Illusory line motion and perceptual latency priming: Two alternative measures for attentional facilitation

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Attention may decrease the perceptual latency of an attended as compared to a non-attended stimulus. In recent years, this assumption has been studied within two independent experimental paradigms, illusory line motion (ILM) and perceptual latency priming (PLP). In ILM, a line appears to develop from an attended end [1]. PLP is the temporal advantage of a visual stimulus that is preceded by a masked peripheral cue [2]. Although both are ascribed to the same mechanism – the facilitating influence of attention –, ILM and PLP have never been directly compared. I propose an experimental design which allows to study them in identical stimulus displays. The results of the two tasks are very similar. The experiment thus corroborates the usefulness of latency measures such as ILM and PLP in the study of visual perception and attention.

1 Introduction

Attention is commonly assumed to facilitate processing of visual information: Attended stimuli are processed more elaborately, accurately and faster than unattended stimuli. One consequence of the last point – faster processing – is that attention may decrease the perceptual latency of a stimulus. Compared to a non-attended stimulus, the attended stimulus is perceived earlier, or – since the time of perception is not necessarily equal to the perception of time – as earlier than an unattended stimulus.

As "prior entry", this phenomenon has been studied for more than a century. It was first described and experimentally investigated by astronomers who simultaneously observed a visual and an auditory event (a star transit and the ticking of a clock). They discovered large mistakes in synchronisation of the two senses [3]. Wilhelm Wundt ascribed these mistakes to the deployment of attention to the two senses and to spontaneous fluctuations of attention [4]. According to his explanation, attention is necessary to raise a sensory event into the focus of consciousness. The stronger attention is, the quicker is this boosting and the earlier the event can be perceived.

By the beginning of the 20th century, Titchener included a "law of prior entry" into his seven fundamental laws of attention [5]. During the second half of the 20th century, interest in prior entry dwindled away. However, in recent years it has been revived within two experimental paradigms, illusory line motion (ILM) and perceptual latency priming (PLP).

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Illusory line motion

In ILM, a spatially extended stimulus, usually a line, is presented. One of its ends is attended to. The line is perceived as developing from the attended towards the unattended end. This results in the impression of motion within the line [1]. According to the standard explanation, attention is distributed in a gradient around its focus. Attention speeds up the perceptual latency of signals at attended locations. The amount of facilitation depends directly on the attentional gradient. Thus, the closer a part of the line is towards the focus of attention, the more it is facilitated and the faster it is processed. The signals from the parts of the line are processed with different speed, reach motion detectors asynchronously and thus foster the detection of motion.

There are two ways to measure facilitation in the ILM paradigm. One is to depict the probability of perceiving motion away from the attended end – typically assessed in two-alternative forced-choice judgments – as a function of cueing interval. The probability quickly rises with cueing interval, has its maximum at 100 to 200 ms (motion is perceived virtually in every trial) and decreases with larger intervals. ILM may arise with intervals longer than one second, for example when the cue remains visible [1]. The other possibility is to induce apparent motion within the line and measure the motion parameters at which ILM and apparent motion cancel each other out [6]. In contrast to the first strategy, this second type of measurement allows to quantify the attentional gain. Unfortunately, the results differ from the typical time course of attention because facilitation linearly decreases with cueing interval [1].

ILM can be induced by spatial precues, by instructed attentional foci [7], intermodal cues [8] as well as moving cues [1]. A pop-out stimulus in an ensemble is also able to cause ILM [9], as well as the target location of a planned movement [10] and perceived gaze orienting of facial precues [11].

Perceptual latency priming

In PLP, the temporal order of two visual targets is compared [2]. One of them is preceded by a peripheral cue, the “prime”. This prime is visually backward masked by a target trailing at its location. The prime causes a robust and large facilitation of the latency of the target at its location: The target is perceived as the earlier one if it is presented simultaneously with an unattended target and also if it trails this second target by a small interval. As ILM, this priming of perceptual latency has been attributed to attentional allocation towards the cue.

PLP is most naturally assessed via temporal order judgments of the primed or attended and an unprimed or unattended stimulus [1, 12], but can also be measured by scaling or manual tasks [13]. Several studies have demonstrated that response tendencies or bias have only a marginal [12] or no influence on the judgments [13]. If the unprimed stimulus appears after the primed one, PLP is larger than when the order is reversed [13]. In the latter case, the unprimed stimulus interferes with shifting attention towards the prime.

PLP can be induced by peripheral cues – even if invisible [2]. Prior entry can also be elicited by instructed attentional focus [14], although it is less reliable in this paradigm [12]. The time course of PLP is very similar to that of other attentional effects [15]. PLP further depends on the current intentions of the observer: If the cue does not match the observer’s target set, it elicits less PLP [16].

