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Saccadic Undershoots and the Relative Localization of Stimuli[1]

Sonja Stork & Jochen Müsseler
Max Planck Institute for Psychological Research
Cognition and Action, Amalienstr. 33, D-80799 Munich
Email: stork@mpipf-muenchen.mpg.de
http://www.mpipf-muenchen.mpg.de/~stork

Abstract. When observers are asked to localize the peripheral position of a probe with respect to the mid-position of a spatially extended comparison stimulus, they tend to judge the probe as being more peripheral than the mid-position of the comparison stimulus. We investigated the relationship between this perceived mislocalization and saccadic undershoots. The findings show that the mislocalization corresponds to the saccadic behavior. Moreover, differences in saccadic undershoots to the stimuli can be used to estimate quantitatively the amount of relative mislocalization.

1 Introduction: A Relative Mislocalization

Visual localization acuity measured with long-presented stationary stimuli is of high precision. However, several studies indicated that spatial acuity is considerably poorer under less optimal viewing conditions. We studied the ability to localize a flashed stimulus and its relationship to saccadic eye movements with a relative judgment task (cf. Fig. 1). When observers judge the peripheral position of a probe with respect to the mid-position of a spatially extended comparison stimulus, the probe is seen more peripheral than the mid-position of the comparison stimulus [4]. We suggested and found evidence that this relative mislocalization emerges from different absolute mislocalizations. When observers point to the position of the spatially extended comparison stimulus they tend to localize it more foveally than the spatially less extended probe (see also [7]).

Comparable foveal tendencies in absolute localizations are known from eye-movement behavior. Eyes tend to undershoot a peripherally presented target, before they reach it with a corrective saccade [1]. Additionally, this undershoot seems to be more pronounced with a spatially extended stimulus [2]. If these results based on a spatial map, which is used by both the perceptual judgment task and the saccade task, the probe's relative position should be perceived more peripheral when compared with the mid-position of the comparison stimulus.

However, the mislocalization is only observed when stimuli are flashed successively (i.e., typically with a stimulus onset asynchrony of about 120 ms). In this case two configurations with different spatial information have to be superimposed and the relative mislocalization between stimuli can emerge. In contrast, when stimuli are flashed simultaneously, they can be processed in one spatial map. Accordingly, the

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localization judgment of the probe relative to the comparison stimulus was found to be more or less precise with simultaneous presentation [4].

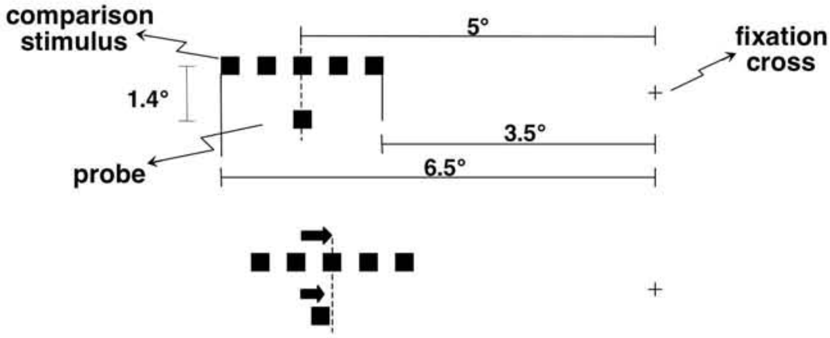

Fig. 1. Stimulus presentation (upper panel) and stimulus perception (lower panel). The perceived mislocalization of the probe relative to the mid-position of the comparison stimulus (lower panel) is assumed to emerge from different absolute localizations (as indicated by the arrows) of the stimuli with respect to the fixation cross.

To conclude our preliminary interpretation of the mislocalization is based on the assumption that saccadic tendencies contribute to the position codes of a spatial map. This map is used to determine the perceived localizations [4, 8]. In contrast, other accounts suggest that eye movements are specified in a direct manner independent of the perceived representation [3]. Several phenomena demonstrate dissociations between perception and action indicating different neural pathways for goal-directed behavior and for the perception of objects. Accordingly, the dorsal pathway is assumed to be involved in the execution of saccades (especially in the medially parieto-occipital sulcus, V5), while the ventral pathway is assumed to be involved in visual illusions. If this is correct, saccadic behavior need not match with the mislocalization observed in the relative judgment task. In order to clarify this issue, we examined whether and how saccadic undershoots are related to the relative judgments (for details see [6]).

