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Paul Beckman
San Francisco State University

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OF MICE AND USERS

Paul Beckman

San Francisco State University
U.S.A.

Abstract

Human-system interaction research proposes that human performance will be higher when there is greater similarity between user, task, and interface characteristics. Force-feedback devices have recently become available as economically feasible additions to human-system interfaces. An experiment is proposed to investigate two aspects of applying force-feedback to the human-system interaction. At a higher level, the experiment will attempt to both (1) specify those user characteristics that most affect the ability of the force-feedback device to influence user performance and (2) extend prior research on task/interface characteristic concordance into the realm of force-feedback devices. At a lower level, the experiment will attempt to derive the most appropriate ways that a force-feedback input/output device can be customized or applied to best enhance a human user's performance on typical home/office computer tasks.

A pilot study and experiment are described in which subjects will complete typical home/office computer-based tasks with both a standard and a force-feedback mouse. Subjects will be tested for their abilities and aptitudes with the force-feedback mouse. An analysis of task performance by subject and device should shed light on both the user/interface and task/interface relationships when the interface is moderated by the use of force-feedback.

1. INTRODUCTION

This paper proposes a new direction of research in human-system interaction, based on previous research and new technology tools. The dual goals of the paper are to provide a motive for research in this area and also to describe a pilot study and experiment related to the application of a new technology tool to the understanding of human-system interaction. The area of human-system interaction under investigation relates to the impact on human task performance of the concordance, or similarity, between user, task, and interface characteristics. In particular, the experiment will explore the use of force-feedback devices and how human-system interaction research can suggest more appropriate applications of such devices.

2. RESEARCH OBJECTIVES

The objectives of the research proposed in this paper are three-fold. The two higher-level goals are to (1) learn more about the characteristics of users that might guide a system designer in more appropriate uses of force-feedback and (2) supply proof that current theories on human performance and task/interface concordance can be extrapolated to force-feedback physical interface devices. The first of these goals will be achieved by performing a statistical analysis on the task performance results of users of various abilities performing typical home/office computer tasks with both a standard and a force-feedback mouse. The second goal will be achieved by examining the general results of the experiment. If task/interface concordance theories are appropriate for modeling human task performance with use of force-feedback, performance will be higher when tasks characteristics are in concordance with force-feedback interface characteristics. The lower-level goal is to discover more details about the particular ways that a force-feedback device could be customized to enhance human task performance. This will be accomplished by analyzing the experimental task performance results by mouse type.

3. THEORETICAL FOUNDATION

3.1 Force-Feedback Devices

Force-feedback technology advances have presented developers of computer-based systems with another tool to give end-users better control of their systems. In particular, force-feedback mouse devices have recently become affordable (approximately \$100) to the average home computer owner. Such devices allow the user to “feel” the various visual and non-visual elements displayed on a computer screen. This suggests that applications might be developed for users with physical disabilities that limit dexterous motor control.

3.2 Task Analysis

Researchers (Farina and Wheaton 1973) have discovered that human performance depends on three principal factors: operator attributes, environmental properties, and task characteristics. Operator attributes are those impactors on task performance that are present in the user, such as the user’s visual acuity, hearing, knowledge, and mental state. Environmental properties are those impactors on task performance that are present in the surroundings of the user and include, among others, ambient temperature and noise, and tools (such as force-feedback devices) used to complete the task. Task characteristics are those impactors on task performance that are inherent in the task, such as how many steps in the task, how many output units per time period, and the cognitive workload required by the task.

The bridge between human performance and interface design is task analysis, which has been investigated by many researchers. For example, Vessey’s theory of cognitive fit (Vessey 1991, 1994; Vessey and Galletta 1991) proposes that human task performance will be greater when information is presented in a format that coincides with task characteristics and will be less when information is presented in a format that does not coincide with the task characteristics. Other researchers (Goettl et al. 1991; Merwin and Wickens 1991; Wickens and Carswell 1995) came to similar conclusions about the impact on human performance of task/interface concordance. Specifically, they found that subject performance on integrative tasks was better when the interface integrated data dimensions than when the interface separated data dimensions.

Of particular relevance to the experiment proposed in this paper is the exact relationship between a task and the interface used to complete the task. One researcher (Beckman 2000) describes an experiment that investigated the utility of two different interfaces for controlling a ground vehicle in a virtual environment. In that experiment, ground vehicle control tasks were constructed in which rotational and translational control was separated (e.g., driving at a constant speed while continuously turning) or combined (e.g., chasing a randomly moving vehicle). Correspondingly, one interface separated rotational and translational control while the other interface combined rotational and translational control. The empirical results of the experiment indicated that subject performance was higher when the task characteristics coincided with the interface control characteristics.

4. RESEARCH METHODOLOGY

The general results of the research described above can be formulated into testable hypotheses related to user characteristics, force-feedback interface devices, and tasks to be completed. In general, these hypotheses are:

H1: Human task performance will be superior when a user’s abilities relate to the enhancements provided by a force-feedback device.

H2: Task/interface concordance theory can be extrapolated to include force-feedback devices.

H3: Human task performance will be superior when force-feedback characteristics are in concordance with task characteristics.

These hypotheses suggests that the particular task control characteristics of the force-feedback mouse must be understood with respect to the capabilities of the human user. These control characteristics must also be understood to a depth from which tasks can be constructed that either coincide with or contradict those characteristics. The most common force-feedback mouse available (Logitech Wingman) can be customized through a programming interface. These customizations can change the type and amplitude of force-feedback given to a particular user performing a particular task.

