Commentary on Romi Nijhawan "Visual prediction: Psychophysics and neurophysiology of compensation for time delays"

Mental and sensorimotor extrapolation fare better than motion extrapolation in the offset condition

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Abstract: Evidence for motion extrapolation at motion offset is scarce. In contrast, there is abundant evidence that subjects mentally extrapolate the future trajectory of weak motion signals at motion offset. Further, pointing movement overshoot at motion offset. We believe that mental and sensorimotor extrapolation is sufficient to solve the problem of perceptual latencies. Both present the advantage of being much more flexible than motion extrapolation.

Nijhawan claims that the offset of a smoothly moving object masks the extrapolated trajectory of the moving object. Therefore, the flash-lag effect is suppressed in the flash-terminated condition. In an experiment using gradual variation of luminance across the trajectory, the final position was found to be misperceived in the direction of motion (Maus & Nijhawan 2006). The reason given was that the gradual variation of luminance reduced the transient at stimulus offset. Contrary to Nijhawan's hypothesis, forward displacement of the final position of a moving target has been repeatedly observed with strong offsets. Jennifer Freyd (1987) was the first to observe displacement of the final position of an object undergoing implied motion (overview in Hubbard 2005). She presented a stationary rectangle for 0.25 s at three different orientations. The successive views implied the rotation of the object in a certain direction. Each view of the object was separated by a blank interval of 0.25 s, and the remembered final position was probed after a retention interval of 0.25 s. It is unlikely that low-level motion receptors were stimulated in this paradigm. The stimuli did not even reliably evoke an impression of apparent motion. Thus, the observed localization error has to be to the result of high-level, cognitive processes. In fact, when the motion type was systematically varied from implied to smooth motion by reducing the stimulus-onset-asynchrony of consecutive presentations, the forward extrapolation was found to decrease: The worse the quality of the motion signals, the larger the error (Kerzel 2003). The interpretation was that observers who are confronted with intermittent motion signals may engage in "mental extrapolation," where they try to predict the upcoming target positions. Mentally extrapolating the future trajectory induces errors in judging the last seen object position. Nijhawan argues that a gradual reduction of luminance contrast reveals motion extrapolation because masking by the transient at target offset is reduced (Maus & Nijhawan 2006). However, it is just as likely that these conditions reveal mental extrapolation that is induced by the absence of a clearly visible offset. Under conditions of high uncertainty, observers are more likely to predict the stimulus position based on what they expect, rather on the basis of what they see. Thus, the gradual luminance variation may bring high-level and not low-level extrapolation mechanisms to the fore. Further, one may wonder how much motion extrapolation contributes to accurate sensorimotor control. Let us consider the case of a subject placed in front of a touch-sensitive monitor. When prompted to rapidly hit a moving object with his index finger, the subject will take ~0.3 s to initiate the movement and another ~0.35 s to transport the hand from a home-key 20 cm in front of the monitor to the screen surface. Thus, a total of ~0.65 ms elapses from the moment the imperative signal is presented to the moment the screen is touched. It is clear that subjects who plan to hit the currently visible position will miss the target considerably (at the most: $0.65 \text{ s} \times v$, where v is target velocity). Thus, accurate interception of moving objects necessarily implies prediction of future positions. An intriguing hypothesis is that sensorimotor computations factor in visual delays. That is, interceptive actions are directed at the position the target will have reached in the time required to move the hand to that position plus visual delays (at the most: $[0.65 + 0.1 \text{ s}] \times v$, with visual delays equaling 0.1 s). Pointing to the offset position of a moving object should isolate sensorimotor compensation for visual delays, as the system does not need to take into account the future trajectory. In fact, pointing movements overshoot the final position by a distance that roughly corresponds to the flash-lag effect (Kerzel & Gegenfurtner, 2003). In contrast, perceptual judgments were centered on the true offset position. Thus, we believe that visual delays are not treated differently from other types of delays (time to decide, time to move, etc.). The sensorimotor system aims at position further ahead that corresponds to the respective delays.

A characteristic of sensorimotor compensation is that it is flexible and task dependent. In a set of experiments on the Fröhlich illusion (Fröhlich 1923), we observed that localization judgments (mouse pointing) were affected by rapidly changing visuomotor strategies. In the classical Fröhlich illusion, the perceived onset position of a moving object is displaced in the direction of motion. Possibly, the first part of the trajectory is missed as a result of attentional latencies and metacontrast. When the onset position is predictable because the target always appears in two narrow regions of space, this error is reproduced with pointing movements. However, when the onset position is highly unpredictable because the target appears randomly in a large region of space, the error is eliminated or even slightly reversed (Müsseler & Kerzel 2004). Our interpretation was that with high uncertainty, subjects try to correct for having missed the initial part of the trajectory by pointing to positions opposite to the direction of motion. Analysis of the time course showed that the effect of uncertainty emerged after only about 10 trials. That is, subjects changed their response strategy as soon as they noticed that the target position appeared in random places. Further, perceptual judgments, which were unaffected by predictability when run in a separate block of trials, showed the same effect of predictability when randomly intermingled with pointing movements (Müsseler et al., in press). Thus, visuomotor strategies may affect the way retinal stimulation is evaluated. Given the capacity to rapidly adapt visuomotor translation to changing circumstances, one may wonder whether motion extrapolation is needed to deal with visual latencies. Although it cannot be ruled out that such a mechanism exists, assuming its existence does not seem parsimonious. Other, more flexible mechanisms may do the job. Our proposal is that mental extrapolation of target motion and sensorimotor predictions solve the problem of visual latencies. <C-Text ends>

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