Relation Between Mental Workload and Useful Field of View in Elderly

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Abstract. The aim of this study is to clarify the relation between mental workload and the useful field of view in elderly. To examine the mental workload relative to the size of the useful field of view, an experiment was conducted with 24 participants (group 1: ages 22–24, group 2: ages 60–75). In the primary task, participants responded to visual markers appearing in a computer display. The useful field of view and the results of the secondary task for mental workload were measured. In the mental workload task, participants solved numerical operations designed to increase the mental workload. The experimental conditions in this task were divided into three categories (Repeat Aloud, Addition, and No Task), where No Task meant no mental task was given. The mental workload was changed in a stepwise manner. The quantitative assessment confirmed that the useful field of view narrows with the increase in the mental workload.

Keywords: Mental workload · Useful field of view · Visual information processing · Comparison of younger and elderly

1 Introduction

In 2015, Japan's aged population (ages 65 and above) reached a historic high of 33,840,000, or 26.7 % of the total population. Therefore, the problem of an aging workforce and the influence on society in general cannot be ignored. We are addressing these issues by comparing visual information processing in the young and the aged, with the aim of examining which processing steps are most affected by aging and clarifying the causes of reduced visual perception in the aged.

Visual information processing is performed on information obtained from not only the center of one's field of view, but also along its periphery. The range of visual information collection that can be effectively used during visual cognitive tasks is called the useful field of view (UFOV), which is an important visual characteristic for recognizing, for example, obstacles and markers [1, 2]. Numerous studies have investigated UFOV with regard to ensuring safety and preventing recognition failures. As a result, the form of UFOV has been determined and methods for its measurement have been proposed. We assume a causal relationship between the increase in mental

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workload (MWL) and the increase in cognition of visual information. However, few quantitative studies have dealt with both MWL and UFOV, and previous research focused on only MWL [3, 4].

In this study, we investigated the relationship between mental workload and effective visual field in younger and elderly people.

2 Experimental Methods

Figure 1 shows a diagram of the experiment and visual stimulus. A participant was seated with his or her head secured on a chin rest (HE285, Handaya Co., Ltd.), and visual stimuli were presented on a computer display (LC-60Z9, Sharp) at a point located 225 cm in front of the eyes. The authors developed a program in Microsoft Visual Basic 2008 that generated the visual stimuli. In the presentation, a white, circular marker with 1.0° diameter is shown in the center of the display. In addition, a Snellen chart index is randomly shown at the screen edge in one of three directions (horizontal, diagonal, vertical) at one of several possible distances (between 1.25° and 3.25°) from the center. The participant then presses button to indicate the direction of the edge of the Snellen chart index.

As a secondary task (MWL task), the participant s were required to solve numerical tasks (e.g., repeating aloud a list of numbers or performing simple addition). Thus, three conditions were created as follows:

- Repeat Aloud: A list of numbers was relayed to the subject by voice at 3-second intervals, and the participant repeated the numbers.
- Addition: The participant added two consecutive numbers and answered only the first digit in reply.
- No task: The participants were not given a secondary task.

MWL quantification of the two numerical tasks was already performed in previous research [5] through simultaneous measurement with the event-related potential. Addition had the highest burden followed by Repeat Aloud, then No Task. The numerical tasks were presented through a speaker placed on the top of the display with the volume set at 70 dB.

The experimental schedule is shown in Fig. 2. The participants perform the experiment under one set of MWL conditions per day, and they fill out an NASA-TLX [6] evaluation sheet for a subjective evaluation index at the end of each day.

Twelve university students aged 23.7 ± 1.1 and twelve elderly peoples aged 70.5 ± 3.6 with corrected or uncorrected vision of 0.8 or better participated in the experiment. An eye tracker (EYELINK-II, SR-Research) monitored whether participants continued visual fixation during the experiment, and those who did not were excluded from analysis. We also simultaneously performed experiments with an unmoving focus point as a measure of the UFOV with a fixed gaze.

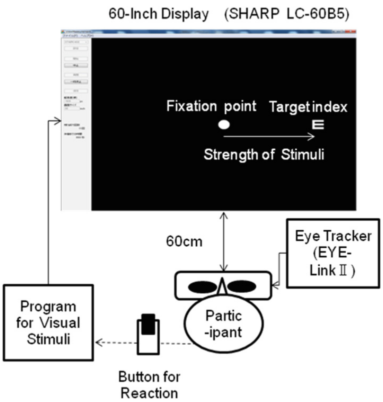


Fig. 1. Experimental setup

First Day (MWL①)			Second Day (MWL②)		Third Day (MWL③)	
Description Practice	Main Task MWL Task	Subjective Evaluation	Main Task MWL Task	Subjective Evaluation	Main Task MWL Task	Subjective Evaluation
10min	18min	NASA-TLX	18min	NASA-TLX	18min	NASA-TLX

Fig. 2. Experimental schedule

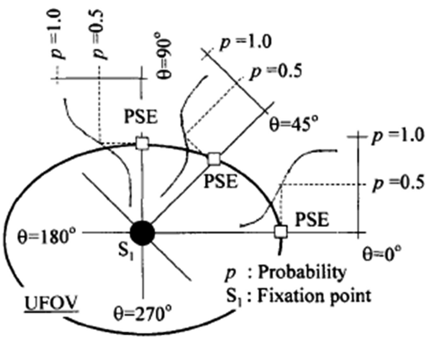


Fig. 3. Definition of useful field of view (UFOV)

