Solving Multi-Target Haptic Problems in Menu Interaction

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ABSTRACT

While haptic feedback has been shown to enhance user performance and satisfaction in single target interactions in desktop user interfaces, it is not clear whether this will hold for more realistic, multi-target interactions. Here we present an experimental study of haptically enhanced menus. We evaluate a visual condition, a haptic condition and an adjusted haptic condition designed to support menu interactions. We conclude that thoughtful design can create multi-target haptic augmentations that provide performance benefits.

Keywords

Desktop, GUI, haptic, multi-target, phantom, multimodal

INTRODUCTION

Appropriate haptic feedback has been shown to benefit targeting in a desktop environment. For the single target case, Oakley *et al.* [6] report a reduction of errors with an attractive force in a targeting task. Similarly, Hasser *et al.* [4] report an increase in speed. Such studies, however, tell only part of the story. In contrast with the environments described in these studies, a desktop interface consists of multiple targets, often presented in such a way that to reach a desired target, other potential targets must be traversed. While this traversal usually presents few problems, users operating a haptified interface could find themselves subjected to undesirable forces, which may perturb and disrupt their movements, and distract them.

One possible solution to this problem is based around target prediction. If the system can determine what target a user is interested in, then forces can be applied only over that target. Munch and Dillmann [5] discuss the design of such a predictive system using application behavior models and trajectory analysis, while Dennerlein & Yang [3] have begun to evaluate the practicality of this idea.

However, target prediction is a potentially costly solution. Munch and Dillmann's system required a learning period for each individual application and user. Target prediction may also prove ineffective for some tasks. One such task is menu selection, due to the large numbers and closely packed nature of the targets. Very accurate target prediction would be required to avoid applying inappropriate feedback in a menu. Furthermore, when submenus are in use, more than one targeting operation is required, yielding haptic multi-target problems even with accurate target prediction for each level of the menu.

Several researchers have investigated issues relating to haptified menus. Dennerlein *et al.* [2] describe decreases in performance time in a haptically augmented condition in a task analogous to moving along a single menu item. Campbell *et al.* [1] demonstrate reductions in both task time and error rate with the use of tactile feedback in a steering task similar to menu interaction.

These studies provide evidence that haptic feedback can support moving along the narrow tunnel of a single menu item. However, menus are always composed of groups of items, so the multi-target case must be considered. Given that target prediction techniques are neither guaranteed to work, nor complete enough to serve as a solution, this research explores an alternative. It describes and evaluates a haptified menu that has been designed to support a user's typical menu interaction. It is hypothesized that this menu will facilitate superior user performance when compared to both standard visual and haptically augmented menus, overcoming the multi-target problem.

EXPERIMENT

Participants interacted with a menu system that had similar appearance and behavior to the Start Menu (from Microsoft's Windows). Each trial consisted of selecting an item from the menu. The current target was displayed in a separate window. Selecting the current target caused the next target to be displayed. Participants used a PHANToM 1.0 (from SensAble Technologies) for cursor control.

Three conditions were examined: Visual, Haptic, and Adjusted. In the Visual condition the menu items were not haptically enhanced. In the Haptic condition each menu item was lined with walls, producing a tunnel-like force profile. The maximum strength of the effect was 0.4 Newtons (N). This effect resembled those used in similar single item targeting and steering tasks [4, 2]. The Adjusted condition was a modified version of the Haptic one. The modifications comprised a reduction of all forces (to 0.08 N) when a user moved slowly (below 2 cm/s) and, when a user moved rapidly (above 2 cm/s), a reduction in force along each axis individually (to zero) in proportion to his or her speed along the opposite axis. These modifications have the effect of providing weak forces opposing a user's motion and strong forces supporting it.

PROCEDURE AND MEASURES

The experiment followed a repeated measures design and lasted approximately 1 hour. 18 participants (11 male, 7 female) took part, fully balanced into 6 order conditions. Training on all conditions took place immediately prior to the experiment. Each experimental condition consisted of the same set of 100 trials, randomly presented.

Time to complete each trial was measured, taken from the time the Start button was clicked, until the selection of the menu item. A variety of errors were also recorded. The number of wrong item selections was counted. When this occurred the time for the trial was reset. Also counted were "slide over" errors, where a subject moved over the correct target, then moved off without progress (either item selection, or moving to the appropriate sub-menu) and "skip ahead" interactions, where a user took a shortcut from the current item to the next submenu by skipping over an adjacent item. These were used to modify the count of slide overs, so that it more accurately reflected actual errors, and also to provide a measure of the conformity of a user's path to the ideal path through the menu. NASA TLX workload ratings were also recorded.

RESULTS AND DISCUSSION

The results are presented in Table 1. All analyses were conducted using repeated measures ANOVA, followed by pair-wise comparisons using Bonferroni CI adjustments.

Users worked significantly slower in the Haptic condition than in both the Visual and Adjusted ones ($p<0.011$, $p<0.003$). The Adjusted and Haptic conditions produced significantly less wrong target selections than the Visual condition ($p<0.039$, $p<0.021$). The Adjusted condition led to significantly less slide over and modified slide over errors than both the Visual and Haptic conditions (all $p<0.001$). The Adjusted and Haptic conditions produced significantly fewer occurrences of skip ahead behavior than the Visual condition (both $p<0.001$). Overall workload in the Haptic condition was significantly higher than in the Visual and Adjusted conditions (both $p<0.001$).

	Conditions		
Measures	**Visual**	**Haptic**	**Adjusted**
Time (secs)	337.58	374.5	330.59
Wrong	7.44	2.67	3.56
Slide Over	116.61	113	65.78
Skip Ahead	27.28	4.06	4.61
Modified Slide Over	89.33	108.94	61.17
Overall Workload	8.16	11.7	7.5

Table 1: Experimental Results.

The results indicate that the adjusted condition produces the best of both worlds. Target selection errors are reduced to the same level as in the haptic condition, while speed is not compromised when compared to the visual condition. Speed in the haptic condition is lower because of the interfering forces. Users find it easier to target in the adjusted condition, as indicated by the lower number of slide over errors while the power to ensure a user remains on a path is similar to that found in the haptic condition, indicated by the similar number of skip ahead actions. Participants also found the adjusted condition less subjectively taxing than the haptic condition.

Previous research on moving along haptified menu items indicates that speed should increase with the additional feedback. We suggest that such an effect was not present here because users were unaware of the potential benefits of the Adjusted condition. Participants felt it was simply weaker than the Haptic condition and consequently took little advantage of the targeting forces provided. One user remarked that she could not understand the increased stability of her movements in the adjusted condition. More prolonged use may increase speed, as could explicit awareness of the beneficial forces.

In conclusion, we have demonstrated that although applying single target haptic feedback strategies to a multi-target case is ineffective, careful consideration of the interactions being supported can transfer the benefits of single target haptic feedback, at no cost.

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