Effects of moving task condition on improving operational performance with slight delay

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Abstract

We made a hypothesis that appropriate delay in operational system would improve its operational performance from some reviews and papers. As an experimental result, performance was improved in slight delay. The sensory evaluation also confirmed that the subject felt support even though there was no actual force support. Another experiment confirmed that depth movement restriction, and the move ratio of the virtual tool on a screen to the input device affected to improve performance. We also investigated that difference of task conditions, i.e. moving task distance and target area size, affect to performance improvement.

Index Terms: Human-centered computing—Interaction design—Empirical studies in interaction design

1 Introduction

It is generally believed that latency has a negative impact on tool operation. However, Japanese car maker "Mazda" said that a slight delay is a necessary factor apparently —*When you start to move the accelerator pedal, the time until the tension of the neck muscle starts is constant at 0.2 to 0.3 seconds. It is the first necessary condition that acceleration is generated in accordance with the "timing of the stance" to realize a reasonable and natural reaction* (last part of section 2.2 in reference [4]). Based on this opinion and previous experiments in which delays made subjects feel partial interference from others that did not exist [2], we made a hypothesis that appropriate delay in operational system would improve its operational performance. Our previous experiment [1] was conducted in tasks that were somewhat more complex than simple button pressing operations [2]. A reach extender was displayed in a screen. Subjects operated it with a 3D position input device. They moved a ball from a table to another table by a reach extender (Figure 1(left)). Delay was inserted intentionally between the operation of an input device and the response of a reach extender. As a result, performance was improved (i.e. the average time to move the ball decreased) in slight delay of about 50 to 100 ms (Figure 2(left)). However, we have not concluded that slight delay improves performance anytime in any condition. Therefore, we researched which conditions affect the improvement in operational performance due to slight delay [3]. We prepared new experimental system which did not show performance improvement in a same task (Figure 1(right)). Parameters were decided with trial and error. The experiment confirmed that depth movement restriction, and the movement ratio of the reach extender on a screen to the input device affected to improve performance. The sensory evaluation also confirmed that the subject felt support even though there was no actual force support. We also investigated that difference of table conditions, i.e. moving task distance and target table size, affect to performance improvement. However, the main objective of this study is not to focus on the mechanism by which delay improves performance, but rather to identify the conditions under which performance improvement occurs.

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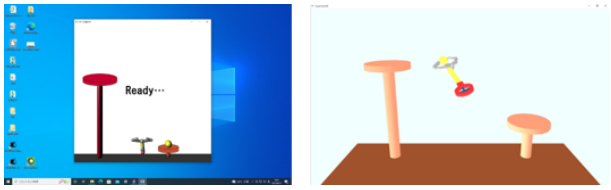

Figure 1: (Left) Screen of experiment 1, (Right) Screen from experiment 2 onward

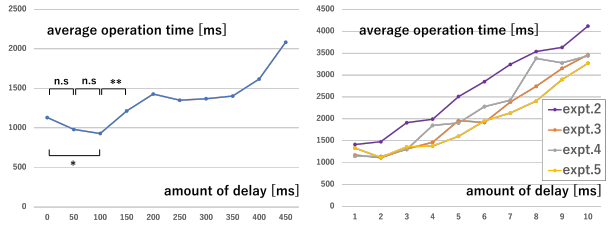

Figure 2: (Left) Result of operating time of experiment 1, (Right) Result of operating time of experiment 2-5

2 First Experiment

The first experiment [1] is referred to as experiment 1. In the experiment 1 (and following sections' experiments), a PHANTOM (Geomagic Phantom Omni) was used as an input device, and a 22-inch LCD display was used as the output device. The subjects operated the reach extender on the screen using a PHANTOM to move the ball object on the screen from a table to another table. Delay was added between the PHANTOM and the reach extender to implement the delay from the subject's hand to the extender and the movement of the object. It was necessary to measure the movement time of the object to obtain the operation scores. It was also needed to clearly distinguish between steady state and transient state. A "lid" was drawn on the object to visually indicate that it was fixed. The reach extender on the screen was also restricted to move, and the PHANTOM was fixed. A 3-second countdown was displayed in numerals to announce the start of the movement operation. After the countdown, the subject could move the reach extender. If the positional relationship between the tables was always the same, subjects might become accustomed to the operation, so the position of the tables could be changed. These distances should not differ significantly, because changing the distance between each other would not maintain fairness among tasks. The delay in this experiment (and followings) was 0 ms to 450 ms, with 10 steps of 50 ms, and each subject performed 10 movement tasks in a trial. In experiment 1, 20 subjects were assigned 5 trials and 5 delays per a subject in random order. Performance was improved in slight delay.

Table 1: Table size and positioning, and ratio of hand to screen coordinate distance

(diameter/vertical dist./horizontal dist./direct dist.)

