Investigating Multimodal Displays: Reaction Times to Visual and Tactile Modality Stimuli

J. Yu[1], K. Moeller[1]

[1] Institute of Technical Medicine, Furtwangen University, Villingen-Schwenningen, Germany

Abstract— **Sometimes pilots, drivers and other professional operators have to perceive and process plenty of information in visual modality simultaneously. However, excessive information may lead to distraction, confusion, and may result in overloading the user's visual sense and cognitive resources. To reduce these overload threats, the sense of touch was employed as a new information presentation scheme.**

Both of the visual and tactile channels have their own merits and defects. In this paper, we focused on the reaction time to the visual and tactile modality stimuli. Our reaction time tasks are simple and four-choice tasks. In the visual stimuli tests, once the visual mode of a word about direction was shown, the participants pressed the corresponding arrow key with their fingers as soon as possible. In the tactile stimuli tests, the stimuli were produced through vibrators that were worn on the participants' waist or legs. Once the participants detected a vibration, they pressed the corresponding arrow key with their fingers as quickly as possible. We analyzed the influence of gender, time spent on computer, left/right finger, and tactile location on reaction time. The accuracy of each test was calculated.

The findings of this study provide a useful reference for engineers and designers to realize how the visual and tactile modality channels could impact the operators, and to determine the most effective modality or combination of modalities for presenting time sensitive information. Besides, the solution will be consultative for the design of tactile navigation system for visually-impaired.

Keywords— **Reaction time, Tactile Stimuli, Visual Stimuli, Vibrator**

I. INTRODUCTION

In daily activities, we obtain different modalities of sensory information to inform and guide us. With the arrival of scientific and technological era, a mass of visual equipments are developed to convey information. The strong dependence on the visual channel may cause visual fatigue, especially for pilots, drivers and other professional operators who have to perceive and process plenty of visual information simultaneously.

The number of receptors in our skin and eyes is almost identical, but they process very different kinds of sensory data. The touch receptors over about two square meters of skin make the sense of touch as an ideal route to convey information. The sense of touch was first systematically developed as a medium for communication by Geldard [1] in the 1950s. In recent years, research shows that tactile display is an ideal alternative channel through which to present information if other senses are impaired [2, 3].

The focus of this paper is on reaction time to visual and tactile modality stimuli in the context of man-machine-interface. Reaction time refers to the interval of time between application of a stimulus and detection of a response. Reaction time experiments have been classified according to the number of stimuli and responses [4, 5]:

1) When the number of stimuli and responses are both equal to one, it is simple reaction time experiment.

2) In recognition reaction time experiments, the subjects should respond to some specified stimuli and not to others. There is still only one correct response.

3) In choice reaction time experiments, the subjects have to give a particular response for each stimulus. In a pure choice reaction time, the sequence of stimuli types is random.

Several studies have been conducted to analyze the influence of different factors on reaction time such as stimulus modality [4, 6], stimulus intensity [4], age [7, 8, 9], gender [10], distraction [11], training [12, 13], and so on.

Reaction experiments were designed to analyze the influence of nature of stimulus, gender and left/right hand on reaction time. The results would help (i) to identify which of visual and tactile stimuli could produce quicker reaction; (ii) to understand female or male individual could produce quicker reaction; (iii) to find out which hand could produce quicker reaction; (iv) to analyze the influence of stimulus location. This would be very helpful for engineers and designers to integrate visual or tactile signal into human-machine systems more effectively and efficiently.

II. MATERIALS AND METHODS

A. Apparatus and Stimuli

An application program written in C# was used to generate visual and tactile stimuli and to capture the participants' responses.

J. Goh (ed.), *The 15th International Conference on Biomedical Engineering*, IFMBE Proceedings 43,
DOI: 10.1007/978-3-319-02913-9_122,

The visual stimuli were black words or arrows on a light grey background presented on the computer screen. Vibration motors which were integrated into a simple belt (Fig. 1) generated tactile signals. The position of the motors could be adjusted as required. As shown in figure Fig. 1, each vibration motor was packed in a small plastic tube to assure smooth revolutions.