2 New Findings and Conclusions

In Experiment 1, saccades to the comparison stimulus or the probe were compared with the perceptual judgments. In the saccade task, subjects were instructed to execute a saccade to a target (the probe or the mid-position of the comparison stimulus) as fast as possible. In the judgment task the position of the probe was varied with respect to the mid-position of the comparison stimulus and subjects were asked which stimulus was more peripheral – the upper one or the lower one?

If the saccadic behavior and perceptual judgment correspond, saccades to the comparison stimulus should show a stronger undershoot than to the probe. Indeed, results show that observers produce smaller saccadic amplitudes to the comparison stimulus than to the probe. This effect in saccades was observed when stimuli were presented separately, that is, only the probe or the comparison stimulus appeared on the screen.

The subsequent experiments were run in order to check whether the eccentricity of stimuli presentation exert an influence on both the judgments and the saccades. As in previous experiments [4], the perceived relative mislocalization increased with eccentricity. In contrast, the saccadic undershoot did not show a corresponding effect, when both stimuli were presented separately (Experiment 2). However, they corresponded to the perceived relative mislocalizations when both stimuli appeared on the screen (as in the relative judgment task). In this case, subjects' task was to generate a saccade to the probe or the mid-position of the comparison stimulus and to ignore the other stimulus (Experiment 3). The finding that only in this case saccadic behavior and perceptual judgment correspond demonstrate the importance of targets' context on the saccadic behavior.

In sum, the pattern of results indicates that – if comparable temporal and spatial configurations are used – the saccadic behavior corresponds qualitatively with the perceived relative mislocalization. In an additional analysis the relationship between both measures was analyzed quantitatively. In a first step of this analysis, the outer edge of the stimuli and further stimulus parameters of the present experiments proved to be important variables to determine the saccadic landing positions (for details see [5]). In a second step, these landing positions were used to estimate the relative mislocalization by computing the difference between the landing positions to the probe and the comparison stimulus.

Observed and estimated relative mislocalizations of the present experiments and of a previous study [4] are plotted in Figure 2. On the one hand, the plot shows a high positive correlation. Thus, it is possible to estimate the perceived relative mislocalization by the variables determining the saccadic behavior. On the other hand, the slope and the intercept of the regression line does not equal 1 and 0, respectively. Accordingly, one could still claim a dissociation between saccadic behavior and perceptual judgment.

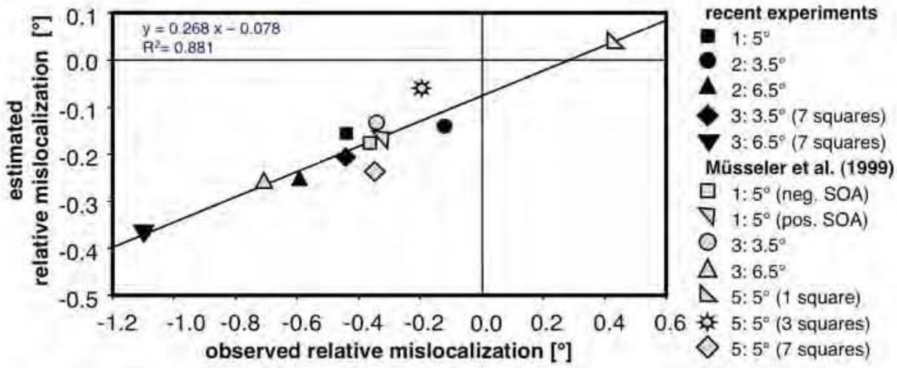

Fig. 2. Observed and estimated relative mislocalization.

Nevertheless, our findings demonstrate an obvious association between both measures. An interesting problem to think about is why eye movements undershoot the target at all and – more critically – why the system does not adapt to this error. One might speculate that the undershoot is an inherent property of any motor system, probably because it is easier to correct a movement in its direction than in the opposite direction. Another argument would be that with an undershoot the retinal image of the target remains in the same cortical hemifield and the system need not switch to the other hemifield. A last, but not least possibility comes from considering more ecological conditions. Usually, targets do not enter the visual field instantaneously but appear in the visual field and move into it. It could be a saccadic undershoot anticipates this movement.

Our interpretation is in accordance with the assumption that the saccadic behavior together with sensory information establishes perceived space. In other words, we assume that the system in charge of the guidance of eye movements is also the system that provides the metric of perceived visual space [8]. The position code for the localization judgment and for saccades shows comparable tendencies, indicating a common mechanism for both purposes. However, the differences in estimated landing positions of the eyes were less pronounced than the relative observed mislocalizations indicating a late modulation of the perceptual judgment.

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