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PSYCHOLOGICAL ANALYSIS OF MENTAL WORKLOAD AT AN ELEVATED WORK PLACE: COMPARISON BETWEEN ELDERLY AND YOUNG WORKERS

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In this research, an experiment measuring the mental workload at the elevated place was conducted to prevent elderly workers fatalities at the elevated place by using dual task method. The results indicated an increase in mental workload caused by the height was observed in elderly workers. However, it was proved that the mental workload of the elderly workers was larger than that of younger workers when dangerous factors such as narrowness of a footing board width and complication of the work were added to a factor of height.

INTRODUCTION

The number of fatalities due to industrial accidents in Japan in 2001 was 1,790, with the construction industry accounting for the greatest share with 644 fatalities. Of which, the number of people who died from falling was 269 accounting for 42 percent, which means that the possibility of causing danger at the elevated place is extremely high. With aging of labor population, the number of labor disaster by the elderly workers tends to increase, and securing safety for the elderly is also becoming an important problem recently. Then, in this research, an experiment was conducted that both elderly and young construction workers as subjects walked on a footing board put over a temporary scaffold either with or without the footing board. This study aimed to obtain standard data, which will enable the establishment of a safe industrial environment for the elderly workers at the elevated place. We measured the degree of mental workload under various work-environment conditions where the height of work place, footing board width, and with or without carrying the footing board were adjusted. In the experiment, a dual task that subjects respond to a specific number announced auditoriarily during walking was conducted, and spare capacity of the subjects at the elevated place was measured by performance of a secondary task.

METHOD

Subjects

Construction workers who have all worked at the elevated place. It consists of 8 elderly workers and young workers respectively. Elderly workers ranged in age from 52 to 65 years with an average age of 57.5 years, SD=4.2. Young workers ranged in age from 18 to 39 years with an average age of 30.3 years, SD=6.4. Two elderly workers and young workers were respectively excluded from the analysis due to incomplete data. The details of the experiment were explained to the subjects and their agreement to participate was obtained.

Temporary scaffold

A temporary scaffold consisting of 8 levels and 6 spans and with a frame width of 1,200mm, span length of 1,800mm and level height of 1,700mm was erected within the experiment building. Figure 1 shows the front and side views of the scaffolding. The levels are shown as horizontal lines and the spans by vertical columns, while the thick lines in Figure 1 represent the parts where the subjects could walk. The spans on the extreme left and right were fitted with footing boards across their entire width of 1200mm (called resting boards), and footing boards either 240mm or 500mm wide were fitted in the four middle spans, on which the subjects walked during the experiment.

Measurement of spare capacity

In the experiment, a system of measuring the mental workload was used. The secondary task for the subjects was to respond by saying “yes” as quickly as possible wherever they heard specific numbers (“4” and “9” by male voice and “5” and “7” by female voice) among random numbers from a speaker (7 numbers ranging from 3 through 9 by male and female voice with total of 14 numbers) at the rate of 1 number per 2 seconds, and the reaction time was measured by wireless using a voice switch (the experiment apparatus was the same as that by Usui and Egawa 2002 [1]).

Subjective assessment

The subjects were asked to indicate to what extent they felt the mental workload by using NASA-TLX immediately after each experiment.

Walking speed

From the subject's walk recorded by the video camera we measured the time required for the subject to walk two round trips, excluding the time spent turning around at each end of the footing board.

Experimental condition

The conditions set in the experiment were as follows.
Height of work place: ground (walk on the footing board on the ground), and level 6 (10.7 m from the ground)
Footing board width: 240 mm and 500 mm
With or without load: with or without carrying the footing board that height is 1,800 mm, width is 500mm, and weight is 9,900g)
Age: elderly and young workers

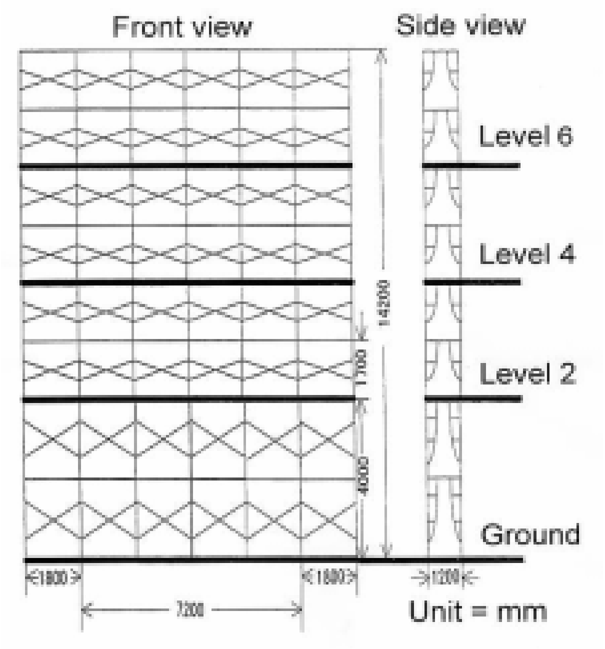


Figure 1. Front view and side view of temporary scaffolding.