One example of a customization that could be made specifically for one user or type of user would be to generate feedback for a user with a rhythmic muscle spasm, such as is sometimes associated with cerebral palsy. When a user with such a condition operates a standard mouse, the cursor oscillates back and forth across the computer screen, due to the constant low friction of the mouse and the users inability to hold the mouse in place. A force-feedback mouse could provide one of two forces to help this user maintain tighter control over the mouse. A simple feedback force could provide the sensation of a highly viscous fluid to dampen the oscillation. At a more complex level, if the oscillation were highly regular and predictable, a force contrary to the oscillation could be generated, to directly oppose the users unintended mouse motion.

One example of a customization that could be made specifically for one type of task would let the user “feel” a small rectangular “ridge” around each of the pull-down menu selections of any Windows-based software application. However, when a user clicks on one of these pull-down menu selections, they have immediately changed the characteristics of the task they are attempting to complete. That is, when working with Microsoft Word (or any other word-processing software application) under normal conditions, a mouse is used to make random movements around the screen. This would occur, for example, when a writer wished to use the menu selection system to add a closing (e.g., “Sincerely yours,”) to a letter. Before the set of menu selections can be made, the user must choose the point in the document at which the closing is to be inserted. The characteristics of this “random search-and-select” task are that the cursor will have to be moved to some arbitrary horizontal and vertical location on the screen. A standard mouse is ideal for this action since it can move at any speed in any direction, and then quickly select an insertion point with the click of a mouse button. However, when the user then decides to use the menu selection system to insert a predefined closing, their task characteristics change drastically.

In Microsoft Word 97/2000, the menu choices required to insert the predefined closing “Sincerely yours,,” are:

“Insert” then “AutoText” then “Closing” then “Sincerely yours,,”

One characteristic of this set of sub-tasks is that, once initiated (by clicking on the “Insert” menu selection), the *only* valid mouse movements are vertical and horizontal (vertically down to the “AutoText” menu selection, horizontally right to the “AutoText” sub-menu, vertically down to “Closing,,” horizontally right to the “Closing” sub-menu, and finally vertically down to “Sincerely yours,,”). A properly configured force-feedback mouse would restrict the user to only vertical and horizontal movements inside the visible block of the current pull-down menu selection, once a “starting” menu selection was chosen.

These examples of a particular user characteristic (rhythmic oscillation) and a particular task characteristic (horizontal/vertical movement only) suggest that a force-feedback mouse, if customized appropriately, could promote higher task performance. When some user characteristic is known or derived, or a particular task characteristic is detected, the force-feedback mouse could alter its own behavior in ways that are simply not possible with a standard mouse.

4.1 Pilot Study

A pilot study is being launched in which a small number of subjects, whose physical control abilities will be measured, will perform the typical personal computer task of making selections from a set of pull-down menus, using both a standard and a force-feedback mouse. The force-feedback mouse will restrict each subject to only vertical and horizontal movements within the block outlined by the pull-down menu choice. The goals of the pilot study are to refine the user physical ability measurements and types of tasks to be performed in the subsequent experiment, to better understand the capabilities of the force-feedback mouse, and to better understand the programming requirements needed to make changes to the capabilities of the mouse.

4.2 Full Experiment

The full experiment will implement a within-subjects methodology employing a larger number of subjects performing a larger number of tasks, again using both a standard and a force-feedback mouse. One of the subjects’ physical abilities to be measured is performance on a “Fitts Law” type pointing task. This type of task requires the subject to move a pointer from one target to another and yields some assessment of the user’s manual dexterity (Dennerlein et al. 2000; Hasser et al. 1998).

Some of the tasks under consideration for the full experiment are (with their possible force-feedback implications):

Task #1: pull-down menu selection (described above)

Force-feedback influence: only vertical/horizontal within-block movement

Description: see above.

Task #2: dialog box button-click

Force-feedback influence: gravity pull toward buttons

Description: Personal computer users are regularly required to click on dialog box buttons, often choosing from at least three options often equating to “Continue,” “Cancel,” and “Help.” A force-feedback mouse could generate the effect of “gravity” toward each button, helping “pull” the cursor onto the button that the user initially moves toward.

Task #3: button click

Force-feedback influence: physical response upon successful click or double-click

Description: Home/office computer users are often required to click a mouse button to initiate a task. For example, when web-browsing, the user often clicks on the “Back” browser button. However, the micro-switch in the mouse is sometimes not activated even though the mouse button has been pressed. The user then waits, believing that a web page will be displayed, while the computer is actually waiting for a successful mouse click.

4.3 Implications of the Research

One result of this research will be a greater understanding of the types of force-feedback that would be most beneficial to users with particular physical characteristics. Some type of slight resistance to their hand motion might aid older users or those with reduced hand motor skills. Another result of this research could be justification, or at least support for, deeper menu selection hierarchies. One current problem with deep menu selection hierarchies is that they are more difficult to traverse than shallow hierarchies because of the increased opportunity for the cursor to drift off of the current menu selection block. A force-feedback device would eliminate this problem.

5. CURRENT STATUS

This research project is currently at the point of pilot study and full experimental design. Hardware and programming time have both been allocated. The complete set of tasks for the full experiment must be derived and implemented and subjects must be enrolled.

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