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The Accuracy of Time-to-Contact Estimation in the Prediction Motion Paradigm

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Abstract

This thesis is concerned with the accuracy of our estimation of time to make contact with an approaching object as measured by the "Prediction Motion" (PM) technique. The PM task has commonly been used to measure the ability to judge time to contact (TTC). In a PM task, the observer's view of the target is occluded for some period leading up to the moment of impact. The length of the occlusion period is varied and the observer signals the moment of impact by pressing a response key. The interval separating the moment of occlusion and the response is interpreted as the observer's estimate of TTC made at the moment of occlusion. This technique commonly produces large variability and systematic underestimation. The possibility that this reflects genuine perceptual errors has been discounted by most writers, since this seems inconsistent with the accuracy of interceptive actions in real life. Instead, the poor performance in the PM task has been attributed to problems with the PM technique. Several hypotheses have been proposed to explain the poor PM performance. The *motion extrapolation hypothesis* asserts that some form of mental representation of the occluded part of the trajectory is used to time the PM response; the errors in PM performance are attributed to errors in reconstructing the target motion. The *clocking hypothesis* assumes that the TTC is accurately perceived at the moment of occlusion and that errors arise in delaying the response for the required period. The *fear-of-collision hypothesis* proposes that the underestimation seen in the PM tasks reflects a precautionary tendency to anticipate the estimated moment of contact. This thesis explores the causes of the errors in PM measurements.

Experiments 1 and 2 assessed the PM performance using a range of motion scenarios involving various patterns of movement of the target, the observer, or both. The

possible contribution of clocking errors to the PM performance was assessed by a novel procedure designed to measure errors in the wait-and-respond component of the PM procedure. In both experiments, this procedure yielded a pattern of systematic underestimation and high variability similar to that in the TTC estimation task. Experiment 1 found a small effect of motion scenario on TTC estimation. However, this was not evident in Experiment 2.

The collision event simulated in Experiment 2 did not involve a solid collision. The target was simply a rectangular frame marked on a tunnel wall. At the moment of "contact", the observers passed "through" the target without collision. However, there was still systematic underestimation of TTC and there was little difference between the estimates obtained in Experiments 1 and 2. Overall, the results of Experiments 1 and 2 were seen as inconsistent with either the motion extrapolation hypothesis or the fear-of-collision hypothesis. It was concluded that observers extracted an estimate of the TTC based on optic TTC information at a point prior to the moment of collision, and used a timing process to count down to the moment of response. The PM errors were attributed to failure in this timing process. The results of these experiments were seen as implying an accurate perception of TTC.

It was considered possible that in Experiments 1 and 2 observers based their TTC judgements on either the retinal size or the expansion rate of the target rather than TTC. Experiments 3 and 4 therefore investigated estimation of TTC using a range of simulated target velocities and sizes. TTC estimates were unaffected by the resulting variation in expansion rate and size, indicating that TTC, rather than retinal size or image expansion rate per se, was used to time the observers' response.

The accurate TTC estimation found in Experiments 1-4 indicates that the TTC processing is very robust across a range of stimulus conditions. Experiment 5 further explored this robustness by requiring estimation of TTC with an approaching target which rotated in the frontoparallel plane. It was shown that moderate but not fast rates of target rotation induced an overestimation of TTC. However, observers were able to discriminate between TTCs for all rates of rotation. This shows that the extraction of TTC information is sensitive to perturbation of the local motion of the target border, but it implies that, in spite of these perturbations, the mechanism is flexible enough to pick up the optic TTC information provided by the looming of the retinal motion envelop of the rotating stimulus.

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