Does Performance in the Face of Delayed Sensory Feedback Change with Practice?

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Abstract. During a target acquisition task, introducing visual delay detracts significantly from performance. However, delaying the haptic feedback given to the participant whilst over the target does not appear to have any effect, a result which is at odds with previous research involving a more complex task. This study examines the extent to which the effects of delayed haptic feedback change when the participant has completed the task many times.

1 Introduction

If telerobotics and collaborative virtual environments are to be used over large distances, the effects of lag on performance must be fully understood. Whilst there have been some efforts to quantify the effect of small amounts of lag on visual feedback [1], [2], there is little equivalent research in the haptic domain. Research that has been conducted indicates that the consequences of delayed haptic feedback are not directly analogous to those caused by a lag in visual feedback. In a telesurgical task, delaying haptic and visual feedback together significantly impaired performance [3]. However, if haptic feedback remained in real time there was no significant detriment to performance, even if visual feedback was delayed. In contrast to this, a study conducted by the current authors examining the effects of delayed haptic and visual feedback on a simple target acquisition task found that haptic delay had no effect on performance, and it was visual delay that posed a much greater problem [4]. A potential reason for this discrepancy is the amount of practice that the participant had at performing the task. In the case of [3], the surgeon was skilled at performing the laparoscopy operations used in the experiment; in [4] however, participants were attempting the task for the first time and may have felt unable to rely on haptic feedback. However, haptic feedback has previously been shown to enhance this type of task [5], and in [4] also significantly improved movement times if kept in real time when visual feedback was delayed - a phenomenon that may become more pronounced as participants gain more experience. The current study assesses this by running a small number of participants in [4] repeatedly on the experiment to see how their performance changes over time.

2 Method

2.1 Design

The experiment used a Fitts' law target acquisition task, in which the participant moved a cursor (a purple sphere of 0.4cm diameter) from a point on the left of the screen to a red target on the right (see Figure 1). The study had a 2 x 2 x 4 x 5 within-subjects factorial design. The factors were width of the target (2 or 4cm), distance of the target from the start (12 or 24cm), type of feedback (visual delayed with no haptic feedback, visual and haptic delayed by the same amount, visual in real time with haptic delayed, haptic in real time with visual delayed) and amount of delay (0, 25, 50, 75 and 150msec).

2.2 Participants

Two males and one female were selected at random from the 12 participants in [4].

2.3 Equipment

The study used a PHANToM desktop force feedback device powered by a Dell Precision 420 with dual Pentium III CPUs and a ReachIn display with a 91Hz Sony Trinitron monitor, with a resolution of 1280 x 1024. Participants used a Microsoft USB optical mouse to signal when they had hit the target. The virtual environment was constructed using MAVERIK [6] and the GHOST SDK, updated at a rate of 67 frames per second.

2.4 Procedure

The participant held the PHANToM stylus in their dominant hand and the mouse in their other hand. To start a trial, the participant placed the cursor over the start (a blue square of 0.4cm). As soon as the target appeared (after approximately 2 seconds) the participant moved the cursor to the target, and clicked the left mouse button on hitting it. The target disappeared and the participant moved the cursor back to the start. Haptic feedback was provided by a vibration of the stylus when the cursor was over the target. Each participant completed a block of practice trials and then 20 test blocks, one of each

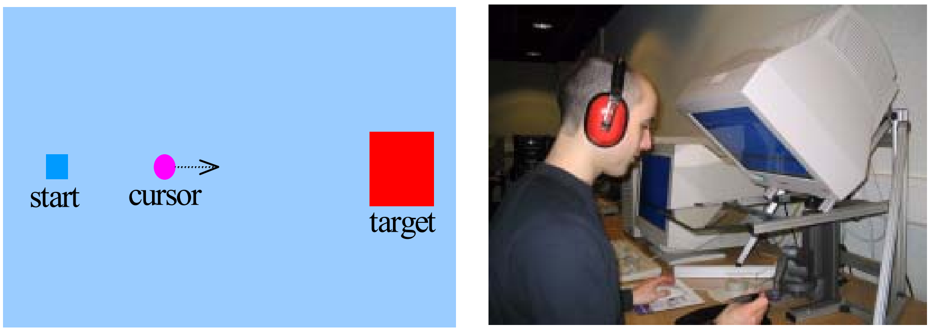

Fig. 1. The stimuli (left) and the equipment (right) used in the experiment.