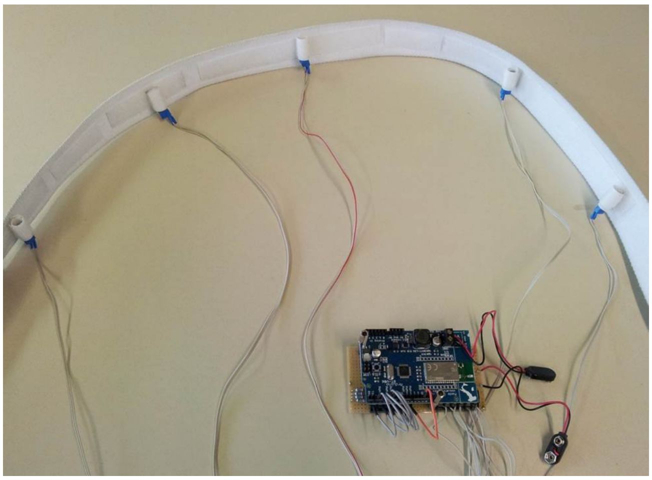

Fig. 1 Vibration belt, number and position of the motors are adjustable

These motors (model number LA4-432A) for the stimulation of the skin receptors are commercially available by the Nidec Copal Company (USA) and are mainly used in mobile phones. In the tactile test, the vibration motors are controlled with a NI-USB card from the National Instruments Corporation (USA). The NI-USB card is connected to the PC with a USB cable. The power supply for the motors was carried out via the voltage output pins of the NI-USB card.

B. Procedure

Above all, the objectives and procedure of the study were illustrated to the participants briefly. The participants were asked to fill in their age, gender, average time spent on computer per day, and dominant hand.

a) Visual stimuli test:

There are two forms of visual stimuli: words (left, right, front and back) and figures (arrows of four directions). There was only one form of visual signals in each trial.

Simple reaction time experiments: For each trial, there were 15 same visual signals. Once the participants found the waiting signal (----) was turned into to word “Back” or down arrow (↓), they had to click the down arrow key on the keyboard as soon as possible.

Choice reaction time experiments: There were 15 signals for each of the four directions in every trial. The order of the 60 signals was random. Once the directional word or arrow appeared on the signal region, the participants were required to press the corresponding arrow key as fast as possible.

All the visual stimuli tests would be repeated four times. For each time, the participants should response with different hands, or the visual signals were in different forms.

b) Tactile stimuli test:

The participants had to wear the vibration belt with four motors which represented four directions by their locations. The one near the navel represented front, the one near the spine represented back, the one on the left side represented left and the one on the right side right. Before the test, the motors were controlled to vibrate one by one to make sure the participants could feel the vibration.

Simple reaction time experiments: For each trial, there were 15 same tactile signals. Once the participants detected a vibration from the back, they had to click the down arrow key on the keyboard as soon as possible.

Choice reaction time experiments: The motors would vibrate 15 times in each direction. All the 60 signals in different directions would come randomly. Once the participants detected a vibration, they pressed the corresponding arrow key as quickly as possible. After the computer detected the click, another vibration signal would be generated.

Again, the tests would be done once with left hand and once with right hand.

Stimulus location: The four motors would be evenly placed around the right thigh. Simple reaction time test and choice reaction time test would be done with right hand.

III. RESULTS

Appropriate statistical analysis was performed to identify whether gender, left/right finger, choice alternatives and sensory modality had significant effects on reaction time.

A. Reaction time to visual stimuli

a) Simple reaction time

Table 1 shows average simple reaction time to visual stimuli in terms of four factors gender, signal form, time spent on computer and left/ right finger.

b) Choice reaction time

Table 2 shows mean choice reaction time to visual stimuli in terms of four factors gender, signal form, time spent on computer and left/ right finger.

