The mechanisms responsible for the flash-lag effect cannot provide the motor prediction that we need in daily life

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Abstract: The visual prediction that Nijhawan proposes cannot explain why the flash-lag effect depends on what happens after the flash. Moreover, using a visual prediction based on retinal image motion to compensate for neuronal time delays will seldom be of any use for motor control, because one normally pursues objects with which one intends to interact with ones eyes.

In his target article, Nijhawan proposes that early visual processing provides the prediction that is needed to deal with sensory-motor delays when we interact with moving objects, rather than such prediction arising from complex motor strategies as is generally assumed. He argues that the flash-lag effect and related phenomena illustrate the visual basis of such prediction. In his discussion of the extensive literature on this topic, he ignores several findings that show that the flash-lag effect cannot be caused by a visual prediction based on the preceding object motion.

Several experiments have been performed in which a target moves both before and after the flash, but changes its speed or direction of motion at an unpredictable moment around the time of the flash. According to Nijhawan's account of visual prediction, the target's motion after the flash should be irrelevant for its perceived position at the time of the flash. However, the perceived position has been shown to depend on the target's motion up to 80 msec after the flash (Brenner & Smeets 2000; Eagleman & Sejnowski 2000; Whitney & Murakami 1998). This result is inconsistent with any kind of motion extrapolation. It is also unlikely that it is primarily caused by neuronal signals pertaining to the flashed target taking longer to reach the brain than ones pertaining to the moving target (Whitney & Murakami 1998), because the flash-lag effect can be demonstrated with a very bright flash and a dimly lit moving object.

The dependence of the flash-lag effect on what happens after the flash can readily be explained if one regards perception as an active process (O'Regan & Noe 2001). If so, the location of the moving object is not evaluated continuously. It is only evaluated when one needs to know it. The flash indicates that this is the case. As determining the position in response to the flash takes time, the result is a judged position that the object only reaches some time after the flash. The fact that the moving object is perceived ahead of its location at the time of the flash is therefore not due to extrapolation, but to sampling its position too late. This implies that the flash-lag effect should decrease if one can convince subjects to start evaluating the location of the moving object before the flash is registered. A way to achieve this earlier sampling is by making the moment of interest more predictable. Indeed, the flash-lag effect is reduced (and even absent in some subjects) under such conditions (Brenner & Smeets 2000).

Besides the doubts about the role of visual prediction in the flash-lag phenomenon, there is also a more fundamental problem with the main claim of the target article. Nijhawan's interesting claim is that visual prediction provides the prediction needed to compensate for neuronal delays when interacting with moving objects. However, when trying to intercept a moving target, subjects tend to pursue the target with their eyes. This is so not only in laboratory conditions (Mrotek & Soechting 2007) but also, for instance, during the final approach phase when hitting a ball in cricket (Land & McLeod 2000). Moreover, subjects are better at an interception task when they pursue the target with their eyes than when they fixate somewhere near the point of interception (Brenner & Smeets 2007). One reason for pursuing the target is that pursuit eliminates the blur caused by retinal motion, leading to more precise vision. However, the lack of retinal motion means that the predictive mechanism proposed in the target article will not be working. Therefore, in the situations in which prediction is needed most in daily life, the proposed mechanism cannot contribute to such prediction.

The way in which subjects pursue moving targets can give us insight into how prediction works. It is known that pseudorandom smooth target motion is pursued with delays of more than 200 msec (Collewijn & Tamminga 1984; Koken & Erkelens 1992). Targets moving at a constant – and therefore predictable – speed are pursued with a negligible delay (Barnes & Asselman 1991). If this reduction in visuomotor delay were caused by the kind of visual prediction proposed in the target article, it would only work when the target motion is constant. This is not the case: Negligible delays are also found when the target motion is predictable, but not on the basis of the directly preceding visual information (Thier & Ilg 2005). For instance, humans can pursue sinusoidal motion with minimal delays. It only takes about half a cycle of the sinusoidal target motion to achieve the minimal tracking delay. If the target disappears, or changes its motion, the sinusoidal eye movement continues for about half a cycle (van den Berg 1988). Additional evidence against the proposed visual prediction is that the prediction in pursuit is task-specific.

When following a target with their eyes, subjects make errors in the smooth pursuit that are corrected by catch-up saccades that are predictive: They compensate for the errors that develop during their programming and execution. These catch-up saccades could be based on a visual prediction, or on a motor prediction specific to the pursuit. In the former case, the errors in pursuing a smoothly moving target should also be compensated for when making a saccade in response to a sudden jump of the target. However, in such an experiment, the saccade amplitude is matched to the target jump (Smeets & Bekkering 2000). So the prediction that subjects make in order to be able to track the moving target is specific to pursuit.

Our conclusion is that if the low-level predictive mechanisms proposed by Nijhawan exist, they are responsible neither for the flash lag effect nor for the motion extrapolation in our interaction with moving objects.