	Hand coord. dist.	Screen coord. dist.	Ratio
Expt.1	71.8/156/156/220	56/122/122/173	0.78
Expt.2 & 3	46/67/147/161	72/89/222/239	1.48
Expt.4 & 5	46/67/147/161	35/52/114/126	0.78
Expt.6	46/92/201/220	35/71/156/171	0.78
Expt.7	58/67/147/161	44/52/115/126	0.78
Expt.8	58/92/201/220	44/71/156/171	0.78

Table 2: Combination of conditions and result of expt.2–5

		Movement ratio	
		0.78	1.48
Depth movement restriction	Yes	Expt.5 [*] P=5.00%	Expt.3 [#] P=34.8%
	No	Expt.4 [#] P=36.8%	Expt.2 [–]

[∗] Improvement with 5% significant difference
[#] Improvement with no significant difference
[–] No improvement

Table 3: Combination of conditions and result of expt.4 & 6–8

		Dist. of table	
		Narrow	Wide
Size of Table	Large	Expt.7 [#] P=22.6%	Expt.8 [#] P=36.2%
	Small	Expt.4 [#] P=36.8%	Expt.6 [–]

[#] Improvement with no significant difference
[–] No improvement

3 Experiment About Depth Restriction and Movement Ratio

Experiments 2–5 examined the effects of two elements, depth movement restriction and the movement ratio of the reach extender on a screen to the input device, on the improvement of slight delay [3]. Although procedure of experiments were same as a first experiment, the system was renewed in terms of, for example, window size, color tones, and shading. In experiment 2, 30 subjects were assigned 8 trials and 8 delays. In experiment 3, 24 subjects and in experiment 4 and 5, 10 subjects were assigned 10 trials and 10 delays. The conditions, combination and results are shown in Table 1 and Table 2. It was suggested that the restriction and the ratio of movement affected to improve performance (Figure 2(right)). In experiment 2, the subjects were informed in advance that it might assist or disturb them with a force display device even though any force was not provided actually. Sensory evaluation was conducted after the experiment. The result showed that the subjects felt that they were assisted at delays of 50 to 150 ms.

4 Experiment About Table Conditions

Experiments 6–8 examined the effects of two elements, the distance between tables and the target table size, along with experiment 4. System and procedure of experiments were also same as previous experiments. In experiments 6–8, 5 subjects were assigned 10 trials and 10 delays. The conditions, combination and results are shown in Table 1 and Table 3. The table distances in experiments 6 and 8 were wider than in experiment 4, and the table sizes in experiments 7 and 8 were larger than in experiment 4. Other conditions were same as experiment 4; there was no depth movement restriction and move ratio was 0.78. The results of experiments 6–8 show that the average time of the task operation was longer for larger delays in general as in previous experiment 4 (Figure 3). In experiment 7 and 8, it was slightly shorter with 50 ms than with 0 ms delay as in previous experiment 4. Although there were no significant differences, the p-values and the result that the performance was not improved in experiment 6 would seem to suggest that closer table distance and larger table size were associated with better performance (Table 3).

Table 4: Combination of conditions and results of all expt.

Depth	Ratio	Large		Small	
		Narrow	Wide	Narrow	Wide
Restrict.	0.78		Expt.1 [*]§ P=4.34%	Expt.5 [*] P=5.00%	
	1.48			Expt.3 [#] P=34.8%	
No restrict.	0.78	Expt.7 [#] P=22.6%	Expt.8 [#] P=36.2%	Expt.4 [#] P=36.8%	Expt.6 [–]
	1.07	P=27.2% [#]	no imp. [–]	P=54.8% [#]	no imp. [–]
	1.48			Expt.2 [–]	

§ Different window size, depression angle of gaze, color tone and shading
[∗] Improvement with 5% significant difference
[#] Improvement with no significant difference
[–] No improvement

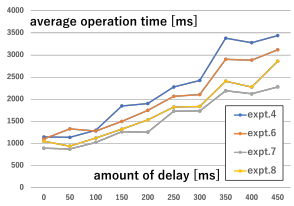

Figure 3: Result of operating time of experiment 4 & 6-8

Figure 4: Appearance of experiments

By the way, four experiments with a ratio of 1.07 had been also conducted earlier as preliminary experiments (Table 4). Although there were no significant differences in these as well, it appeared that a similar trend could be observed. However, it is not clear whether further increasing the table size and decreasing the distance would lead to better results.

5 Conclusion

We have made a hypothesis that appropriate delay in operational system would improve its operational performance. In our previous experiment, performance was improved in slight delay. We researched which conditions affect the improvement in operational performance due to slight delay. Table size and distance would have less affect than depth restriction and movement ratio. These findings will contribute to VR interface design. In the future, we would like to examine other combinations, and with further changes in movement ratio, table distance, and table size. We would also like to test for differences in window size, depression angle of the gaze, color tone, and shading, which have not yet been closely examined. After the conditions for the positive effects of delay are found out, the addition of slight delay will be considered for an operating devices. It would surely have a significant influence on the UI and enrich the experience associated with the operation.

Acknowledgments

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