FORCE AND DISPLACEMENT PREFERENCES FOR AN ALTERNATIVE KEYBOARD

Florian Jentsch
James M. Hitt, II
University of Central Florida

Peter McAlindon
Keybowl, Inc.
Winter Park, Florida

Over the past several years, much attention has been given to repetitive strain injuries (RSI's) in the office environment. Perhaps the most common and widely publicized of these RSI's is carpal tunnel syndrome (CTS). CTS is an insidious, progressive RSI that affects millions of typists every year. The effects of CTS are far reaching. In the office, CTS reduces worker job satisfaction and productivity which may ultimately affect the company's bottom line. U.S. businesses spend in excess of $10 billion each year to combat the CTS problem. The AID-CTS keyboard (commercially referred to as the OrbiTouch by Keybowl, Inc.) is an alphanumeric input system that is developed to combat CTS and numerous other upper extremity disabilities. It is designed to offer all typists a more comfortable means of typing and navigation. The purpose of the current study was to determine what combination of dome force and dome displacement were most acceptable to the user. A study was conducted to evaluate different dome forces and different dome displacements using a variable force joystick to establish the most appropriate range of acceptable force and displacement characteristics. The study resulted in an optimum force and displacement that minimizes arm and wrist movements while maximizing user comfort.

INTRODUCTION

The research described here was part of a human factors development project for an alternative keyboard, called the Alternative Input Device for Carpal Tunnel Syndrome (AID-CTS) (McAlindon, 1995; 1997). The AID-CTS (commercially referred to as the OrbiTouch by Keybowl, Inc.) is a keyboard alternative that replaces the use of individual keys by combinations of movements of two domes. Each dome is flexibly coupled to a base. The dome design was chosen because it closely approximates the at rest posture of the hand, which reduces static muscle fatigue and increases long-term comfort. The device is intended to significantly reduce wrist and finger movements, reduce the impact of typing on the development of repetitive strain disorders, and allow people with disabilities or disabling conditions to use a computer.

The AID-CTS keyboard is an extremely flexible typing device and was developed to accommodate the user's needs. In fact, AID-CTS keyboard users are expected to be the ones that (a) have an upper extremity disability, (b) suffer from CTS, or (c) are worried about CTS risk as it relates to typing and are willing to consider a keyboard alternative. Different attachments can be used in place of the dome (e.g., ball, flat board, or joystick). Other features of the AID-CTS keyboard include adjustable dome movement force and displacement, adjustable tilt and height, and complete self-containment for use in underwater or hostile environments. In addition, the AID-CTS keyboard is a perfect candidate for miniaturization and can be used by one or both hands.

As a chordal device, the AID-CTS keyboard typing methodology entails creating a keystroke via a combination of positions of the two domes. Each dome moves in a compass rose arrangement: N, S, E, W, NE, SE, NW, SW. The order in which the domes are moved to their respective locations does not matter, nor does the timing between the two domes. The lateral movements of each dome are the same for all characters. For example, moving the left-hand dome to its "north" position and the right-hand dome to its "north" position would result in typing of the letter "e."

Purpose of the Current Study

The purpose of the current, engineering/psychophysical study was to identify beneficial movement characteristics (i.e., combinations of force and displacement of the domes). In past prototypes of the AID-CTS keyboard (McAlindon & Lee, 1995; McAlindon, Stanney, & Silver, 1995), we had used an equivalent to the standard keyboard, that is 4 mm of displacement and 0.7 N of actuation force (cf. McAlindon & Jentsch, 1999). This allowed us to compare the AID-CTS prototypes to standard keyboards, but it did not mean that 4 mm/0.7 N were necessarily the most comfortable or most beneficial actuation force and displacement, respectively – a reasonable hypothesis given similar findings with traditional keyboards (Rempel, Serina, Klinenberg, & Martin, 1997).

As part of the study, participants were asked to identify differences in movement forces and displacements among a number of devices. They were also asked to give ratings of ease of use, comfort, and preference for the various combinations of force and displacement.

