A NEW PROCEDURE FOR PSYCHOPHYSICAL ASSESSMENT OF PERFORMANCE ON COINCIDENCE TIMING: EVALUATING THE EFFECTS OF DURATION OF TARGET PRESENTATION AND TARGET MASKING

Judith Haldemann & Thomas H. Rammsayer
Institute of Psychology, University of Bern, CH-3000 Bern 9, Switzerland

Abstract

In traditional Coincidence Timing (CT) tasks participants are required to make a response when a moving target coincides with a stationary line. The present study was designed to examine the effects of duration of target presentation and of different levels of target masking on performance on CT. For this purpose, we introduced two newly developed CT tasks. Participants were presented with two lines moving diagonally from the bottom left and right corners across a monitor screen towards each other and intersecting. As indicators of CT performance, mean absolute error (MAE; i.e., the difference in time between the intersection of the two moving lines and the participant's response) and individual standard deviation (ISD) of response times were computed. While duration of target presentation affected neither MAE nor ISD, a systematic influence of target masking on CT performance could be revealed: MAE and ISD decreased linearly with decreasing size of the mask.

Coincidence Timing (CT) is an elementary cognitive task, which typically requires the participant to view a computer monitor on which a target (e.g., a small square) moves at a constant speed towards a stationary line and to make a response at the moment the target coincides with the line (Jensen, 2006; Larson, 1989; Saccuzzo, Johnson, & Guertin, 1994; Smith & McPhee, 1987). For optimal performance on this type of task, information has to be integrated over time in order to adequately estimate when two objects coincide. Possible correlates of everyday CT skills are, for example, the ability to predict a gap in the traffic for crossing a road or to pick something on a conveyor belt in the right moment (Smith & McPhee, 1987).

Jensen (1998) posits that the original CT task suggested by Smith and McPhee (1987) cannot be considered as a simple reaction time task because subjects have to anticipate and predict a future event. We argue that the original CT task has a lot in common with conventional simple reaction time tasks. This is because participants only have to accurately respond to an observable event. But for the successful execution of a "genuine" CT task, spatiotemporal coordination ability should be required as an essential characteristic of CT. In order to more validly and sensitively assess the anticipatory character of the CT task, the present paper introduces different levels of target masking as an additional feature. Thus, with our novel task, the targets disappear behind a mask before their collision point is reached. Therefore, in the absence of visual information on the temporal occurrence of the actual collision point, the participant is required to mentally visualize and anticipate the time of coincidence.

There are studies dealing with a similar construct referred to as *time-to-contact* (T_c). The major aim of this field of research is to identify the kind of information an observer uses when he or she has to anticipate a collision of two objects. With this experimental paradigm, participants are commonly required to make T_c judgments about a moving object which disappears before its collision with another object (e.g., Schiff & Oldak, 1990). This experimental approach operates commonly with experiments where a moving object virtually approaches the participant (i.e. a moving vehicle) or the participant is approaching a target (Cavallo & Laurent, 1988; McLeod & Ross, 1983; Schiff & Detwiler, 1979; Schiff & Oldak, 1990; Sidaway, Fairweather, Sekiya, & McNitt-Gray, 1996). In these so-called prediction-motion tasks the moving object typically disappears before its arrival at the position of the observer or another particular location in space. The observer is then required to respond at the estimated moment of collision (e.g., DeLucia & Liddell, 1998). Thus, these experiments typically involve approach events where participants are presented with impending contact between two objects or an object and the self.

Based on Tresilian's (1995) notion that prediction-motion tasks involve cognitive operations, DeLucia and Liddell (1998) postulate two kinds of cognitive operations involved in tasks measuring judgments of T_c. According to this account, the first type of operation represents *cognitive motion extrapolation* which means that the observer developed a cognitive model of the visible motion. This model becomes active as soon as the moving object has disappeared in order to extrapolate mentally the object's motion. In particular mental imagery, eye movements, and attentional shifts may be involved in cognitive motion extrapolation. An inaccurate cognitive model will lead to errors in estimations of T_c. As a second type of cognitive operation, DeLucia and Liddell (1998) proposed temporal information processing based on a cognitive timing mechanism. More specifically, participants may initially estimate T_c before the object disappears and subsequently take advantage of a cognitive clock that counts down T_c. Participants are required to time their response such that it coincides with the predicted T_c of the object. Thus, participants respond when the time reaches the estimated T_c (see also Tresilian, 1995). Generally, results were consistent with the assumption that performance in prediction-motion tasks is based on cognitive operations, particularly on cognitive motion extrapolation.

