Design and Evaluation of a Virtual Reality-based Driving Task to Investigate Temporal Preparation

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Abstract— **Implicit timing is one of the less investigated components of human time perception. In particular, temporal preparation,which means reduced reaction time to act before an expected event ,has not received enough attention. The focus of this study is to design and validate a Virtual Reality (VR)-based driving task to examine this important aspect of implicit timing. During the VR test,the participants were expected to implicitly learn the time between the yellow light and red light being shown to them in the virtual street at three different intervals(i.e. 2,5,8s). We hypothesized that the young adults ,with no sex differences,can successfully form their temporal expectancies in our task by showing a significant decline in their reaction times. Our results confirm the significant reduction in absolute errors of the participants' reaction times for longer time intervals(5 and 8 s) with no difference between males and females.**

Keywords— **Implicit timing,Temporal preparation,Virtual Reality,Driving task.**

I. Introduction

Time perception can be divided into two main components: explicit timing and implicit timing [1]. Explicit timing means consciously making an estimation of a discrete duration in order to compare it with a previously memorized elapsed time. Implicit timing refers to sensorimotor activities that can predict the onset and the duration of future events such as ball catching,playing a piano or driving. The implicit and explicit timing mechanisms are found to be controlled by different brain regions [2,3]. One of the important but less-investigated sub-components of implicit timing is "temporal preparation" which relies on anticipation of event timing or future-oriented attending. If people can develop temporal expectations,their responses to expected sensory stimuli are quicker and more accurate than those appearing at unexpected intervals [4]. Such expectations make use of timing information in order to optimize motor or perceptual performance [5,6].

Generally,the body of research in the field of time perception has focused on explicit timing. In the past,our team showed the potential of Virtual Reality (VR) programs in explicit timing experiments to predict cognitive scores of older adults during either verbal estimation [7] or interval production/reproduction [8] tasks. To investigate the potentials of implicit timing for detecting cognitive decline, we need to establish the validity of a designed VR experiment on younger adults. Therefore,the focus of this study was to develop a VR test for examining the ability of younger adults to orient their attention to the time that a relevant event is expected. We presented a motor task with fixed-interval design that allowed the study participants to form and use their temporal expectancies. Our hypothesis was that the young adults,with no sex differences, can successfully form their temporal expectancies by showing a significant decline in their reaction times after preparation.

II. METHOD

A. *Participants*

Twenty-seven young adults (14 females) with an age range of 22 to 36 years (28.6 ± 3.6 yr) and education range of 13 to 21 years (19.0 ± 2.0) were recruited for this study. Two-tailed t-tests revealed no significant differences in terms of the participants' ages and education between males and females (p= 0.20 for age and p =0.69 for education). All participants signed an informed consent approved by the Biomedical Research Ethics Board of the University of Manitoba.

B. *Apparatus*

A street-like VR environment was implemented by Microsoft Visual Studio using C++ (see Fig. 1). For handling the graphic components of the program OpenGL,Glut (OpenGL Utility Toolkit) were used. The Logitech WingMan Formula Force GP setting was used for providing the pedal that the participants needed for interacting with the software program. The output module of the software was the participants performance in an excel file.