METHOD

Participants

Twenty-five volunteers were recruited from a local university research participant pool. Participants were screened for pain and/or discomfort in their arms/hands/wrists and for previous diagnoses of repetitive strain disorders/cumulative trauma disorders, such as carpal tunnel syndrome or tennis elbow. For the screening, the informed consent form and a detailed questionnaire developed with input from an orthopedic surgeon was used. Participants were reimbursed $5.00 for each begun 30 minutes of participation.

Materials

AID-CTS testing tools. Five commercially available joysticks were modified for the study. The joysticks had already built into them a variable force feature. The joysticks were modified to include a variable displacement characteristic and to accommodate the dome of the AID-CTS keyboard.

Testing points. The testing points, i.e., combinations of actuating forces and displacements, engendered in the joystick-derived AID-CTS test devices (TD) were:

1. Five actuating forces, ranging from 0 N (free movement) to 20 N, with the five testing points: 0 N, 5 N, 10 N, 15 N, 20 N.
2. Five actuating displacements, ranging in equal intervals from 2 mm to 10 mm.

Measures

The following measures were collected as part of the study:

Comfort ratings. User rating of comfort using the AID-CTS for each combination of AID-CTS actuating force and distance were collected (COMRATE). There were two ratings for each of the 25 combinations of actuating force and displacement (each combination was presented twice; once in the context of differing forces, then in the context of differing actuating displacements), resulting in 50 ratings overall.

Comfort rankings. User ranking of comfort using the AID-CTS for each combination of AID-CTS actuating force and displacements (COMRANK). These relative rankings were derived from a number of test series which kept either actuating force or distance constant and varied the other variable, respectively. Thus, each combination of force and distance was rated twice: First for a given force, ranked against the possible displacements, and secondly for a given displacement, ranked against the possible forces. This resulted in ten (5 force, 5 distance) series of rankings.

Rankings of force and displacement (psychophysical judgments). User rankings of the differences in force or distance (respectively) within a test series of TDs (FORRANK and DISRANK, respectively). Users were asked to rank the five devices in a series (which differed either by force while keeping distance constant or by displacement while keeping force constant) in the order of increasing force or increasing actuating displacement. This resulted in ten (5 force, 5 distance) series of rankings.

Procedure

After completing the necessary paperwork (including information, instruction, informed consent, instrumentation, and practice), the participants were presented with the first test series (i.e., either five different forces while keeping distance constant or five different distances while keeping force constant). The devices were lined up in a row in front of the participant in random order. First, the participant was allowed to feel the movements of the first device by executing a test pattern of letters. The participant was then asked to provide a "first feel" rating of the comfort level for that device, thereby providing COMRATE. The process was repeated for the remaining four devices.

After providing the comfort ratings, each participant was instructed to order the devices from left to right in order of increasing force or distance, as appropriate. The ranking order created by the participant was recorded, providing either FORRANK or DISRANK, respectively. Then, the participant was asked to again use the devices for a brief moment, before he/she was asked to re-order the five devices in order of perceived comfort. The order created by the participant was recorded as COMRANK. After COMRANK was provided, the test series ended. Each participant was given a brief break, while the experimenter prepared the next test series.

Test series were conducted counterbalanced by either starting with force or distance and then completing the other related test series, before switching from forces to distances or vice versa, as appropriate. Further counterbalancing was conducted with respect to the order of forces (or distances) within the test series.

After the first five test series were completed, the participants were given a ten-minute break. After all ten test series were completed, the participants were debriefed, received payment as appropriate and were released.

RESULTS

Comfort Ratings and Rankings

Initial summaries of the results for comfort ratings and rankings have been combined and are graphically represented in Figures 1 and 2. The average comfort ratings and rankings showed remarkably similar results: In each case, there was a clear preference towards a set of combinations of force and displacement at relatively light forces (F1 = 0N and F2 = 5N) and at the second-smallest displacement (D4 = 4mm of total actuating displacement). All other combinations of forces and displacements in the test series were given lower ratings and rankings, respectively.