The present study was designed to examine the effects of duration of target presentation and of target masking on CT performance. For this purpose, we introduced a novel CT task in which either the duration of target presentation or the level of target masking was systematically varied. With both these types of task, participants could follow speed and path of two converging lines for a certain duration. The intersection point of the two moving lines, however, was no longer visible but hidden by a mask. Therefore, participants were required to estimate when the two lines coincided.

Method

Participants

Participants were 30 female volunteers ranging in age from 20 to 28 years (mean ± standard deviation: 22 ± 1.68 years). All participants had normal or corrected-to-normal visual acuity.

Coincidence Timing Task Version 1

Apparatus and Stimuli. Stimuli were lines 1 mm in width moving diagonally with constant speed (7cm/sec) from the bottom left and right corners across a 17-inch computer monitor screen towards each other. The mask had a vertical size of 13.5 cm and reached from the left to the right side of the screen. The lines and the mask were presented in black color on a white background. A serial response-box with a 0-ms debounce period was used as an input device.

Procedure. This version of the Coincidence Timing Task was designed to determine the effect of duration of target presentation on CT performance. For this purpose, participants were presented with two black lines moving diagonally with constant speed from the bottom left and right corner towards each other across a monitor screen. The participant was seated approximately 50 cm in front of the computer screen and was instructed to indicate by a key press the point in time when the two lines intersect. On each trial, the upper half of the display was completely masked so that the intersection point was hidden (see Figure 1). There were four experimental conditions, which differed with regard to the starting point of the lines. Each of the two lines evolved from four different designated starting points in the left and right lower quadrant of the screen. Thus, the visible part of the lines before disappearing behind the mask systematically varied across conditions (see Figure 1). Depending on the experimental condition, the moving lines were visible for a moving distance of 4.8, 9.6, 14.4, or 19.2 cm. This corresponded to a viewing time of about 0.4 s, 1.1 s, 1.6 s, and 2.5 s, respectively. Each experimental condition consisted of 12 trials. Thus Coincidence Timing Task Version 1 comprised a total of 48 trials. Trials from all four experimental conditions were presented in randomized order with an intertrial interval varying randomly from 1 to 2 s.

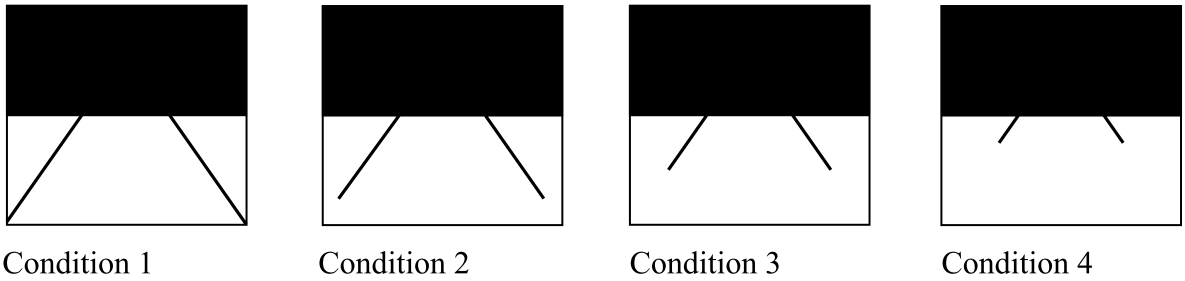


Figure 1. Static display of the four conditions of Coincidence Timing Task Version 1.

As indicators of performance on CT, individual standard deviation (ISD) and mean absolute error (MAE) scores were computed for each participant. MAE was defined as the absolute difference between actual intersection time and the intersection time judged by the participant. Thus small MAE scores indicate better accuracy in CT, while ISD represents a measure of timing variability.

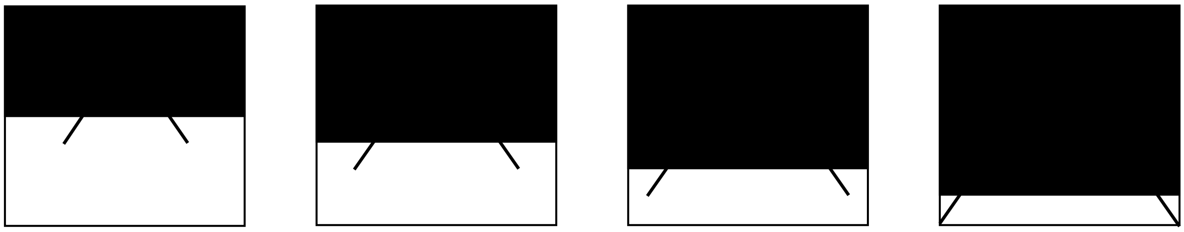
Coincidence Timing Task Version 2

Apparatus and Stimuli. Apparatus and Stimuli were the same as in Coincidence Timing Task Version 1, except that there were four levels of mask size (13.5, 17, 20.5, or 24 cm).