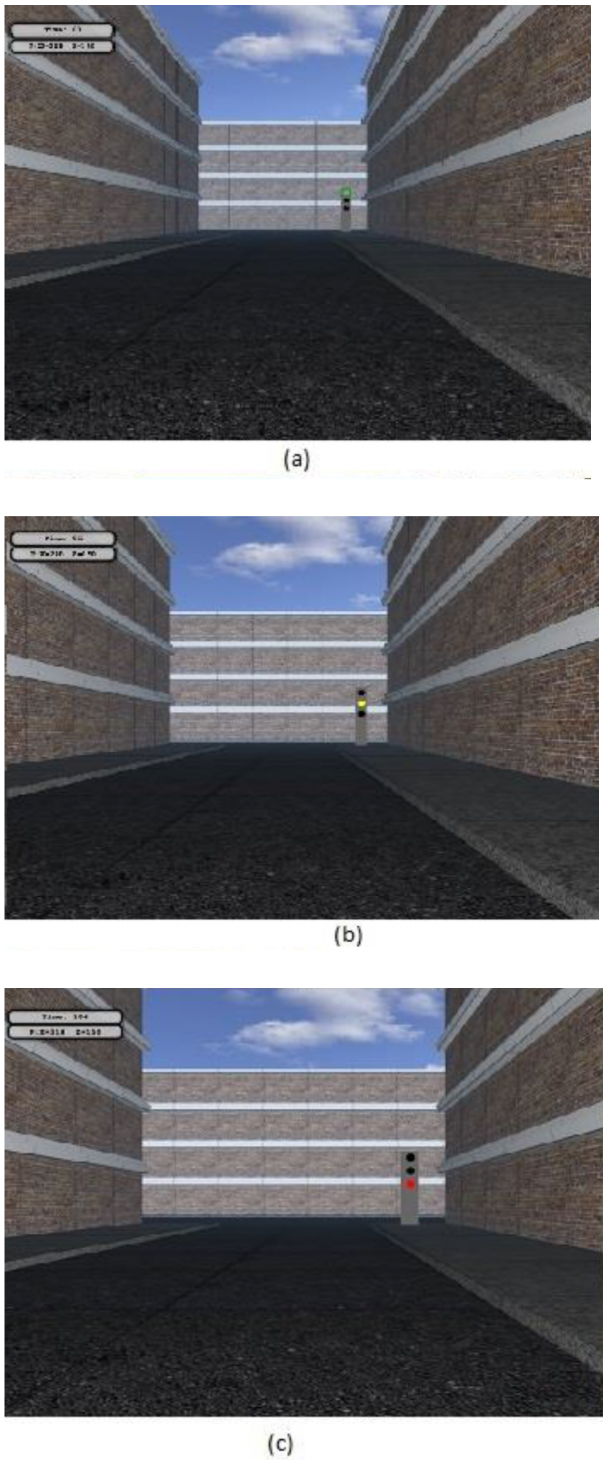

Fig. 1 View of the designed VR driving task. (a). The participant's point of view is inside a moving car running toward the end of a street where a traffic light is located. (b) Yellow light (c) Stop signal

C. Experiments

The user held a wheel and felt s/he was the driver; the car moved with a predefined speed in a virtual street toward the traffic light. The speed of the car moving on the street was fixed for all of the participants. At some points during the driving the traffic light changed yellow or red,and the user was expected to react by pressing the brake pedal with their right foot to stop the car.

The experiment was designed with four blocks of trials. Each block consisted of 6 trials including 2 repetitions of each appearance time of the stop signal (i.e.2,5,8 s) in a pseudo-random sequence such that two identical intervals were not consecutive and no apparent ascending/descending trend was presented in trial sequences (e.g. 2-5-8 or 8-5-2). At the beginning of each experimental session,every participant was given two practice trials for each paradigm. No feedback was given to the participants during the experiment.

In the first block (i.e. Baseline condition), only the red stop signal was shown to the participants and they would be asked to press the brake pedal as soon as noticing the red light (i.e. simple reaction time test).

In the second and third block (i.e. Preparation condition),the participants saw a yellow light signal before the red signal. The interval time between the warning and the stop signals remained constant across the trials (e.g. 1500 msec). The participant was instructed to press the brake pedal as soon as seeing the red signal. The purpose of these blocks was to have the participants implicitly learn the time interval between yellow and red signals in order to reduce their reaction times to red signals. As a large enough number of trials should be provided for this learning,two joint blocks,including 12 trials,were used in Preparation condition.

In the fourth block (i.e. Test condition),only warning signals were shown to the participants and they were asked to press the brake pedal in an appropriate time after the yellow signal based on their experience in the Preparation condition. Overall,each participant underwent 24 trials.

D. Data Analysis

In all trials,the participants' reaction times were recorded and compared to the appearance time of the warning signal and stop signal for calculating the magnitude and direction (i.e. pressing pedal before or after stop signal) of the errors. The calculated absolute errors for each interval were averaged among all of its appearances in each experimental block. For instance,per having two appearances for each time interval in the Baseline and Test blocks,the participants' absolute errors were averaged over the two trials. For the Preparation block that each interval appeared four times,the obtained absolute errors averaged over the four trials. It should be noted that unlike the reaction times which can have negative values,absolute errors can only be positive. Therefore,averaging them does not have the risk of negative values canceling out positive values.

At the final stage,each participant had nine associated absolute errors which meant having 81 errors in each experiment block and 27 values for each Interval X Block (e.g. 2-second interval on Test condition). As the final sample size is limited in each of the sub-groups,it could not grant adherence to normality; thus,non-parametric statistical tests were employed to investigate the difference between the groups. This includes Mann–Whitney U test (non-parametric equivalent to t-test) and Wilcoxon signed-rank tests (non-parametric equivalent to paired t-test).

III. RESULTS

There was no missing data obtained,nor any outlier in the data collected. Mann–Whitney U test revealed no significant differences between the males and females for all of the intervals and conditions. The result is summarized in Table 1.

