Consciousness and Cognition 30 (2014) 36–47

Contents lists available at ScienceDirect

Consciousness and Cognition

journal homepage: www.elsevier.com/locate/concog

Distorted subjective reports of stimulus onsets under dual-task conditions: Delayed conscious perception or estimation bias? ☆

Daniel Bratzke *, Donna Bryce, Tanja Seifried-Dübon

University of Tübingen, Germany

ARTICLE INFO

Article history:
Received 11 February 2014

Keywords:
Attentional bottleneck
Psychological refractory period
Introspection
Conscious perception
Clock paradigm

ABSTRACT

We investigated whether selecting a response for one task delays the conscious perception of another stimulus (delayed conscious perception hypothesis). In two experiments, participants watched a revolving clock hand while performing two tasks in close succession (i.e. a dual-task). Two stimuli were presented with varying stimulus onset asynchrony (SOA). After each trial, participants separately estimated the onsets of the two stimuli on the clock face. Across two experiments and four conditions, we manipulated response requirements and assessed their impact on perceived stimulus onsets. Results showed that (a) providing speeded responses to the stimuli did lead to greater SOA-dependent misperceptions of both stimulus onsets as compared to a solely perceptual condition, and (b) that response grouping reduced these misperceptions. Overall, the results provide equivocal evidence for the delayed conscious perception hypothesis. They rather suggest that participants' estimates of the two stimulus onsets are biased by the interval between their responses.

1. Introduction

It is widely agreed that attention and consciousness are highly related. The precise nature of the relationship, however, is still under debate. While some theorists view attention as a prerequisite for consciousness (e.g., Dehaene, Changeux, Naccache, Sackur, & Sergent, 2006), others contend that attention is neither necessary (van Boxtel, Tsuchiya, & Koch, 2010) nor sufficient for consciousness (Kentridge, Nijboer, & Heywood, 2008). Consistent with the former view, several authors have put forward the notion that decision-making (e.g., response selection) and conscious access (via consolidation of a stimulus representation into short-term memory) are subject to the same central or attentional bottleneck (Arnell & Jolicoeur, 1999; Marti, Sigman, & Dehaene, 2012; Ruthruff & Pashler, 2001; Tombu et al., 2011). Accordingly, while perceptual and motor processing of one task can occur in parallel with the processing of another task, response selection and conscious access are strictly serial.

Such a unified attentional bottleneck has been proposed to account for two dual-task phenomena that were originally thought to arise from separate central and perceptual processing limitations: the psychological refractory period (PRP) effect and the attentional blink. The PRP effect arises when participants provide speeded responses to two stimuli that are presented with varying stimulus onset asynchronies (SOAs); responses for the second task slow down as the SOA decreases (e.g., Pashler, 1994). For the PRP effect, response selection is thought to be the critical bottleneck process; responses for Task

☆ This study was supported by the Deutsche Forschungsgemeinschaft (BR 4297 1-1). We thank Lisa Katharina Schreiber for assistance in data acquisition, and Rolf Ulrich for helpful discussions.

* Corresponding author. Address: Fachbereich Psychologie, Universität Tübingen, Schleichstrasse 4, 72076 Tübingen, Germany. Fax: +49 7071 29 2410.
E-mail address: daniel.bratzke@uni-tuebingen.de (D. Bratzke).

http://dx.doi.org/10.1016/j.concog.2014.07.016
1053-8100/

2 are slowed at short SOAs because response selection for Task 2 is postponed until the response for Task 1 has been selected. The attentional blink occurs when participants are required to detect two targets in a stream of briefly presented visual stimuli; participants often fail to report Target 2 if it appears shortly after Target 1 even though they are not required to provide a speeded response to the targets as in the PRP paradigm (e.g., Raymond, Shapiro, & Arnell, 1992). For this effect, short-term consolidation is considered the critical bottleneck process; consolidation of Target 2 cannot take place as long as Target 1 is being consolidated. The sensory representation of Target 2 decays over time and can also be masked by another stimulus. If the sensory representation of Target 2 has completely faded or is disrupted before Target 1 has been consolidated, participants do not become aware of Target 2.

Evidence in support for the notion that the PRP effect and the attentional blink arise from the same attentional bottleneck comes from studies that combined the PRP and the attentional blink tasks. These studies found that the proportion of trials in which participants failed to report Target 2 was related to the speed of Task 1 processing (Jolicoeur, 1999; Ruthruff & Pashler, 2001), and that the encoding of a target delayed a subsequent speeded response (Jolicoeur & Dell'Acqua, 1999; Ruthruff & Pashler, 2001; Tombu et al., 2011). These results suggest that while response selection is ongoing, short-term consolidation cannot occur and vice versa (see Jolicoeur, 1999). That is, response selection of one task can block the conscious awareness of another stimulus. While in the attentional blink paradigm, the temporal dynamics of conscious access can be directly inferred from Target 2 detection rates, in a PRP paradigm it is less clear when participants gain conscious access to the second stimulus. If response selection of a speeded Task 1 delays conscious access to a second target in a combined PRP and attentional blink paradigm it is conceivable that in a standard PRP paradigm, conscious access to the second stimulus can also be delayed.

