# Eyeblink rate during a virtual shopping game performance for cognitive rehabilitation

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## ABSTRACT

We developed a virtual shopping game having four levels using virtual reality technology for realistic cognitive rehabilitation. The objective of this study was to investigate characteristics in eyeblink rate in relation to task difficulty level. Six healthy adults were asked to buy two specific items in level 1, four items in level 2, six items in level 3, and eight items in level 4 at a virtual mall. Shopping items were daily necessaries which were independent of each other. Task performance, subjective assessments, and eye blinks during the game performance were recorded. As a result, the mean numbers of movements buttons used and the mean time required were higher/longer in level 4 than in level 1. The average subjective assessment scores were higher in level 4 than in level 1. Although the transitions of eyeblink rates were individually different, there was no statistical difference between phases, there were some relationships between subjective assessments and eyeblink rates. It suggests that eyeblink rate could be an index that reflects psychological aspects.

## 1. INTRODUCTION

Virtual reality (VR) technology provides an environment that is similar to everyday life conditions and enables people to evaluate and train cognitive functions in it. In cognitive rehabilitation for brain-damaged patients and people with dementia/mild cognitive impairment (MCI), exercises with an appropriate difficulty level for each individual increase the patient’s motivation and produce good results. However, difficulties have been associated with establishing an appropriate task level because of the lack of evidence on its effectiveness (Cicerone et al, 2011). Although various VR techniques have been proposed for cognitive rehabilitation (Knight et al, 2006; Kang et al, 2008), a small number of study including a virtual action planning supermarket considered the task difficulty level and/or related brain activation (Josman et al, 2009; Tarnanas et al, 2012).

We previously developed a Virtual Shopping Test (VST) for a realistic assessment of cognitive function using VR technology (Okahashi et al, 2013). In the present study, the VST was modified to “a virtual shopping game” that had four task difficulty levels. Subjects were asked to buy specific two items, four items, six items, and eight items in a different virtual mall in each task. We focused not only subjective assessments but also eye blinks as a psychophysiological index affected by task difficulty level unconsciously. The objectives of this study were to examine eyeblink rate in relation to the game phase and the task difficulty level. We aimed to gain basic knowledge for the application of the game in medical rehabilitation settings.

## 2. METHODS

### 2.1 A virtual shopping game

The hardware system included a personal computer, a screen (LCD-MF222FBR-T, I-O DATA). As shown in Figure 1, a visual environment consisted of a Japanese shopping mall was developed with Metasequoia and Open GL. The width of the virtual mall was about five meters and the depth was about one hundred meters. An audio environment of natural sounds associated with a shopping mall was also provided. By clicking on an icon/a shop picture of the screen, users could move forward and turn back in the virtual shopping mall, enter a


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shop and buy an item. Two hint buttons (e.g. List and Bag) were provided to allow users to view some hints during the shopping task. The operation of buttons was recorded automatically, and outputted as a log file after finishing the test.


**Figure 1.** *Scene of the experiment with a sample screenshot.*

*2.1.1 Level setting.* We constructed a virtual shopping mall in a virtual space, and set up four different difficulty levels. The virtual shopping mall used in each task had twenty shops and a train station, whereas the arrangement of these shops in the mall differed between tasks. The bottom of the map was the start point, while the top was the goal. Level 1 asked subjects to buy two specific items, level 2 asked them to buy four specific items, level 3 asked them to buy six specific items, and level 4 asked them to buy eight specific items on each shopping list. Subjects had to search the shops that sold specific items and select the target item from six items inside the shop.

*2.1.2 Experimental procedure.* The subjects were first asked to memorize the specific shopping items while looking at the shopping list with listening to the reading of the contents by a tester. If they failed the first recall test, they were allowed to memorize the items again while looking at the list. Then, they started shopping in the virtual mall when they are ready. They were asked to buy the specific items as quickly and efficiently as possible, while minimizing the use of hints. They were allowed to refer to a blank map set on the left side of the screen at any time during the game.

*2.1.3 Outcome variables*. The game had eight outcome variables: the number of times subjects used each button on the screen (Bag use, List use, Forward movement, and Reverse movement), the number of items bought correctly (Correct purchases), Total time, Time in the shops, Time on the road, and those could be calculated from the recording data automatically.