of the combinations of feedback and delay, which remained constant throughout the block. The blocks were ordered according to a latin square. Each block consisted of 22 trials: two practice trials and 5 of each of the 4 combinations of amplitude and distance, presented at random. After a rest, the participant completed the blocks of trials again, in the reverse order. The experiment lasted 2 hours in total. Each participant completed the experiment 4 times over the period of a week.

3 Results

The mean time to complete each trial after 1 or 4 sessions of the experiment is shown in Figure 2. Contrary to expectation, the small advantage provided by haptic feedback when visual feedback was delayed in the first session is reduced to nothing by the fourth session. Participants learn to cope better with the visual delay, but also learn to ignore the haptic feedback.

4 Conclusions

[4] showed that in the case of a Fitts' law target acquisition task, despite the fact that the addition of haptic feedback significantly improved movement times, a lag in this type of feedback had no effect on task performance. The current study shows that when participants are well rehearsed in the task, this pattern continues: there is an improvement in the face of visual delay (cancelling out the advantage previously provided by haptic feedback), but participants remain insensitive to a lag in haptic feedback and are not able to rely on it when visual feedback is delayed. This reluctance

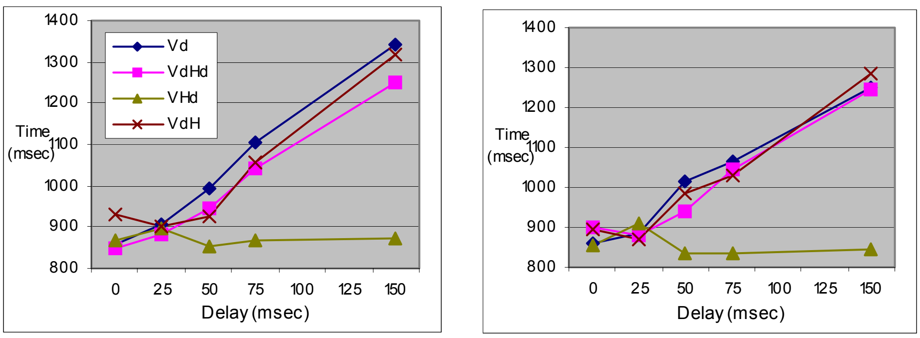

Fig. 2. mean time to complete a trial after 1 session (left) or 4 sessions (right). Vd = delayed visual feedback, no haptic feedback, VdH = visual delayed, haptic real time, VHd = visual real time, haptic delayed, VdHd = visual and haptic delayed by the same amount.

to trust real time haptic feedback in the face of delayed visual feedback, which directly contrasts to the user behaviour in a more complex telesurgery task [3] cannot, therefore, be attributed to a lack of familiarity with the task, but must instead be due to other factors. One possible reason is that as participants were not explicitly informed that lag would be present, they were not aware that the asynchrony in feedback was caused by delay[1], and chose to rely on visual feedback as this was more useful in terms of determining their position in the environment, unaware that in the VdH condition the haptic feedback was in fact more reliable. The fact that participants did not become more sensitive to this with practice means it is likely they remained unaware of how lag was affecting their performance. This has important consequences for the information given to users under these circumstances: if they were informed of the presence of delay, their reactions to both visual and haptic feedback could well change.

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1. One participant commented that it was disruptive when “the haptic feedback was early”, an effect caused in reality by the lag in visual feedback.