Analysis of mental workload at high-elevated work place (1)

-- Measurement of Psychological Responses --

SHINNOSUKE USUI
Graduate school of Human Sciences, Osaka University, Osaka, Japan

YOSHIYUKI EGAWA
National Institute of Industrial Safety, Tokyo, Japan

Backgrounds

- The number of fatalities due to industrial accidents in Japan in 1999 was 1992, with the construction industry accounting for the greatest share with 794 fatalities.
- Working at an elevated place was one of the most dangerous jobs, with 325 deaths in the construction industry resulting from falls.
- However, there has been little research from a human factors point of view, and so the degree of mental workload of people at an elevated place remains largely unclear.

Purpose

- This experimental study aimed to measure the degree of mental workload at height by an analysis of the psychological and physiological responses of the subjects under different conditions.
- The mental workload at height was assessed by dual task method.
- We also clarified the behavioral characteristics of skilled workers working at height and their risk factors during the work.

Method

Subjects

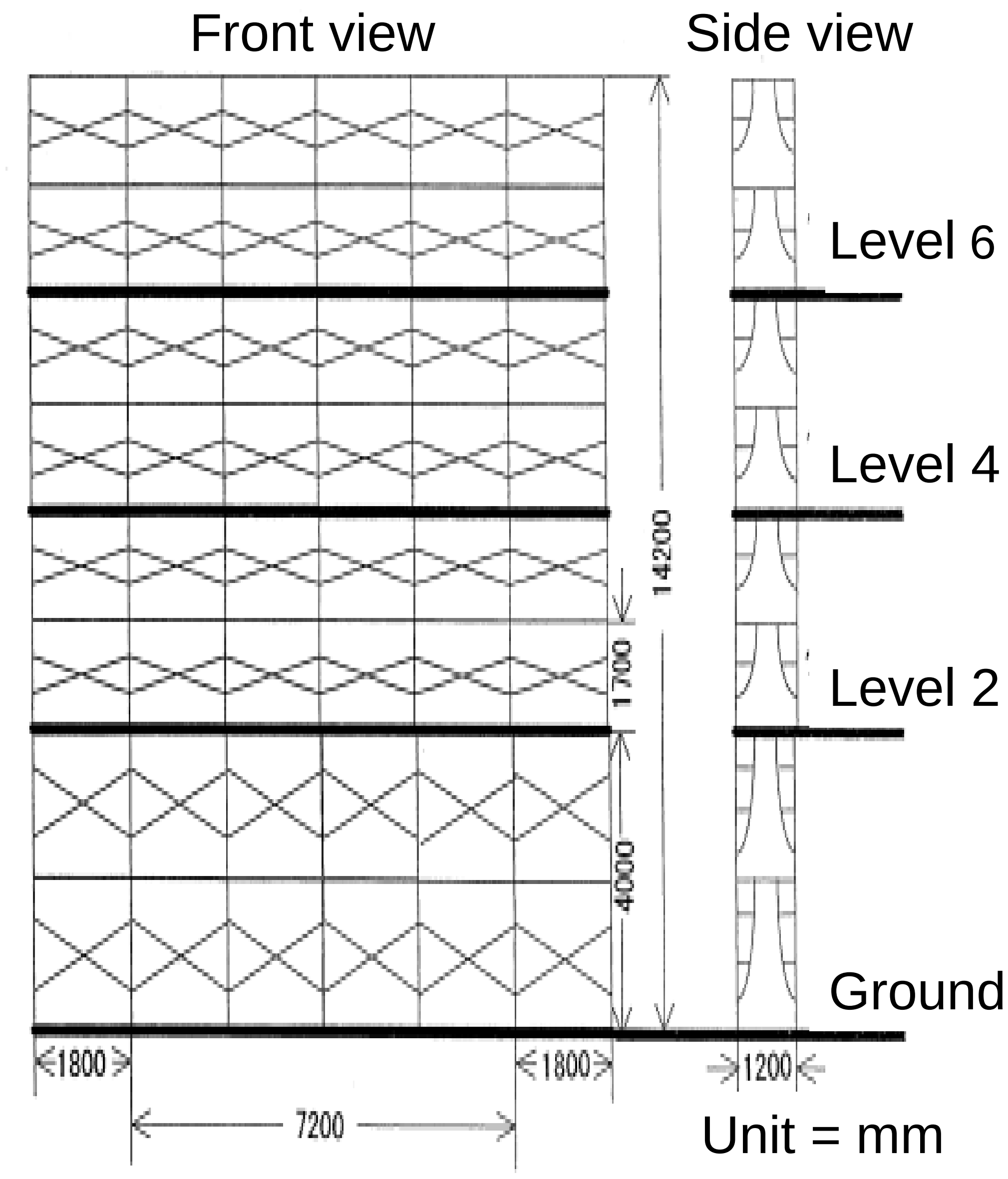
- 10 skilled scaffolding workers (average age = 26.2 years, SD = 10.8)
- 7 unskilled office workers (average age = 26.3 years, SD = 4.8)

Temporary scaffold

- The scaffolding consisting of 48 frames (8 levels and 6 spans) was erected within an experimental building.

