Acta Psychologica 147 (2014) 34–41

Contents lists available at ScienceDirect

Acta Psychologica

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

Prospective duration judgments: The role of temporality and executive demands of concurrent tasks

Halil Duzcu *, Annette Hohenberger

METU Informatics Institute, Cognitive Science Department, Universiteler Mah. Dumlupınar Blv. No.1, 06800 Çankaya Ankara, Turkey

ARTICLE INFO

Article history:
Received 14 January 2013
Received in revised form 1 September 2013
Accepted 4 October 2013
Available online 28 October 2013

PsycINFO codes:
2300 Human Experimental Psychology
2346 Attention

Keywords:
Prospective duration judgments
Concurrent temporal task
Concurrent executive task
Simon task
Attentional gate model
Duration length effect

ABSTRACT

It is known that concurrent non-temporal tasks shorten reproduced temporal durations in prospective duration judgments. Two experiments were carried out, one comparing a concurrent temporal task to a minimally demanding concurrent task (Experiment 1) and one comparing an executive concurrent (Simon) task with a less demanding non-executive concurrent task (Experiment 2). An effect of the concurrent task type on temporal reproductions was found. Furthermore, a duration length effect was found, where longer durations were underestimated more than shorter durations. This effect tended to be stronger for the experiments that included a concurrent task that demanded high attention.

1. Introduction

Accurate timing is required for the sake of efficient adaptive behavior in humans. Representation of time intervals on different scales from milliseconds to years is a crucial necessity for various mechanisms. However, psychologically relevant characteristics of temporal operations (e.g., estimation of a time interval to perform a particular task) usually are necessary on a scale of several seconds (Block, Zakay, & Hancock, 1999).

It is widely accepted that performance in a dual-task design is dependent upon the competition for attentional resources between temporal and non-temporal features of a stimulus since they share a limited common pool (e.g., Block & Zakay, 2006; Block et al., 1999; Brown, 1985; Brown & Boltz, 2002; Casini & Macar, 1999; Zakay, 1993; Zakay & Block, 2004). Performing concurrent non-temporal tasks during an interval decreases the accuracy of subsequent temporal reproduction and this decline increases with more difficult tasks. Attentional demands of the concurrent task influence prospective judgment, that is, subjects underestimate the time duration (Block & Zakay, 2006). Underestimation of durations when there are less available attentional resources for the temporal task has been explained by various internal clock models of time perception. In these models, pulses are emitted at a constant rate by the pacemaker and registered by an accumulator. In the attentional gate model (Block & Zakay, 2006), an advancement of the internal clock model more suitable for human subjects, attentional resource allocation is achieved by an attentional gate. If more resources are allocated to timing, more pulses pass through the gate since it is more open and more signals reach the accumulator. Concurrent non-temporal tasks consume some attentional resources and leave fewer resources for timing, which leads to the experience of shorter durations and underestimation of reproductions.

There are numerous concurrent tasks which affect time perception. For instance, syntactic ambiguity in reading and task switching (Zakay & Block, 2004), the Stroop task and its variations (Marshall & Wilsoncraft, 1989; Zakay, 1993; Zakay & Fallach, 1984), picture naming (Gautier & Droit-Volet, 2002), driving a car in a simulator or watching a videotape of a car (Gruber & Block, 2005), working memory span test (Ulbrich, Churan, Fink, & Wittmann, 2007), the randomization task (Brown, 2006), categorizing words (Macar, 1996), visual search (Brown, 1997), and the card sorting task (Zakay & Shub, 1998). Zakay (1993) could show effects of highly resource demanding tasks (such as Stroop) on the timing of a single interval (12 s) as compared to less resource demanding tasks. These studies indicate that time perception is sensitive to a large variety of concurrent tasks. However, there are also studies which failed to find concurrent task effects on timing between a secondary task that demanded verifying additions, an active cognitive process, and letter recognition, a more passive perceptual process (e.g., Taatgen, Van Rijn, & Anderson, 2007). Given these varied results, it would be more explanatory if those concurrent tasks in the literature could be categorized under some types of cognitive load.

* Corresponding author. Tel.: +90 312 210 78 73.
E-mail address: hduzcu@metu.edu.tr (H. Duzcu).

0001-6918/$ – see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.actpsy.2013.10.005

Block, Hancock, and Zakay (2010) categorized cognitive load types of concurrent tasks in the dual task paradigm of duration judgment studies in terms of attentional, response and memory demands, familiarity, processing changes and difficulty. This classification will be considered to explain the nature of the two experiments in the present study.

Although there are numerous non-temporal tasks that are used as concurrent tasks in time perception studies, to our knowledge, there are only few studies in the literature that directly investigate the effect of a concurrent temporal task within a duration judgment task. One example is the study by Brown and West (1990) that showed inaccurate reproductions when performing multiple timing tasks. Multiple temporal tasks were either consecutive or overlapping in this study. Whereas the results of Brown and West (1990) indicated the limited capacity of the attentional resources if they have to be allocated to more than one timing task, in the present study, we aim to show the effect of a concurrent temporal task that is entirely embedded in a longer interval which should be reproduced. We suggest that performance in a concurrent temporal task should be tested with the same method as in usual dual-task experiments (in which a non-temporal concurrent task is always carried out during the interval) to observe more clearly the effect of the concurrent temporal task on the actual time experience of the entire duration. Therefore, in Experiment 1 (temporal group), we used an interval comparison method including three relatively brief durations in the concurrent task embedded in the entire duration to be reproduced. As a control condition (sequence group) we used the same design, however, subjects had to report only the sequence of the colors and not to attend to the durations of the stimuli. Therefore, we could equalize memory demands (keeping track of the order of the sub-intervals and reporting them) of the two conditions and reveal the effect of Block et al.'s (2010) attentional demand types in the temporal task.