As participants always provide two responses in a standard PRP paradigm, and are therefore said to be 'aware' of both stimuli, an alternative methodology is required to assess any possible delay in their conscious perception of the second stimulus. To assess the subjective (conscious) timing of the two tasks in a PRP paradigm, two previous studies introduced the method of quantified introspection (Corallo, Sackur, Dehaene, & Sigman, 2008; Marti, Sackur, Sigman, & Dehaene, 2010). In each experimental trial, participants performed the PRP task and subsequently estimated their reaction times for the two tasks (RT1 and RT2) on a visual analogue scale. While objective RT2 showed the typical PRP effect, estimates of RT2 were independent of SOA. That is, even though responses to Task 2 were delayed at short SOAs, participants did not report this response slowing in their RT2 estimates. This result pattern could be interpreted as an underestimation of RT2 at short SOAs, caused by a delayed conscious perception of the second stimulus. Marti et al. (2010) extended this method and reconstructed the subjective phenomenology of a PRP trial based on several introspective reports. In addition to the estimates of RTs, they asked participants to estimate the temporal gap between the onsets of the two tasks (i.e., the SOA), and the interval between their Task 1 decision and Task 2 onset. SOA estimates showed underestimation of long SOAs and overestimation of short SOAs. Even at zero SOA, when the two stimuli were presented simultaneously, participants estimated the SOA to be about 250 ms. As one would expect, estimates of the interval between Task 1 decision and Task 2 onset decreased with increasing task overlap. At very short SOAs, the Task 1 decision should occur much later than the Task 2 onset, and therefore this interval should be strongly negative. The estimates of this interval, however, did not differ from zero for the three shortest SOA conditions (ranging from 0 to 232 ms). Marti and colleagues interpreted these results as indicating that at short SOAs the conscious perception of the second stimulus is delayed until the end of Task 1 response selection.

The misperception of SOAs observed by Marti et al. (2010) is crucial to this interpretation. However, Corallo et al. (2008) observed a very similar misperception of SOAs in a control condition in which participants estimated the SOA without processing the two tasks. Thus, the distortions of the SOA estimates might be due to a general estimation bias rather than response selection of Task 1 delaying conscious awareness of Task 2. For example, these distortions might reflect a well-known bias in quantitative judgments called contraction bias or regression effect (i.e., the tendency for responses to gravitate toward a reference magnitude; Poulton, 1989). Accordingly, stimuli larger than the reference magnitude are underestimated and stimuli smaller than the reference magnitude are overestimated. Poulton noted that such a contraction bias is facilitated if the observer is provided with a limited range of responses with an obvious central value. To assess estimates of SOA, Marti et al. used a visual analogue scale with a range that corresponded to the range of possible objective SOAs (0–1000 ms). Thus, the consequence of participants avoiding the extremes of this scale would be an overestimation of short SOAs and an underestimation of long SOAs. Accordingly, the overestimation of short SOAs found by Marti et al. could reflect a methodological artefact induced by the limited response range of the visual analogue scales rather than delayed conscious perception of Task 2.

In the present study, we investigated whether response selection for Task 1 causes a delay in the conscious perception of the second stimulus in a standard PRP task (delayed conscious perception hypothesis). To assess the moments of conscious access in the PRP task more directly, we employed a widely used method of timing subjective events, that is, the clock paradigm—sometimes also referred to as rotating spot method (e.g., Libet, Gleason, Wright, & Pearl, 1983; Miller, Vieweg, Kruize, & McLea, 2010; Pockett & Miller, 2007). In this paradigm, a clock hand moves around a clock face on the screen while participants perform another task. At the end of each trial, participants are asked to indicate the position of the clock hand when a certain internal (e.g., Haggard & Cole, 2007; Pockett & Miller, 2007) or external (e.g., Joordens, van Duijn, & Spalek, 2002; Seifried, Ulrich, Bausenhart, Rolke, & Osman, 2010) event occurred. For the present purpose, the clock method offers two potential advantages over the use of visual analogue scales. First, in contrast to visual analogue scales which assess the temporal relationship between two points in time (e.g., the interval between the perceived onsets of the two stimuli), the clock method allows us to assess the specific points in time when participants perceived the stimulus onsets. Second,