Frame width : 1200 mm
Span length : 1800 mm
Level height : 1700 mm

Temporary scaffold



- The thick lines represent the parts where the subjects could walk.
- The footing boards either 240 mm or 500 mm-wide were fitted in the four middle spans, on which the subjects walked during the experiment.

View of the experiment

The test being carried out is at level 4 with a 500 mm-wide footing board.

The footing boards

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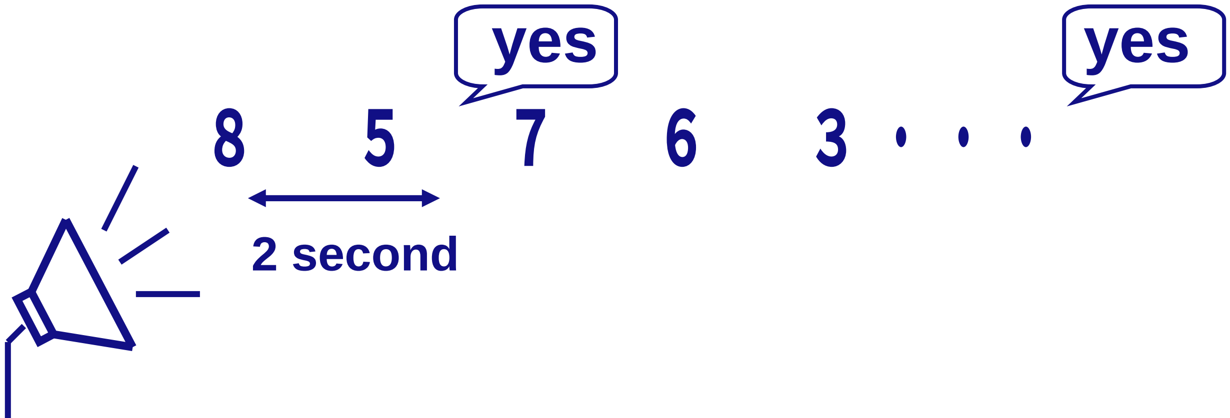
500 mm-wide

240 mm-wide

Measurement of spare capacity

- The secondary task was for the subject to respond by saying “yes” as quickly as possible whenever he heard the specified numbers 3, 5 or 7 among a series of random numbers between 3 and 9 emitted from a speaker once every 2 seconds.
- The reaction time was measured by radio using a voice switch.



Procedure

- In each test, 91 numbers were given over a period of 182 seconds.
- During the test on level 6 (both 240mm and 500mm footing boards), the subject was instructed when to start and stop making return trips along the footing board between the resting position and a point 4 spans away while performing the secondary task.
- The subjects performed the test a total of three times including the test at ground level.