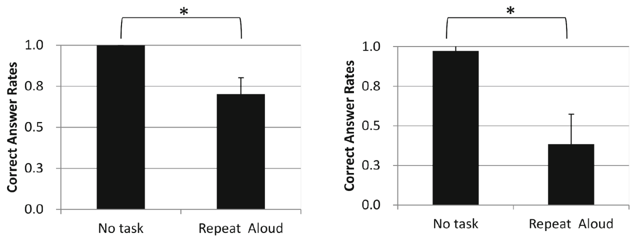
3 Measurement of Useful Field of View

The purpose of this experiment is to measure the threshold of recognition when the response category changes from “possible to detect” to “impossible to detect”, or vice versa. It is well known that the function linking the possibility of detection and the strength of the stimulus can be obtained as a psychometric curve [7]. Since the distance of the boundary between the "possible to detect" and "impossible to detect" categories indicates the threshold of recognition, the "impossible to detect" category can be estimated by the psychometric curve. Therefore, it may be possible to obtain psychometric curves in any direction from the fixation point. It is also known that the stimulus threshold can be obtained as a probabilistic percentile of the psychometric curve. One of the examples of this threshold with a 50 % probability is the point of subjective equality (PSE), which is equivalent to the threshold of recognition. As shown in Fig. 3, if we can assume that the region plotted within these stimulus thresholds is defined as the UFOV, then the outer limit of the region connected with the PSE for each angle is also defined as the UFOV [8].

4 Experimental Results and Discussion

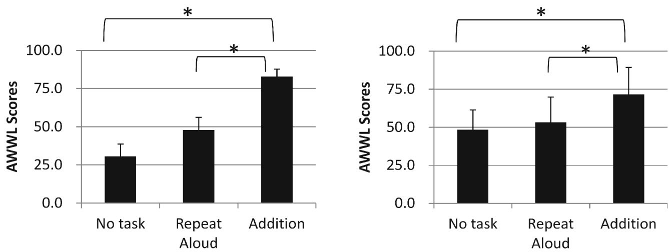
Figures 4 and 5 show the correct answer rates for the MWL task and the adaptive weighted workload (AWWL) scores [6] calculated by using the responses to the subjective evaluation index, NASA-TLX. Both graphs show the averages for all participant s under all conditions, and the error bars in the graphs indicate the standard deviation. In Fig. 4(a), the correct answer rate in the MWL task is almost 100 % for the Repeat Aloud task, whereas it significantly drops to approximately 70 % for the Addition task ($p < 0.05$, t-test). Moreover, in Fig. 5(a) the AWWL scores were approximately 80 points for Addition, 50 points for Repeat Aloud, and 30 points for No Task. Significant differences were found between No Task and Addition ($p < 0.05$), and between Repeat Aloud and Addition ($p < 0.05$) in an analysis of variance and a multiple comparison test. On the other hand, In Fig. 4(b), the correct answer rate in the MWL task is almost 100 % for the Repeat Aloud task, whereas it significantly drops to approximately 40 % for the Addition task ($p < 0.05$, t-test). Moreover, in Fig. 5(a) the AWWL scores were approximately 70 points for Addition, 50 points for Repeat Aloud, and 70 points for No Task. Significant differences were found between No Task and Addition ($p < 0.05$), and between Repeat Aloud and Addition ($p < 0.05$) in an analysis of variance and a multiple comparison test. The AWWL scores did not differ significantly between the two groups. However, in the correct answer rates, the ability to perform addition, which imposed the highest mental workload among the tasks in this study, was significantly lower in elderly compared with younger people.

Figure 6 shows the measurement results for the UFOV. In the MWL task as shown in Fig. 6(a), the UFOV is the narrowest for the Addition condition, and the widest for the No Task condition. It was found from the analysis of variance and multiple comparison test using the graph values as attributes that the MWL task factor ($p < 0.01$) is the affector. Significant differences were found between No Task and Addition ($p < 0.05$), and between Repeat Aloud and Addition ($p < 0.05$) in the multiple comparison test. On the other hand, In the MWL task as shown in Fig. 6(b), the UFOV is the narrowest for the Addition condition, and the widest for the No Task condition. It was found from the analysis of variance and multiple comparison test using the graph values as attributes that the MWL task factor ($p < 0.01$) is the affector. Significant differences were found between No Task and Repeat Aloud ($p < 0.05$), and between No Task and Addition ($p < 0.05$) in the multiple comparison test.



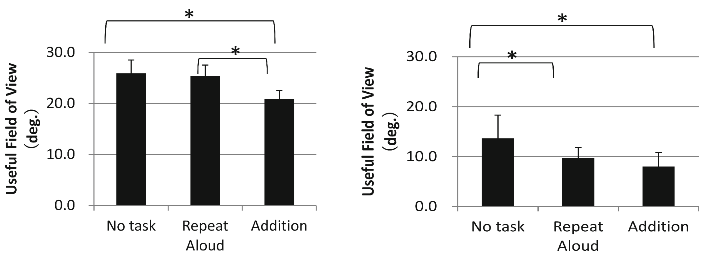
(a) Younger (b) Elderly

Fig. 4. MWL task and correct answer rate (*: p < 0.05)



(a) Younger (b) Elderly

Fig. 5. MWL task and NASA-TLX AWWL scores (*: p < 0.05)



(a) Younger (b) Elderly

Fig. 6. MWL task and UFOV (*: p < 0.05)

The AWWL score representing subjective workload levels in this study was higher for Addition compared to No Task, and the correct answer rates were also low. Based on these results, we can assume that these tasks formed a high MWL for the participant s and so these individuals markedly narrowed their UFOV. However, useful field of view differed significantly between the Repeat Aloud task and the Addition task in young adults but not in elderly adults. These findings suggest that because of a decline in visual function, a small load like the read-aloud task causes narrowing of useful field of view in elderly.

5 Conclusions

In summary, the above findings show that (1) an increase in mental workload causes narrowing of useful field of view in both young and elderly adults and (2) equivalent mental workload has a greater effect on visual information processing in elderly adults because of functional decline.

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