Procedure

One experiment lasted 280 seconds, during which time the numbers were announced 140 times by voice. The numbers to be responded were announced 40 times accounting for 28.6 percent.
First, each subject was given 3 practice of the secondary task by sitting on a chair on the ground, and then made sure that he was able to respond to the secondary task without problem. In the experiment, the subject was instructed to walk back and forth 4 spans starting from resting board on the footing board between the signal of the "start of the experiment" and the "end of the experiment" by responding to the secondary task. The subject walked on the footing board 8 times in total by the width of 240 mm and 500 mm respectively on the ground and 6 level by possessing the footing board and without possessing. Finally, solely the secondary task was conducted as a control condition in a stable condition on the ground, and then the experiment was completed. The order for conducting eight experiments was counterbalanced.

RESULTS AND DISCUSSION

Walking speed

Four-way ANOVA(age × height × footing board width × with or without load) showed significant main effect for age, height, footing board width and with or without load in regard with walking time for 4 spans, $F(1,368)=162.94$, $p<0.001$; $F(1,368)=86.76$, $p<0.001$; $F(1,368)=36.17$, $p<0.001$; $F(1,368)=6.48$, $p<0.05$, respectively. The significant interaction was found between age and height, age and footing board width, $F(1,368)=20.71$, $p<0.001$; $F(1,368)=13.43$, $p<0.001$, respectively. Three way interaction between age, height and footing board width was also significant, $F(1,368)=11.83$, $p<0.001$. But the interaction between age and with or without load was not significant. These results showed that the elderly workers walked slower than young workers, and in addition, they walked much slower in comparison to young workers if the footing board width was narrower at the elevated place. However, slow speed by carrying the footing board had nothing to do with age.

Answer rate for secondary task

The rate that the subjects did not answer the number they were supposed to answer (miss rate) was 2.4 percent for elderly workers and 2.1 percent for young workers. The rate that the subjects answered the number they were not supposed to answer by mistake (false alarm rate) was 0.64 percent and 0.2 percent respectively. In other words, the subjects answered the secondary task almost correctly, and there was not difference between age groups. Table 1 shows the mean miss rates and mean FA rates in age group by experimental condition. The miss rates are low in general, but the miss rate in the elderly group is somewhat higher than other condition in the most dangerous working environment where the footing board width is 240 mm at level 6.

Reaction time

Table 2 shows the mean reaction times of the secondary task. Four-way ANOVA (age × height × footing board width × with or without load) showed significant main effect for both age and height, $F(1,3690)=273.22$, $p<0.001$; $F(1,3690)=4.14$, $p<0.05$, respectively. A main effect of footing board width was not significant. In addition, the interaction was not significant among 4 factors such as age, height, footing board width, and with or without load respectively. However, three way interaction between age, height and footing board width was almost significant, $F(1,3690)=2.88$, $p<0.10$. These results showed that the

Table 1. Mean rates of miss and false alarm in each age group.

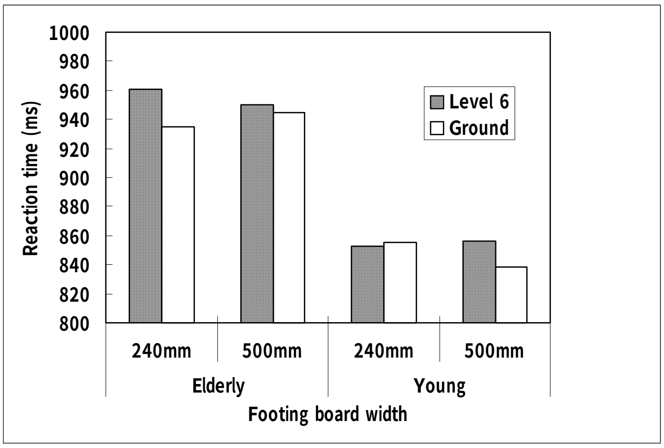
		Level 6		Ground	
		240mm	500mm	240mm	500mm
Elderly	Miss	3.46	2.31	1.89	2.11
	FA	0.66	0.72	0.30	1.01
Young	Miss	2.71	2.31	2.29	1.89
	FA	0.12	0.48	0.12	0.12

elderly workers responded to the secondary task slower in comparison to young workers. A number of researchers have confirmed that there has been an effect of aging in the reaction time in various tasks (for example, Welford, 1980), and it turned out that the effect was supported in the task of this research as well. This experiment revealed significant main effect for height, but it was different from the result conducted by Usui and Egawa (2002) where an experiment was conducted on the same temporary scaffold with scaffolding men. It is explained that the reason is that the secondary task by Usui and Egawa was simply to detect in which solely a woman’s voice stimulated was announced, and from which a specific number was detected, while an element where a male and female voice were distinguished was added to the secondary task this time, causing the problem to be more difficult. It was also proved that, although the spare capacity at the height decreased a certain degree, it had nothing to do with age since the interaction between age and height was not significant.

