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The time course of temporal preparation in an applied setting: A study of gaming behavior

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ABSTRACT

We examined the time course of temporal preparation in the practice of computer gaming. Participants held an infrared rifle to shoot animated figures ("terrorists") that appeared from an elevator that opened briefly after the sound of a bell. The sound was either loud or soft and the interval between the sound and the opening of the elevator varied between 100 and 600 ms. We found that shooting latency decreased exponentially as a function of interval, reflecting growing temporal preparation towards an optimum. When the sound was soft, this function was shifted to the right as compared to when the sound was loud. These findings are consistent with a model assuming that preparation starts upon the detection of a warning (i.e., later for the soft than for the loud sound) and continues until the detection of a target (i.e., longer as the interval increases). These results signify a successful application of a theoretical model in an applied setting.

1. Introduction

Preparation for future action is among the most prevalent adaptive mechanisms human beings apply in daily life (Requin, Brener, & Ring, 1991). Preparatory mechanisms are highly diverse and range from very complex (e.g., preparing a talk for a conference) to very simple. A prime example of the latter category is temporal preparation, where a mere temporal warning (e.g., a tone) informs the participant that a target stimulus is impending. Many studies have shown that this minimal information suffices to considerably speed up response to the target stimulus as compared to a condition without preceding warning (see Niemi & Näätänen, 1981 for a review). The warning apparently triggers a process of temporal preparation that facilitates impending target processing.

Recent studies have revealed a great deal about the time course and dynamics of temporal preparation (e.g., Janssen & Shadlen, 2005; Leonhard, Bratzke, Schröter, & Ulrich, 2012; Los & Van den Heuvel, 2001; Los & Van der Burg, in press; Steinborn, Rolke, Bratzke, & Ulrich, 2009; Vallesi & Shallice, 2007), but share the limitation of being performed in the deprived environment of the laboratory. This is unfortunate because our understanding of the mechanisms of temporal preparation has potentially important practical implications for such areas as sports (e.g., the athlete preparing for the starting signal) and traffic (e.g., faster braking when warned by the sound of a horn). Apparently, researchers have been reluctant to sacrifice rigorous experimental control for ecological validity, to avoid the risk that subtle experimental findings disappear in the noise of everyday life. However, unless we are prepared to take that risk, we will not be able to find out whether our models have any applicability outside the lab (e.g., Kingstone, Smilek, Ristic, Friesen, & Eastwood, 2003; Sanders, 1998).

In the present study we used a first-person-shooter arcade game to simulate a situation where adequate temporal preparation may be a matter of life and death: the elimination of terrorists attacking a public building. The terrorists were represented by computer animated figures that appeared from an elevator that opened briefly after the sound of an elevator bell. The participants were involved as defenders of the building, and were instructed to shoot the simulated terrorists as quickly as they could, using a hand held infrared rifle. Our general objective was to examine how temporal preparation, triggered by the elevator bell, influenced the participants' shooting behavior in this real-world inspired setting. More specifically, we examined whether temporal preparation would develop according to the predictions of a theoretical model that was recently validated on the basis of well controlled lab findings (Los & Schut, 2008; Los & Van der Burg, in press).

We considered computer gaming to be perfectly suited to bridge the gap between fundamental and applied research. On the one hand, gaming is an everyday activity for many people, and the level of veracity of the present life-size application added to the feeling of being immersed

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in a real-life situation. On the other hand, by allowing repeated presentations of critical situations, a gaming approach enabled us to extract effects of relevant psychological mechanisms from noise.

2. The time course of temporal preparation

In laboratory research, the time course of temporal preparation has been studied by varying the stimulus onset asynchrony (SOA) between a warning stimulus (S1; typically a brief tone) and a target stimulus (S2; typically a visual stimulus) to which the participant is instructed to respond as quickly as possible in accordance with some task rule. For instance, Los and Van der Burg (in press) used a choice-reaction task in which S2 was a square that appeared left or right of fixation, and participants were instructed to press a spatially compatible key as quickly as possible. This and several other studies have shown that, when SOA is varied up to about half a second, mean reaction time (RT) with respect to S2 decays exponentially as a function of SOA (e.g., Los & Schut, 2008; Los & Van der Burg, in press; Müller-Gethmann, Ulrich, & Rinkenauer, 2003; Niemi & Näätänen, 1981).[1] This RT–SOA function suggests two fundamental properties of the underlying preparatory process. First, temporal preparation develops very quickly after the presentation of S1, taking only a few hundreds of milliseconds to reach an optimal level for processing S2. Second, temporal preparation is subject to diminishing returns as it develops over time (Los & Heslenfeld, 2005). In particular, adding a unit quantity of preparation has a greater effect when the initial state of preparation is low (SOA < 100 ms) than when it is high (SOA > 200 ms) and its effect becomes negligible as preparation approaches an optimal state (SOA ~ 300 ms).