The Simon task (Hommel, 2011; Proctor, 2011) is one of the most widely used executive tasks to study cognitive control and has similar demands as the Stroop task used by Zakay (1993). The spatial position of the stimulus activates a fast response tendency to respond to the stimulus location even if the subjects should respond considering the shape, color, etc. of the stimulus. In a Simon task, interference occurs during the response selection part of information processing. The conflict that is present in incongruent cases (when the irrelevant spatial and the relevant non-spatial dimension of the stimulus do not overlap) has to be resolved by cognitive control. Response selection in conflicting situations is dealt with by the executive control mechanism. In Experiment 2, we aim to reveal the effect of response selection demand (Simon task) by equalizing motor response execution demands.

Another goal of this study is to investigate the effect of duration on time judgment. According to Zakay (1990) there is a tendency for longer durations to be more underestimated than shorter durations. Moreover, also other time-based processes such as prospective remembering seem to be sensitive to the length of the interval (Block & Zakay, 2006). Therefore, three different duration lengths (15, 30, and 45 s) are chosen which are thought to be appropriate for a prospective duration estimation study covering the most relevant part of the second scale of the interval timing paradigm.

2. Concurrent temporal task effect (Experiment 1)

A between-subject design was used to study the effect of a concurrent temporal task on duration reproduction. Participants in the "sequence task" group, which served as a control group, had to remember the sequence of three different background colors, blue, red, and yellow. Participants in the "temporal task" group were asked to pay attention to the relative durations of the three background colors with respect to each other. Subjects had to order the background colors with respect to their duration as short, medium and long on a sheet of paper. This makes the concurrent task a temporal task too. Subsequently, subjects in both groups had to reproduce the time interval. There might be a small difference in terms of workload while ordering just the color sequence vs their durational lengths. While reporting the sequence of colors requires just keeping track of that sequence, ordering the colors in terms of their duration (short, medium, long) requires some minimal update after the presentation of each color, i.e., whether the current color's duration was short, medium, or long relative to the other colors' durations. However, the memory demands of both ordering tasks seem minimal.

2.1. Participants

A total number of 23 subjects participated voluntarily in this study. There were 11 participants in the sequence group (*Mean age* = 21.1, *SD* = 2.3) and 12 participants in the temporal group (*Mean age* = 25.4, *SD* = 2.1). All subjects had normal or corrected-to-normal vision.

2.2. Procedure

Experiments were run in a silent room at METU Cogs-Lab, in front of a CRT monitor at a comfortable distance for the subjects and conducted with E-prime 1.2. They started with a practice phase including one trial from each duration length, namely short, medium and long. However, these durations (12, 25, 37 s) were not the same durations that were used during the experimental sessions. In the main test phase, there were five trials for each duration (15, 30, 45 s) that were randomly presented to the subject. All participants were instructed not to count loudly or silently during their performance.

The general set-up was as follows: a black square was shown in the center of the screen and the background color changed randomly between white, yellow, red, and blue. The white background was used as a default and participants were asked to write down the sequence of the other randomized background colors ((the Turkish equivalents of) Y for yellow, R for red, and B for blue) on a sheet of paper according to their order of appearance (sequence task group) or relative durations (temporal task group) after completing the study phase. Participants were asked to pay equal attention to both tasks, namely the duration comparison of the three background colors and the duration of the entire interval. During short intervals (15 s) yellow, red and blue backgrounds were seen on the screen for periods lasting 1, 2, or 3 s. The background durations were 2, 4, or 6 s for medium and 3, 6, or 9 s for long intervals (background colors appeared in 40% of the entire duration for each duration length).

Then an instruction page was shown that informed the subjects to continue with the duration reproduction part of the trial. After the instruction page, the same black square was shown on the screen to let them know the clock was ticking. Then they had to press a defined key to stop their estimation for the most recent entire duration that they had perceived in the sequence or temporal ordering task (Fig. 1).

2.2.1. Ranking of the comparison scores (temporal task group)

If the sequence that subjects noted on the response sheet was correct, they obtained 2 points because distinguishing two different durations is sufficient to obtain the correct order of the color durations. On the other hand, if they were correct about the longest (or shortest) duration but were mistaken about the short and medium (or medium and long) colors, they obtained 1 point as in this case that they could distinguish only one color's duration as longer (or shorter) than the remaining ones correctly, while being unable to do so for colors of short and medium (medium and long) length. Therefore they were given 1 point, or half of the total points available. As a last option, they could be wrong about all color durations. In this case the subject obtained 0 points.

2.3. Results

The descriptive results of the reproductions and ratios (reproduced/objective durations) are given in Table 1. A mixed ANOVA with the three