Table 1 Mean simple reaction time to visual stimuli

Factors	Level	Mean reaction time (ms) Left	Right
Signal form	Word	296	295
	Figure	276	287
Gender (Word)	Female	287	284
	Male	302	301
Gender (Figure)	Female	276	291
	Male	277	284
Time spent on computer (Word)	>=10 hours	286	281
	<10 hours	313	319
Time spent on computer (Figure)	>=10 hours	275	287
	<10 hours	279	286

Table 2 Mean choice reaction time to visual stimuli

Factors	Level	Mean reaction time (ms) Left	Right
Signal form	Word	611	613
	Figure	460	452
Gender (Word)	Female	578	589
	Male	630	627
Gender (Figure)	Female	433	423
	Male	476	469
Time spent on computer (Word)	>=10 hours	586	590
	<10 hours	652	650
Time spent on computer (Figure)	>=10 hours	444	438
	<10 hours	485	474

c) Findings

Signal form: No significant differences were found between reaction time to visual signals in form of word and figure in simple reaction task (paired t test, $p>0.05$). In four-choice reaction task, signal form had significant effect on left and right reaction time (paired t test, $p<0.01$). Subjects responded significantly faster to figures than to words. More importantly, less error were made when subjects responded to figure form signals.

Gender: For the reaction time to word form signals, the reaction time of females was shorter than that of males across all reaction tasks. For the reaction time to figure form signals, the reaction time of females was shorter than that of male in choice reaction task. No significant differences were found between females and males in simple reaction task with figure form signals.

Time spent on computer: For the reaction time to figure signals, there were no significant differences between 'less than 10 hours' and 'longer than 10 hours' groups in the simple reaction task. Time spent on computer had significant effect on reaction time in other reaction tasks.

Left/right finger: There were no significant differences between left and right hand reaction time across all tasks (paired t test, $p>0.05$).

Choice alternative: Simple reaction time is significant shorter than choice reaction time.

B. Reaction time to tactile stimuli

a) Simple reaction time

Table 3 shows mean tactile reaction time to visual stimuli in terms of four factors gender, stimulus location, time spent on computer and left/ right finger.

Table 3 Mean simple reaction time to tactile stimuli

Factors	Level	Mean reaction time (ms) Left	Right
Location	Waist	261	263
	Leg	-	261
Gender (Waist)	Female	252	245
	Male	266	273
Time spent on computer (Waist)	>10 hours	253	243
	<10 hours	274	296

b) Choice reaction time

Table 4 shows mean choice reaction time to tactile stimuli in terms of four factors gender, stimulus location, time spent on computer and left/ right finger.

Table 4 Mean choice reaction time to tactile stimuli

Factors	Level	Mean reaction time (ms) Left	Right
Location	Waist	470	470
	Leg	-	521
Gender (Waist)	Female	468	460
	Male	470	476
Time spent on computer (Waist)	>10 hours	445	450
	<10 hours	510	504

c) Findings

Gender: Males responded almost as fast as females both in simple reaction task and four-choice reaction task.

Time spent on computer: Time spent on computer had significant effect on reaction time across all reaction tasks.

Left/right finger: There were no significant differences between left and right hand reaction time across all tasks (paired t test, p>0.05).

Choice alternative: The reaction time of the simple reaction task was significantly shorter than that of four-choice reaction task.

Stimulus location: The position of vibrators did not have significant influence on reaction time in simple reaction task, but have significant influence in choice reaction task.

IV. DISSCUSSION

The study was about reaction time to visual and tactile stimuli.

Females were found to respond faster than males to visual stimuli. But reaction time to tactile stimuli of males was almost the same as that of females. This finding was similar to the result done by Han et al. [14], which revealed that females responded faster than males during the detection of threat cues in visual scenes.

The longer the time spent on computer, the shorter was the reaction time in this study. The reaction time with left and right hand was almost the same.