Results : Walking speed

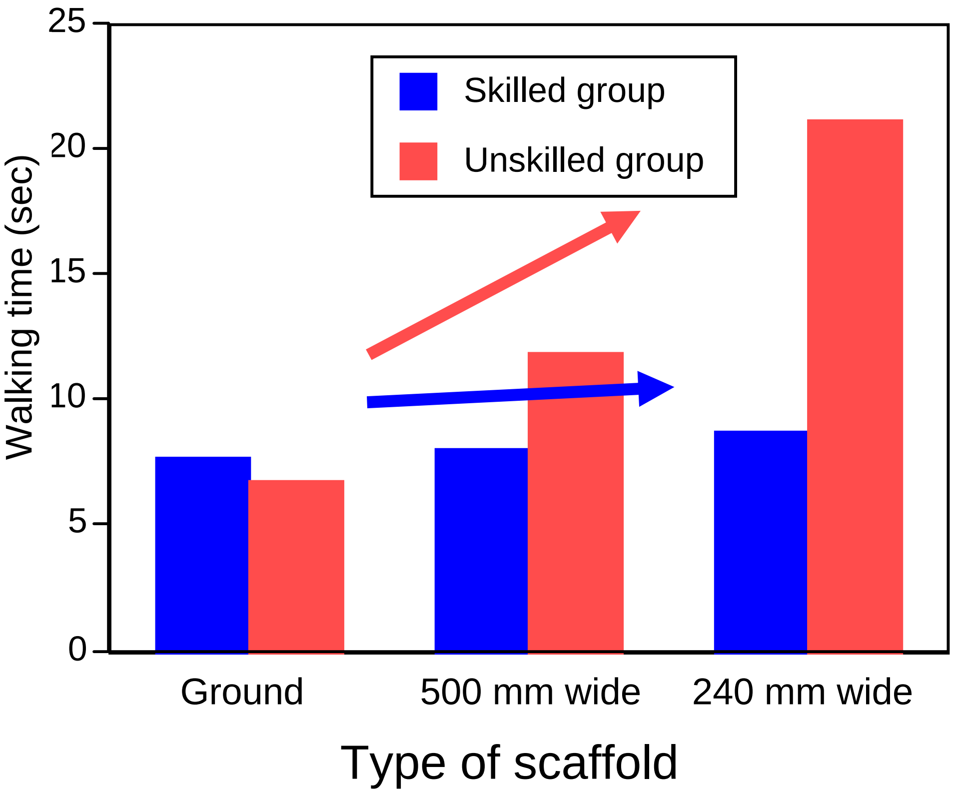


Fig.1 Mean walking times between the resting position and a point 4 spans away

Skilled group

Ground = 500mm

Ground = 240mm

500mm < 240mm (p<.10)

Unskilled group

Ground < 500 mm (p<.001)

Ground < 240 mm (p<.001)

500mm < 240mm (p<.001)

- Walking speed of the unskilled group was reduced when the height was increased, when the footing board was narrower.

Results : Reaction time

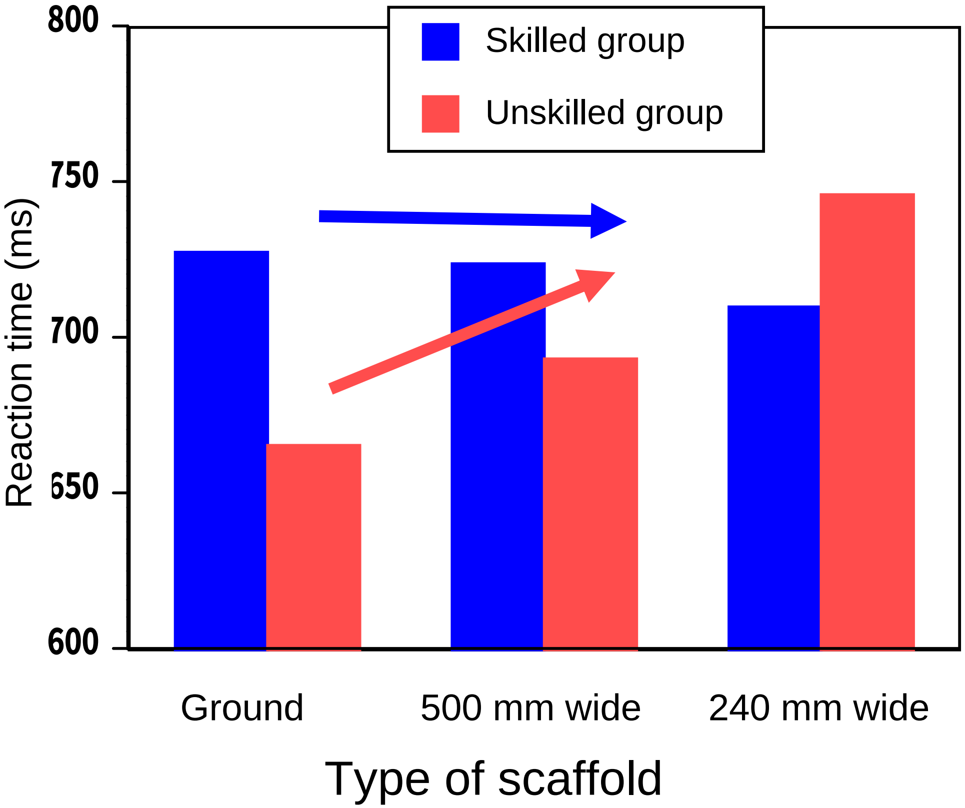


Fig. 2 Mean reaction times of the secondary task

Skilled group

Ground = 500mm

Ground = 240mm

500mm = 240mm

Unskilled group

Ground < 500 mm ($p<.10$)

Ground < 240 mm ($p<.001$)

500mm < 240mm ($p<.001$)

- Unskilled group: Spare capacity was reduced with footing board width and height.
- Skilled group: There was not much mental workload with tasks of this degree.

Results : To separate the walking into two phases

- Video monitoring suggested that the task demands in the walking test were greater when turning around because the subjects were paying attention to their footing in order to keep their balance.
- So we separated the reaction time into those when walking in a straight line and those when turning (phase of walking).