Further, as indicated in Figures 1 and 2, force and displacement combinations garnered lower ratings the farther they were away from the optimum set of combinations (i.e., F1 or F2 and D4). In fact, the combination of the highest force (F5 = 20N) and the largest displacement (D1 = 10mm of total travel) was consistently rated the lowest. Finally, it can be noted that the differences between the most and least preferred combinations of force and displacement were large and almost spanned the entire scale in the case of the comfort ratings (approx. 2.2 vs. 7.7, respectively, on a scale from 1 to 10). This indicates that there were very large perceived differences between the most and least preferred combinations of force and displacement.

Perceptions of Differences in Force and Displacement

An initial look at the results from the psychophysical judgments suggests that participants were generally quite able to distinguish among the different actuation forces and actuation displacement used in the study. Furthermore, they were somewhat more accurate at judging displacements under high forces, and somewhat more accurate overall in judging different forces when keeping displacements constant as compared to judging differences in displacements while keeping forces constant.

DISCUSSION

The two main objectives of this study were to measure and analyze five different force feedback and displacement characteristics in using the AID-CTS keyboard. The most preferred combination of force and displacement were at the relatively light forces (0N and 5N) and at the second-smallest displacement (4mm). It was found that the differences between the most and least preferred combinations of force and displacement were large and almost spanned the entire scale in the case of the comfort ratings (approx. 2.2 vs. 7.7, respectively, on a scale from 1 to 10). This indicates that there were very large perceived differences between the most and least preferred combinations of force and displacement.

One of the most important considerations in developing an ergonomically designed keyboard relates to that of accommodating the user. Because the AID-CTS keyboard has as one of its major design characteristics a capability for force and displacement adjustment, the user can adjust the AID-CTS to fit the user's particular needs. The ramifications of these results are far reaching. The research can be extended to those with different upper extremity disability (e.g., arthritis, paralysis, and neuromuscular control problems, children specific needs), and to those of special application (e.g., wearing gloves). Dome size and shape may also have a bearing on the outcome of this type of study. Such analyses would only further our understanding of how the unique AID-CTS keyboard compares to that of the QWERTY standard layout in terms of acquisition of learning, overall typing speed, and comfort.

Author Notes

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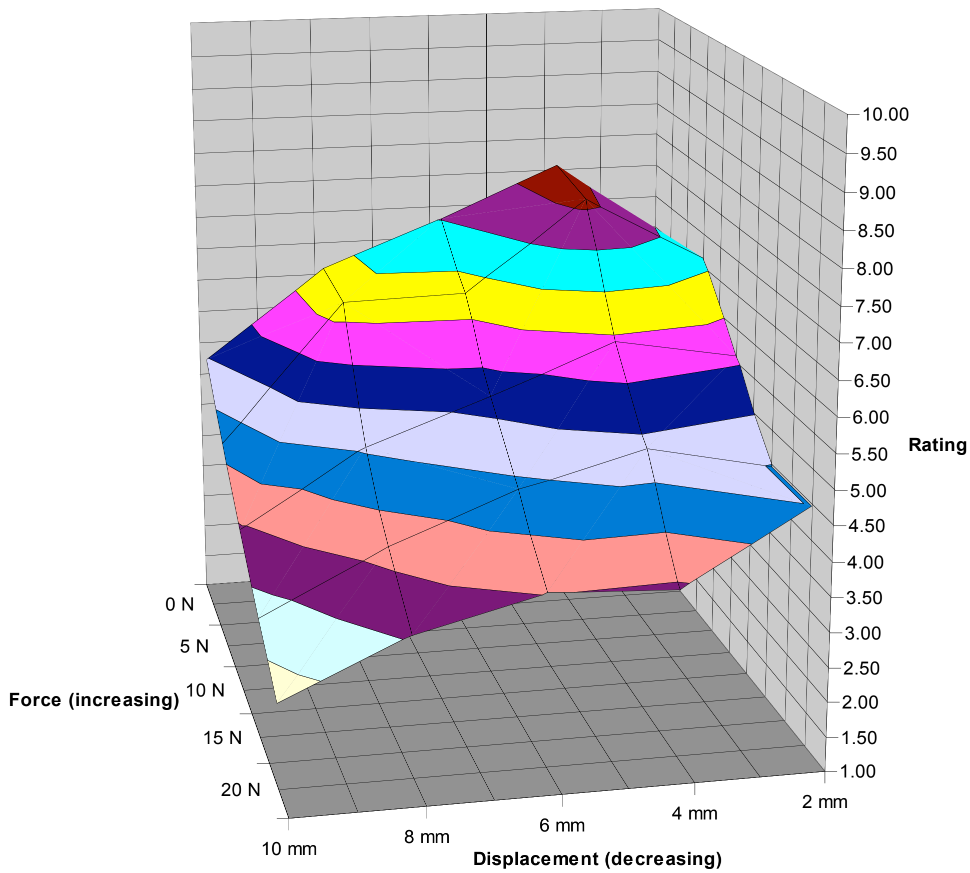