Recently, Los and Van der Burg (in press) observed subtle variations in the RT–SOA function (for SOAs up till 400 ms) depending on the specific nature of S1. Coarsely, when S1 was a low-contrast visual stimulus, the RT–SOA function was shifted to the right as compared to when S1 was a high-contrast visual stimulus. Similarly, when S1 was a visual stimulus, the RT–SOA function was shifted to the right as compared to when S1 was an auditory stimulus. Los and Van der Burg considered this evidence for their temporal preparation model, which assumes that preparation can start only after S1 has been detected. As a result, preparation would start later when the contrast of S1 is low than when it is high, because it takes longer to detect a low-contrast S1. Preparation would also start later when S1 is visual than when it is auditory, in view of slower sensory transduction at the retina than at the cochlea (e.g., Fain, 2003; Nickerson, 1973). The model further assumes that, once S1 is detected, the preparation process is invariant across S1 conditions. This explains the observed systematic shifts of the RT–SOA functions for the different S1 conditions.

So, temporal preparation starts upon the detection of S1, but when does it end? During what interval does the recruitment of preparatory resources aid to speed up response to S2? From a perspective of cognitive economy, Los and Schut (2008) reasoned that temporal preparation should maximally exploit the available time, and thus continue until its target process (i.e., the process that it facilitates) starts. The issue of which process is facilitated by temporal preparation has a long and controversial history (for reviews, see Müller-Gethmann et al., 2003; Rolke & Ulrich, 2010), but some recent studies seem to point at a central locus (e.g., Hackley, Schankin, Wohlschlaeger, & Wascher, 2007; Los & Schut, 2008). According to this view, temporal preparation facilitates S2 processing at some perceptual stage following the early detection of S2 and preceding response selection. Combined with Los and Schut's principle of cognitive economy, this locus of influence implies that temporal preparation continues until S2 processing has reached the central level.

Fig. 1 shows a flow diagram that summarizes the assumptions about the starting point and end point of temporal preparation. The interval between these time markers is referred to as effective preparation period (EPP), that is, the period during which preparation proper occurs. Note that EPP may differ in duration from SOA, depending on the relative durations of the time needed to detect S1 (D_{S1}) and the time needed to detect S2 (D_{S2}). For instance, in Fig. 1, EPP is longer than SOA, because D_{S1} is shorter than D_{S2}. The precise relationship between these quantities can be simply expressed as

$$\mathrm{EPP} = \mathrm{SOA} + D_{S2} - D_{S1}. \tag{1}$$

After adding the straightforward constraint that EPP cannot be negative, Eq. (1) turns into

$$\mathrm{EPP} = \mathrm{Max}(0, \mathrm{SOA} + D_{S2} - D_{S1}). \tag{2}$$

Knowing the duration of EPP comes in very useful when comparing effects of temporal preparation across different S1 conditions, such as those examined by Los and Van der Burg (in press). The reason is that, unlike the RT–SOA function, the RT–EPP function should not depend on D_{S1}, because this variable is excluded from EPP. However, estimating EPP is not a trivial matter, since the D_{S1} and D_{S2} terms of Eq. (2) are unobservable. To solve this problem, Los and Van der Burg had their participants perform supplementary simple-RT tasks in addition to the choice-RT task described earlier. In these simple-RT tasks, S1 and S2 were presented isolated from each other in separate blocks of trials, without any preceding warning. Participants were instructed to respond as fast as possible to the occurrence of S1 and S2 by pressing a single response key. On the assumption that the difference in simple mean RT between S2 and S1 merely reflects the difference of their detection times, it should equal the $D_{S2} - D_{S1}$ term of Eq. (2), thus enabling the calculation of EPP. As mentioned earlier, Los and Van der Burg observed, in their choice-RT task, considerable differences in the RT–SOA functions corresponding to the different S1 conditions. Crucially, these differences disappeared when RT was expressed as a function of EPP, consistent with the predictions of the temporal preparation model.

In the present study, the task used by Los and Van der Burg (in press) was transformed into a computer-generated first-person-shooter arcade game. In this game, S1 was the sound of an elevator bell, the intensity of which was varied in different blocks of trials. S2 was the opening of one of two elevators, which exposed the target object — the "terrorist" the participant was instructed to shoot. In the choice-RT task, six different SOA levels, ranging from 100 to 600 ms, were randomly intermixed in a block of trials. We expected to replicate the main finding of Los and Van der Burg, namely that the intensity of the elevator bell would modify the RT–SOA function, but not the RT–EPP function. This finding would support the hypothesis that temporal preparation starts upon completion of S1 detection. It would also indicate that this property of the preparation process would be sufficiently robust to come to expression in a natural setting.

3. Method

3.1. Participants

Eighteen participants (13 female), 12 students from VU University and 6 volunteers from the Cognitive Psychology department, participated in a single 1-hour session. In return for their services, students either received €8 or course credits. Informed consent was obtained from each participant after the nature of the study was explained to them. All participants were naïve with respect to the purpose of the experiment.

[1] When SOA is varied across a wider range of values, the RT–SOA function may obtain highly different shapes depending on whether the different SOA levels are presented randomly intermixed or fixed within a block of trials (e.g., Los, Knol, & Boers, 2001; Niemi & Näätänen, 1981). These differential shapes may reflect a variety of sources, including time uncertainty, conditional probability of target occurrence or intertrial priming (e.g., Los, 2010). The contribution of these sources is presumably minimal for SOAs up to about half a second, when the attained level of temporal preparation is primarily determined by the available time to recruit preparatory resources.