The reaction time in simple reaction task was faster than in four-choice reaction task. Kamitani et al. [15] also found that the response on choice reaction time task was significantly longer than simple reaction time task. A primary cause is that choice reaction task required not only execution of the response but also decision-making processes.

For the reaction time to visual stimuli, subjects responded faster to figures than to words. Compared to words, figures were easier to understand and produced less error.

In choice reaction task, when applied the vibration to legs, the distance between motors are closer than waist. That caused the extension of decision-making time.

With respect to the sensory modality, reaction time to tactile is shorter than to visual stimuli, over all. But there were no significant differences between right hand reaction time to figure form visual signals and to tactile signals which were applied to waist. .

V. CONCLUSIONS

This study focused on the effects of gender, time spent on computer, left/right finger, choice alternative, visual stimulus form and location of tactile vibrators on reaction time. We expected the findings of this study would be useful for designing a more effective human-machine-interface in the future.

ACKNOWLEDGMENT

This work was supported by the Bundesministerium für Bildung und Forschung (BMBF), IH-2 iVIEW, FKZ 13EZ1129A.

REFERENCES

1. Geldard FA (1957) Adventures in tactile literacy. Am. Psychol., 12: 115-124 DOI: 10.1037/h0040416
2. Koo IM, Jung K, Koo JC et al. (2008) Development of Soft-Actuator-Based Wearable Tactile Display. IEEE Trans Robot 24(3):549-558 DOI:10.1109/TRO.2008.921561
3. Möller K, Möller J, Arras KO et al. (2009) Enhanced perception for visually impaired people evaluated in a real time setting, IFMBE Proc. vol. 25/9, World Congress on Med. Phys. & Biomed. Eng., Munich, Germany, 2009, pp. 283-286
4. Luce RD (1986) Response Times: Their Role in Inferring Elementary Mental Organization. Oxford University Press, New York
5. Welford AT (1980) Choice reaction time: Basic concepts. In Welford AT (Ed.), Reaction Times. Academic Press, New York, pp. 73-128
6. Brebner JT (1982) Reaction time in personality theory. In Welford AT (Ed.), Reaction Times. Academic Press, New York, pp:309-320
7. Welford AT (1977) Motor performance. In Birren JE and Schaie KW (Eds.) Handbook of the Psychology of Aging. Van Nostrand Reinhold, New York, pp: 450-496
8. Jevas S and Yan JH (2001) The effect of aging on cognitive function: a preliminary quantitative review. Res Q Exercise Sport 72: A-49
9. Luchies. CW, Schiffman J, Richards LG et al. (2002) Effects of age, step direction, and reaction condition on the ability to step quickly. J Gerontol Med Sci 57:M246–M249
10. Engel BT, Thorne PR and Quilter RE (1972) On the relationship among sex, age, response mode, cardiac cycle phase, breathing cycle phase, and simple reaction time. J Gerontol 27: 456-460
11. Hsieh S (2002) Tasking shifting in dual-task settings. Percept Mot Skills 94(2): 407
12. Rogers MW, Johnson ME, Martinez KM et al. (2003) Step training improves the speed of voluntary step initiation in aging. J Gerontol, Series A 58(1): 46-52
13. Fontani G, Lodi L, Felici A et al. (2006) Attention in athletes of high and low experience engaged in different open skill sports. Percept Mot Skills 102(3): 791-816
14. Han S, Gao X, Humphreys GW et al. (2008) Neural processing of threat cues in social environments. Hum Brain Mapp 29(8):945-957
15. Kamitani T, Kuroiwa Y, Li M et al. (2003) Relationship between cerebellar size and variation of reaction time during a visual cognitive task in normal subjects. J. Neurol. 250:1001-1003

Use macro [author address] to enter the address of the corresponding author:

Author: Knut Moeller
Institute: Institute of Technical Medicine
Street: Jakob-Kienzle-Str. 17
City: Villingen-Schwenningen
Country: Germany
Email: Knut.Moeller@hs-furtwangen.de