Table 1 Comparing Absolute Errors obtained by Male vs. Female participants (using Mann–Whitney U test)

Block	Interval	Male (Mean ± Std)	Female (Mean ± Std)	U-value	p-value
Baseline	2-seconds	781.5±240.7	695.9 ± 203.8	112.0	0.320
	5-seconds	570.1 ±107.4	580.8 ± 75.1	91.0	1.0
	8-seconds	569.2 ± 66.6	555.4 ±78.3	101.0	0.64
Preparation	2-seconds	558.0±132.5	587.5±90.9	93.0	0.94
	5-seconds	538.3±81.2	635.6±69.9	87.0	0.86
	8-seconds	550.2±89.1	579.6±93.1	88.0	0.90
Test	2-seconds	634.4±435.8	626.8±320.7	89.0	0.94
	5-seconds	412.6±316.3	412.8±281.5	86.5	0.84
	8-seconds	392.9±196.3	368.5±132	102.0	0.61

The differences between the absolute errors of all participants across different conditions and time intervals are illustrated in Fig.1. As it can be seen,in all the time intervals the mean absolute errors decreased from Baseline condition to the Test condition; this shows the successful temporal expectation during formation in the preparation condition.

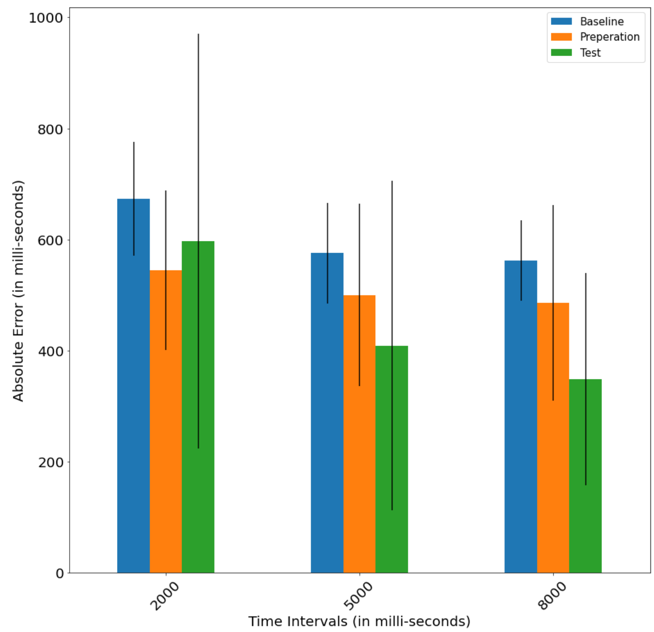

Fig. 1 The mean value of absolute errors across different trials based on the experimental conditions. The Error bars indicate standard deviation

To examine statistical significance for the illustrated differences,Wilcoxon signed-rank test was applied to each pair of the results. The statistical test showed significant difference between Baseline and Preparation conditions for 2-second ($Z = 40.0, p = 0.00$),5-seconds (Z=73.5,p=0.01) and 8-seconds (Z=97.0,p=0.03) intervals. In addition,comparing the Baseline and the Test conditions revealed significant differences for 5-seconds (Z=74.0,p=0.01) and 8-seconds (Z=18.5,p=0.00) intervals but not for 2-second interval (Z=139.0,p=0.23). Moreover,comparing the Preparation and Test conditions showed significant difference for 8-seconds(Z=59.0,p=0.002) but neither for 5-seconds (Z=122.0,p=0.107) nor for 2-seconds interval (Z=173.0,p=0.701).

IV. CONCLUSIONS

Our results confirm the validity of our proposed virtual reality for examining temporal expectations. The lack of sex differences in our results is congruent with previous studies [9,10,11] which showed no overall sex effect for the prospective paradigm of interval timing.

The different behavior of the 2-second interval in our results,including not having a significant difference between the Baseline and Test conditions,was due to a very large variation in the participants' performance during this specific interval. Compared to the 5-seconds and 8-seconds intervals,it seems that the participants did not form temporal expectations very well when facing the 2-seconds interval. This is in agreement with previous studies suggesting the primary role of different brain regions in timing intervals below 3 seconds [12,13].

As the previous studies show that components,such as speed of processing,could reveal significant differences between the younger and older groups [14],as a future work,one should conduct our validated experiment on older adults (60-80 yrs) for elucidating the effect of aging on temporal expectation.

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Conflict of Interest

The authors declare that they have no conflict of interest.

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