the stimulus and eye of presentation. However, this does not mean that the split priming effect is totally void of top-down processes. In this context, we have found in pilot experiments with memorized primer locations, that top-down processes can produce a central collision within the split priming paradigm (Faubert & von Grünau, 1992b) but further research is required to determine the relative strength of such processes. Unlike the split priming effect, the single priming effect appears to be processed primarily at higher levels and seems less dependent on attribute characteristics than the split priming effect. We believe that motion induction in general, involves both bottom-up and top-down processes along with early and late processing stages. When a single primer is used, MI appears to be biased towards top-down and late stages of processing. The split priming effect, however, appears to be biased towards bottom-up and early stages of processing. We propose that this difference between the single and split priming MI effects *does not* imply that the two phenomena are of a fundamentally different nature. Rather, we think both are related effects within a continuum where low-level, bottom-up and high-level, top-down processes interact with each other to create a motion illusion. The difference between the single and split priming MI effects may arise as the result of limited resources (serial processing) of top-down and high-level processes, and that when more than a single primer is used, MI is mostly influenced by the presumably unlimited (parallel) bottom-up process.

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