Usui and Egawa (2002) revealed that subject who has no experience of working at the elevated place performed the secondary task performance poorer, in other words, their spare capacity decreased when the footing board width was 240 mm at level 6. On the other hand, this experiment showed the main effect of the footing board width for the elderly workers was not significant in spite of the fact that the secondary task became more difficult. Furthermore, it turned out that there was basically no effect of age in the viewpoint of the spare capacity of subject since the interactions between age and other factors were not significant. However, the three-way interaction between age, height and footing board width was almost significant. Figure 2 shows the result of the reaction time by the footing board width on the ground and level 6. These results suggest that there was a dangerous working environment for elderly workers such as the elevated place and the footing board width was narrower where the spare capacity was decreased.

Table 2. Mean reaction times (time in milliseconds) for the secondary task.

	Level 6				Ground				
	240mm		500mm		240mm		500mm		
	Without load	With load	Without load	With load	Without load	With load	Without load	With load	Control
Elderly	962	960	964	936	930	931	954	937	959
Young	861	845	867	846	849	860	837	839	827



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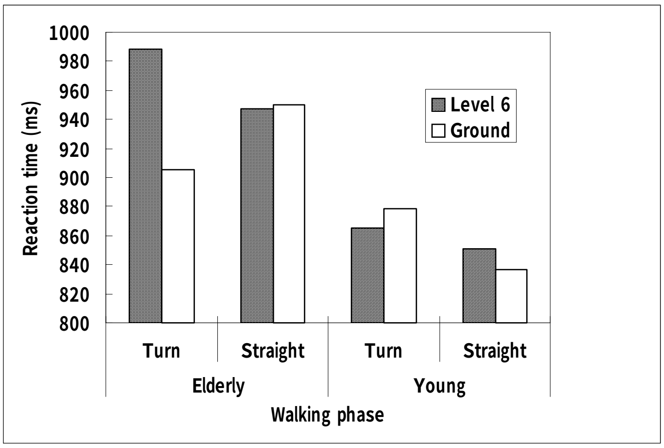

Figure 3. Mean reaction times for the secondary for according to the phases of walking.

Table 3. Mean reaction times for the secondary task according to the phases of walking.

		Level 6		Ground	
		240mm	500mm	240mm	500mm
Elderly	Turn	993	983	901	910
	Straight	953	942	946	955
Young	Turn	878	854	880	878
	Straight	846	857	847	827

Similar to Usui and Egawa (2002) we separated the reaction times of the secondary task into those when walking in a straight line and those when turning, from the viewpoint that the task demands in the walking. Table 3 shows the mean reaction times for the secondary task according to the phases of walking. Four-way ANOVA (age × height × footing board width × walking phase) showed that the main effect of walking phase was almost significant, $F(1,3690)=3.38$, $p<0.10$, and three-way interaction between age, height and walking phase was significant, $F(1,3690)=16.13$, $p<0.001$. Figure 3 shows the result of the reaction time by walking phase on the ground and level 6. These results suggest that there was a dangerous working environment for elderly workers such as elevated place and task demand was increased, in other words, the task became complicated where the spare capacity was decreased.

Table 4. Average scores in NASA-TLX.

	Elderly	Young
Mental demand	42.9	42.3
Physical demand	44.4	41.5
Temporal demand	41.4	38.4
Performance	72.7	66.6
Effort	67.2	45.9
Frustration level	36.3	34.3
Mean	50.9	44.5

NASA-TLX

Table 4 shows a mean assessment score for each index in NASA-TLX. There was a significant difference in index of “effort” (question: to what degree a subject has to work hard mentally and physically to achieve and maintain the level of work achievement) between elderly and young group, but there was no difference between age groups in other index. That is to say, there was almost no difference between age groups in the subjective assessment of the mental workload including mental and physical hardship. However, elderly workers feel more severely than young workers according to make effort mentally and physically they manage to achieve and maintain the work performance. These results suggest the spare capacity was decreased for elderly workers as they concentrated on the work in the working environment where the task demand was increased including the case that the footing board width became narrower at the elevated place.

REFERENCES

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