Despite their close resemblance, ILM and PLP have so far never been directly compared. I propose an experimental design which allows to study them in identical stimulus displays. Most importantly, these displays contain both a line and an asynchronous stimulus pair. In one of the sessions, the observers judge the direction of motion within the line (line motion judgment, LMJ). In the other session, they judge which of the targets was presented first (temporal order judgment, TOJ).

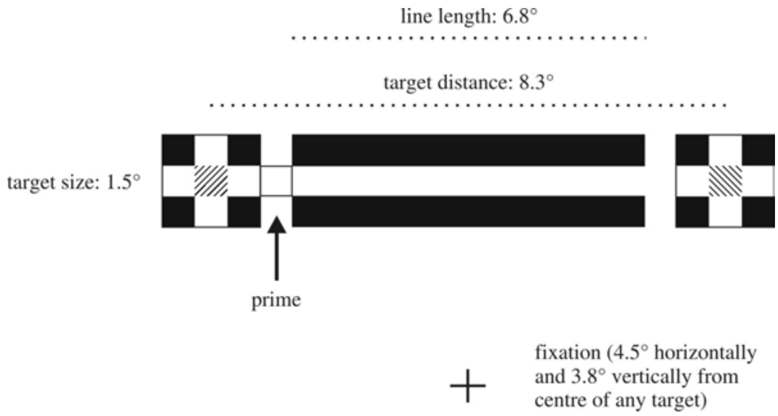

Fig. 1. Spatial arrangement. Stimuli are not drawn to scale. The prime, here depicted as outline drawing, was solid.

2 Experiment

The display consisted of three or four stimuli: two asynchronous targets, a line which was presented spatially and temporally in between the two targets, and, in half of the trials, a prime. The two targets serve a) as targets for the TOJ task and b) in unprimed trials, the first of them serves as attention attractor. In the primed trials, the prime is supposed to attract attention. The line is relevant for the motion judgment.

The targets were two checkerboards, either with a red or a blue square in the centre. The prime was a small square, and the line consisted of two solid bars. Stimuli were depicted dark grey on a light grey background. The temporal intervals between the targets were –128, –96, –64, –32, +32, +64, +96 and +128 ms. Negative numbers denote that the attended target preceded the unattended one (low interference), positive numbers the opposite order (high interference, see Fig. 2). Prime duration was 32 ms, target duration 160 ms, and line duration 320 ms. The prime preceded the primed target by 96 ms. Spatial and temporal conditions are depicted in Fig. 1 and 2.

The observers took part in two sessions in random order. In one of them, they reported which of the two checkerboard targets appeared first ("red first" or "blue first"). In the other session, they reported the direction of motion ("towards left" or "towards right"). In addition, they were allowed to judge the targets as "simultaneous or unclear" or the line as "not moving or unclear". The third category served to reduce the opportunity for a response bias in the line-motion task. Note that the line never moved or changed. If the observers are provided with only the two motion judgments, they may use some other aspect of the display, such as the presence of the prime, for deciding upon the judgment. In that case, a bias toward reporting motion away from the prime, and not perceived motion, would be responsible for the apparent ILM.

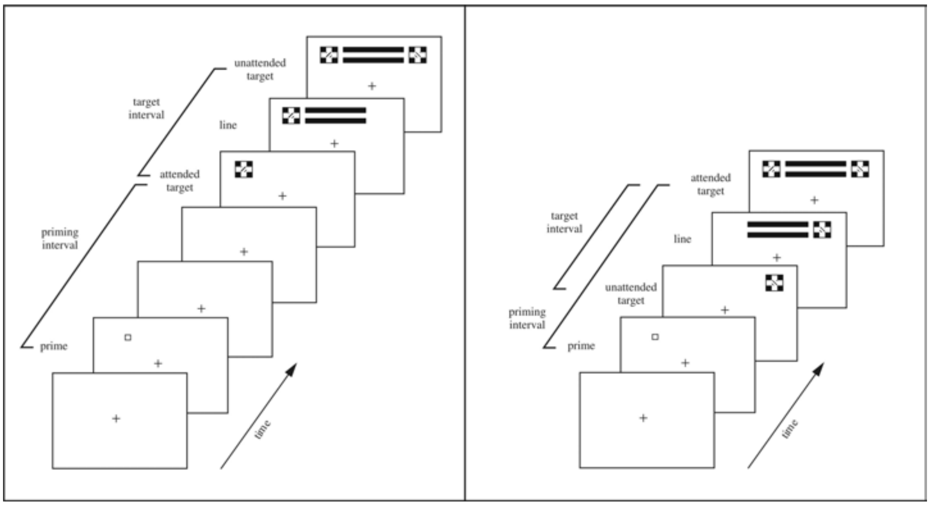

Fig. 2. Sequence of events in sample trials. On the left, the attended stimulus appears before the unattended stimulus (low interference). On the right, the attended stimulus trails the unattended one (high interference: the unattended stimulus may capture attention away from the prime).