Procedure. Coincidence Timing Task Version 2 was designed to determine the effect of masking on CT performance. In addition to the starting point of the lines, also mask size was experimentally varied. Thus, duration of line presentation was held constant across conditions to determine the effect of masking on CT performance. Again, there were four experimental conditions, which differed in terms of mask size (see Figure 2). In each experimental condition, a moving distance of the line of 4.8 cm was visible before the moving line disappeared behind the mask (see Figure 2). As in Version 1, the participant's task was to judge the intersection point as exactly as possible by pressing a designated key. Each condition comprised 12 trials resulting in a total of 48 trials. Trials were presented in randomized order with a randomly varying intertrial interval ranging from 1 to 2 s. Again, ISD and MAE scores were computed as indicators of CT performance.

Time course of an experimental session

Each participant was tested individually in a sound-attenuated room with constant lighting conditions. An experimental session took about 15 minutes and consisted of Versions 1 and 2 of the Coincidence Timing Task. Half of the participants started with Version 1 and half of the participants with Version 2.



Condition 1 Condition2 Condition 3 Condition 4

Figure 2. Static display of the four conditions of Coincidence Timing Task Version 2.

Results

Coincidence Timing Task Version 1

Figure 3 displays the results of one-way ANOVAs with experimental conditions as four levels of a repeated-measurements factor. For MAE, Mauchly's Test of Sphericity was significant, thus, Greenhouse-Geisser corrected values are reported. No significant mean effect could be revealed for MAE, $F(2.01,58.30) = .068$; $p = .51$, $\eta^2 = .02$. Accordingly, duration of target presentation did not affect the accuracy of performance on CT. For ISD it showed a significant main effect of duration of target presentation, $F(3,87) = 3.74$; $p < .05$, $\eta^2 = .11$, but Bonferroni post-hoc comparisons revealed that only Conditions 3 and 4 differed significantly ($p < .05$). Thus, participants' responses were significantly more variable in Condition 4, where the lines could be followed only very shortly, than in Condition 3, where the lines were visible slightly longer.

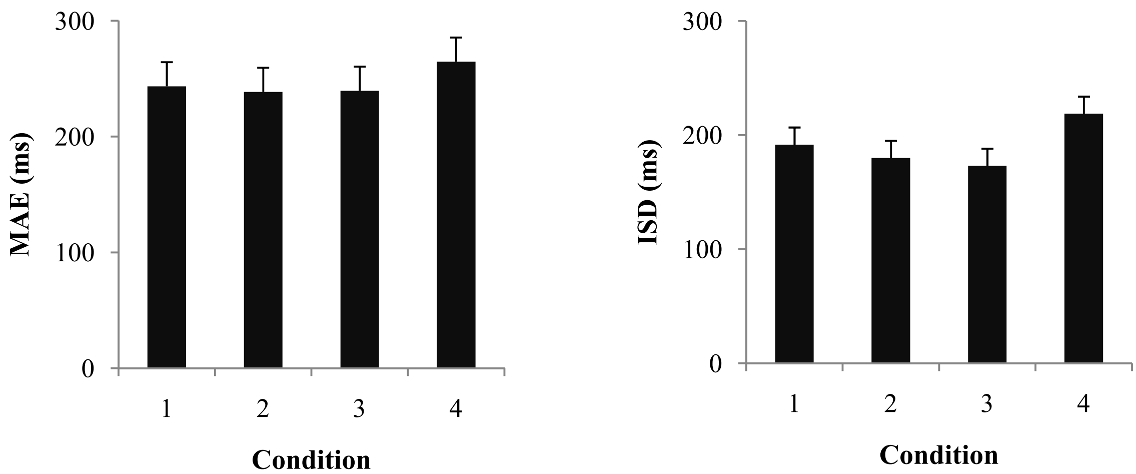
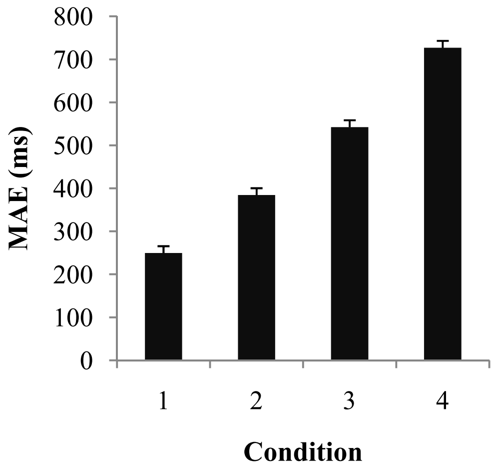


Figure 3. Mean performance (MAE and ISD ± S.E.M.) on Coincidence Timing Task Version 1 as a function of duration of target presentation (Conditions 1 to 4).