Figure 1. Average comfort ratings (10 = best, 1 = worst) of force and displacement combinations.

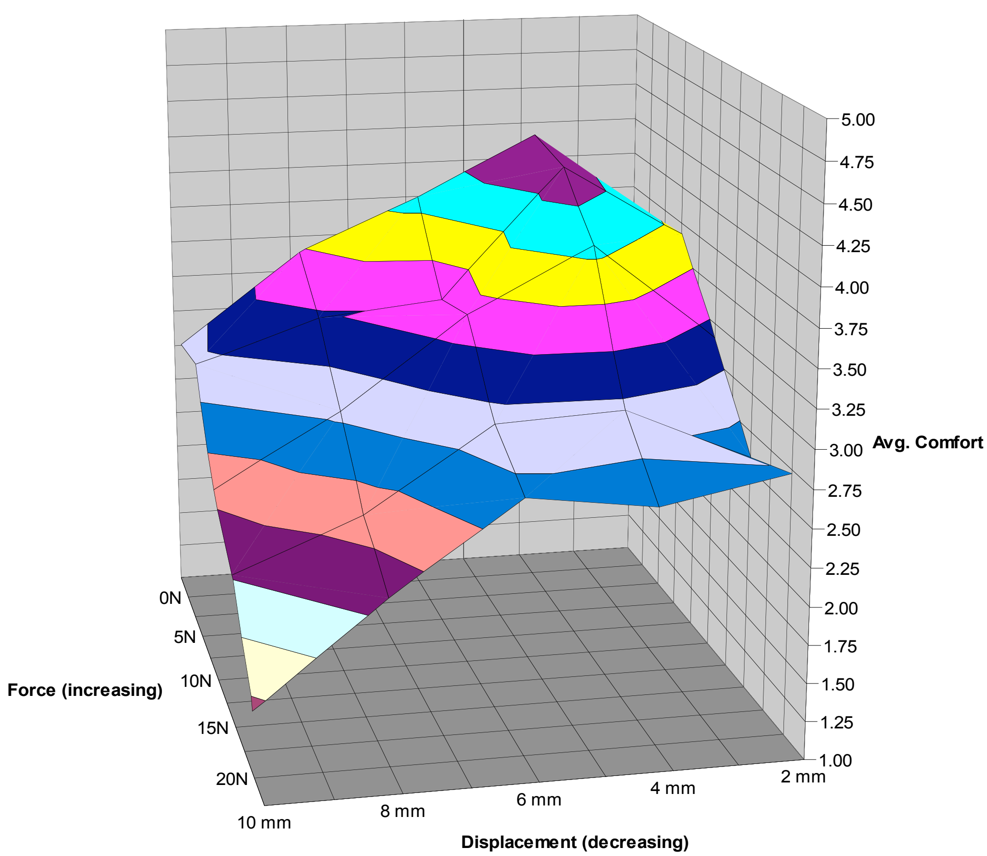

Figure 2. Average comfort rankings (5 = best, 1 = worst) of force and displacement combinations.