### *2.2 Data Collection*

*2.2.1 Participants.* Six healthy adults (four woman, two men), aged 19-23 years (mean age: 21.3) participated in this study. All participants received written and verbal information about the study and gave written informed consent. The protocol of the study was approved by the Kyoto University Medical Ethic Committee.

*2.2.2 psychophysiological index*. We recorded the number of times of eye blinks per second during the game performance by using a versatile biological amplifier: AP1000 (Nihonsanteku Co., Osaka, Japan). We adopted an electrooculogram (EOG) detection method to detect eye movements and eye blinks, which was analysed by Bio-Parametar Real Time Analysis System: Map1058 (Nihonsanteku Co., Osaka, Japan).

*2.2.3 Procedure.* All participants were administered the game in the order of level 1, 2, 3, and 4 with EOG recording and questionnaires concerning subjective assessment after each task. The questionnaire consisted of three questions concerning the degree of task difficulty, the effort required, and psychological load. Each answer was rated on a five-point scale (1-5). Higher scores indicated higher load task.

## 3. RESULTS

### *3.1 Behavioral data and subjective assessments*

The average game performance was presented in Figure 2-a, b. All subjects accomplished all level tasks. As shown in Figure 2-a, the mean numbers of List use was larger in level 3 than in level 1. The mean numbers of Forward/Reverse movement were larger in level 4 than in level 1. As shown in Figure 2-b, the mean time required to complete the task was longer in level 4 than in level 1. The average time required per shop was the longer in level 2 than in levels 1 and 3. Next, the average subjective assessments was presented in Figure 2-c. All three indexes scores were larger in level 4 than in level 1 ($p<0.01$).


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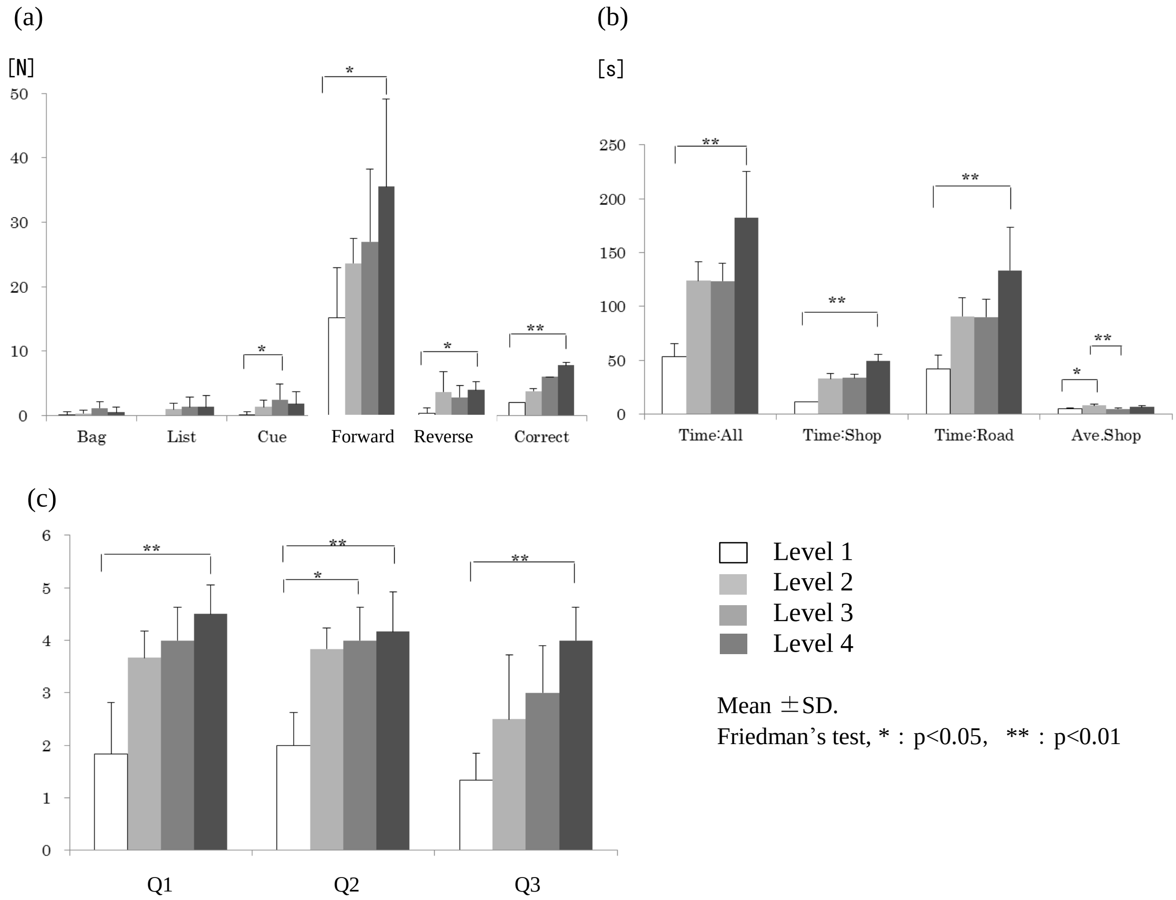