Coincidence Timing Task Version 2

Figure 4 displays the results of the two one-way ANOVAs. Again, Greenhouse-Geisser corrected values are reported due to a lack of sphericity. For MAE, a significant main effect could be shown $F(1.52,43.98) = 44.61$; $p < .01$, $\eta^2 = .61$. As indicated by Bonferroni tests, all four conditions differed significantly from each other ($p < .01$); MAE increased linearly with increasing mask size. For ISD, a significant main effect of masking [$F(1.94,56.16) = 24.31$; $p < .01$, $\eta^2 = .46$] revealed that mask size had an effect on timing variability; all conditions, but Conditions 3 and 4, differed significantly from each other ($p < .05$). This indicates that timing variability increased continuously from Condition 1 to Condition 3 with increasing mask size. The increase of ISD from Condition 3 to 4 was somewhat lower and failed to reach statistical significance.



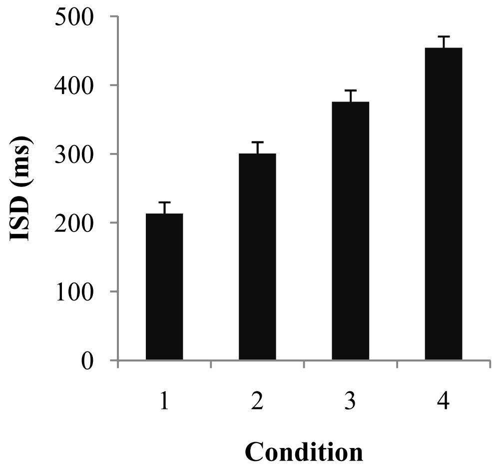


Figure 4. Mean performance (MAE and ISD ± S.E.M.) on Coincidence Timing Task Version 2 as a function of mask size (Conditions 1 to 4).

Because Condition 4 from Coincidence Timing Task Version 1 was identical to Condition 1 from Coincidence Timing Task Version 2, we didn't expect a difference in performance between these two Conditions. Results of a paired samples *t* test showed that performance on the two Conditions differed neither for ISD [$t(29) = -.27$, $p = .79$] nor for MAE [$t(29) = -.50$, $p = .62$] indicating that CT performance remained stable across the two different contexts of the respective CT tasks.

Discussion

The goal of the present study was to investigate the effects of duration of target presentation and of target masking on mean absolute error (MAE) and individual standard deviation (ISD) as two aspects of CT performance. For this purpose, performance on two versions of a newly developed Coincidence Timing Task was examined. Coincidence Timing Task Version 1 was designed to identify the effect of duration of target presentation on CT performance, whereas with Coincidence Timing Task Version 2, the effect of target masking was investigated.

The results showed that mainly the size of the mask had a systematic influence on the performance: MAE and ISD increased linearly with increasing size of the mask, while no systematic effect of duration of target presentation could be revealed. Therefore, in terms of MAE, participants could judge the intersection point of the two lines more accurately when they were masked only minimally. Also, individual timing variability, as indicated by ISD, increased linearly with increasing mask size. As an exception, ISD in Conditions 3 and 4 did not differ significantly.

By contrast, the duration of target presentation, i.e., the period of time during which the participant can accumulate spatial and temporal information on the moving lines, did not systematically affect CT performance. Although a statistically significant main effect of duration of target presentation was found for ISD, post-hoc comparisons showed that only two Conditions 3 and 4 differed significantly. While timing variability remained stable from Conditions 1 through 3, it was significantly increased in Condition 4. In this latter condition, the lines were visible only for a very short period of time and the point of coincidence was reached briefly after the lines disappeared behind the mask. In Condition 4, therefore, participants had to be very attentive in order not to miss the very moment to respond and to indicate the time point of coincidence. From this perspective, Condition 4 might have put higher attentional demands on the participants than the other three experimental conditions and, thus, resulted in increased intraindividual timing variability.

In conclusion, our findings provide convincing evidence that when the observer had to judge the collision time of two moving objects, the accuracy and individual variability of that judgment depends largely on how long the target objects were masked until they intersected rather than on the duration of target presentation.

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