Results : Reaction time

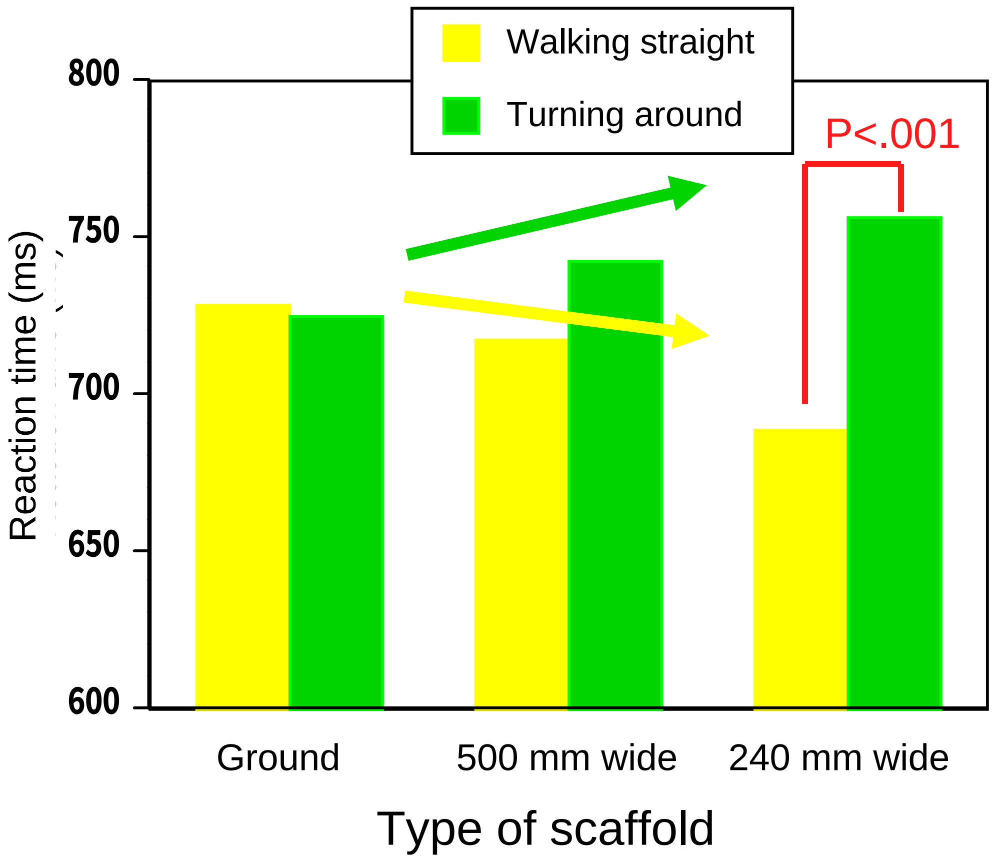


Fig. 3 Mean reaction times of the secondary task according to phase of walking in the skilled group

- In the skilled group, the interaction between type of scaffold and phase of walking was significant (P<.05).
- There was less spare capacity at an elevated place when turning around than when walking in a straight line, an effect that was more pronounced with a 240mm footing board.

Discussion : unskilled group

- Results of secondary task and walking speed clearly showed an increased mental workload at an elevated position.
- There was’t significant difference between RT on 500mm at height and on ground level.
- The subjects probably walked slowly on the 500 mm at height to concentrate on the secondary task (trade-off between walking speed and secondary task performance).
- On the 240mm board, however, the subjects lacked the spare capacity to compensate even when they reduced their walking speed.

Discussion : skilled group

Why didn't the mental workload increase?

1. The attention required for walking at height is a separate resource from the attention needed for numerical detection ; the multiple resources theory.
2. The secondary task used in this experiment was also comparatively simple and therefore might have been unsuitable for measuring spare capacity.
3. The primary task of walking at a height of 10m might have been too easy for the skilled group.

Discussion : skilled group

- The secondary task reaction time when turning around was greater than walking in a straight line, and that there was interaction between walking phase and footing board width.
- The mental workload increased when the task performed at height was made more difficult, and became even greater when using the narrower 240mm footing board.

Conclusion

- While there is a large mental workload at a height of about 10m, this can be controlled to a large extent by practice.
- However, if the work involved is made more complicated or the footing board is narrower, there seems to be an increase in mental workload even in skilled workers.
- In Japan, two main types of footing boards used on actual work sites are 240mm and 500mm wide, but the results of this experiment lead us to recommend the use of 500mm footing boards in order to increase work safety.

Correspondence to:
Shinnosuke USUI
Graduate School of Human Sciences,
Osaka University
Suita, Osaka, 565-0871, Japan
E-mail : usui@hus.osaka-u.ac.jp