Fig. 3 depicts the judgments frequencies of the two order/motion judgments for the two tasks. Two features are very obvious: First, the judgments from the tasks are very similar. The sole exception is an apparent deviation in the “attended first” judgments in the primed condition. In the line motion task, they are shifted farther to the right. Second, priming one of the targets horizontally shifts the psychometric functions to the right – the hallmark of latency facilitation.

Points of subjective simultaneity (PSS) and discrimination accuracy (DL) were computed from the two judgments by logit analysis [17]. The amount of facilitation was computed by subtracting the PSS of the primed condition from that of the unprimed condition. All 4 values (see Fig. 4) differed significantly form zero (all $t > 6.03$; all $p < .001$). A two-way ANOVA showed no significant effect of task ($F[1, 10] = 2.76$; $p = .13$). However, facilitation was larger in “attended first/motion from primed” judgments than in “unattended first/motion from unprimed” judgments ($F[1, 10] = 8.76$; $p < .05$; see Fig. 4). This can be explained by more interference by the unattended target in the latter cases.

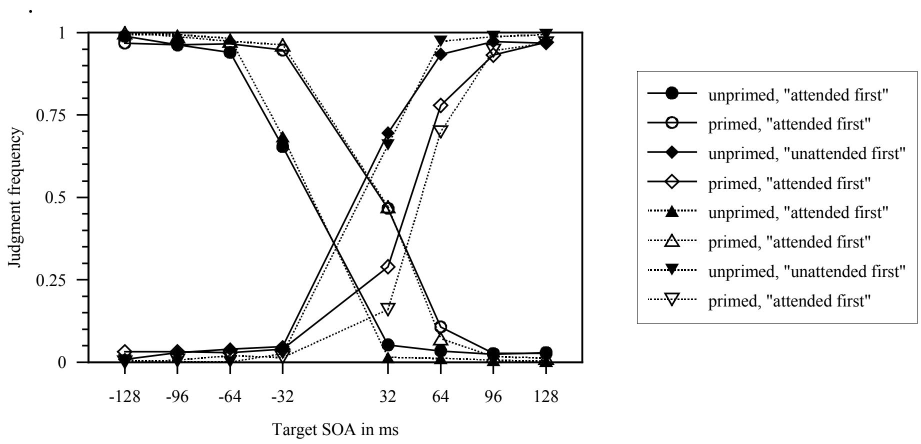

Fig. 3. Psychometric distributions. Solid lines: TOJ. Dotted lines: LMJ.

A three-way analysis of absolute DL values with the factors task, judgment, and priming revealed that motion judgments were more accurate than order judgments (16 vs. 22 ms DL, $F [1,10] = 11.24$; $p < .01$), and that priming reduced judgment accuracy (15 vs. 23 ms, $F[1,10] = 17.63$; $p < .01$). Judgment as main effect and all interactions did not reach significance (all $F < 2.02$; all $p > .18$). The reduction of DL by priming – a very rare finding – might be due to inappropriate selection of target intervals. As can be seen in Fig. 3, the psychometric distributions of the unprimed and the primed conditions are distributed differently over the target intervals. More in detail, it may contribute to the larger DL that no measurement was made between –32 and +32 ms.

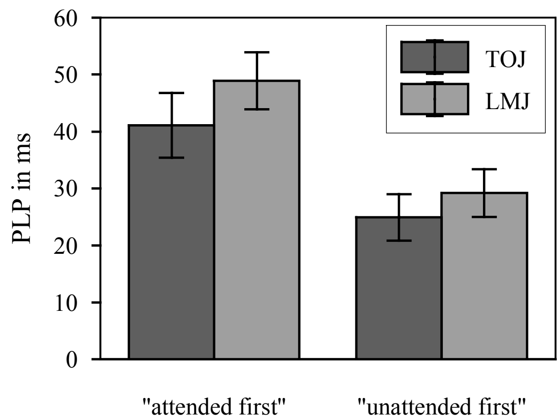

Fig. 4. Attentional facilitation. Error bars indicate standard errors of means. Facilitation is depicted separately for the two tasks and for trials in which the attended vs. unattended stimulus was perceived first.

3 General Discussion

Both the line motion and the temporal order task revealed attentional facilitation. Even the amount of facilitation was the same. This finding substantiates the supposition that ILM and PLP reflect the same attention-mediated facilitation of perceptual latency, even though they are measured on different levels – perception of time and motion discrimination.

Apart from this main finding, there were some concomitant findings which may prove important for future research. First, motion judgments were slightly more accurate than order judgments. Thus, motion judgments should be preferred, especially if discrimination is difficult, for instance if temporal intervals are very small. Further, the experiment revealed ILM by a masked prime. Spatial and temporal conditions of the sequence met conditions for metacontrast masking. However, since masking strength was not measured, this is only tentative evidence.

4 References

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