**Figure 2.** *The average game performance (a, b) and subjective assessments(c) on each task level: (c) Q1: the degree of task difficulty, Q2: the degree of the effort required, and Q3: the degree of psychological load. Higher scores indicated higher load task.*

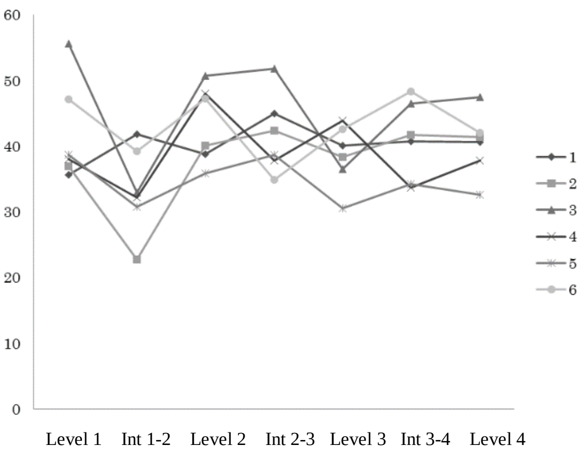


**Figure 3.** *Eyeblink rate in each phase in each subject.*

### *3.2 Eyeblink rate*

Figure 3 shows eyeblink rate during each level task and each interval between tasks in each subject. The *average* eyeblink rates (number per minute; mean±SD) were 42.0±7.8 in level 1, 33.3±6.7 in the interval between levels 1-2, 43.5±6.0 in level 2, 41.8±6.1 in the interval between levels 2-3, 38.7±4.8 in level 3, 40.9±6.0 in the interval between levels 3-4, 40.3±4.9 in level 4. There was no statistically significant difference between phases.

### *3.3 Relationship between subjective assessments and eyeblink rate*

There were positive relationships between the degree of the effort required in level 1 between eyeblink rates in levels 2 and 4 ($r=0.85$, $p<0.05$). There was positive relationship between the degree of psychological load in level 3 between eyeblink rate in the interval between levels 3-4 ($r=0.84$, $p<0.05$) statistically.

## 4. DISCUSSION AND CONCLUSIONS

Regarding the game performance and subjective assessment, the mean numbers of Forward/Reverse movement and the mean time required to complete the task tend to be larger/longer in level 4 than in level 1. The average subjective assessments were larger in level 4 than in level 1. It is same tendency with our report using 2-item, 4-item, and 6-item shopping at the 10th ICDVRAT. Then, the eyeblink rates transitions were individually different. There was no statistically significant difference in the mean value between phases. We consider that some personal factors (e.g. characteristic tendencies, experience and taste of TV game) would affect eyeblink rate during virtual shopping game performance. While, there were positive relationships between the degree of the effort required in level 1 between eyeblink rates in levels 2 and 4. There was positive relationship between the degree of psychological load in level 3 between eyeblink rate in the interval between levels 3-4. It suggests that eyeblink rate could be an index that reflects individual psychological aspects on task difficulty, effort required, psychological load, and so on. Blink frequency and duration change significantly over time during a vigilance task, and eye blink information may be an indicator of arousal levels (McIntire et al, 2014). Future research will be needed to analyse the interrelation between blink condition and other indexes such as personal factors and attention in both healthy people and patients with cognitive impairments.

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