An Analysis of Motion in Typing with the Keybowl

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ABSTRACT

A new device called the Keybowl has been developed to curb the incidence of alleged cumulative trauma caused by typing. The Keybowl totally eliminates finger motion and drastically reduces wrist motion– two of the most critical factors in causing cumulative trauma as it relates to typing. However, with the lack of finger and wrist motion used to type using the Keybowl, issues related to biomechanics and performance arise. The first issue is related to the relocated of stress in using the Keybowl. The second relates to performance issues based on the relocation of the stress. This paper describes the different aspects of typing in the absence of finger motion and how it may affect typing performance. Numerous biomechanical and performance issues are examined.

Introduction

Several researchers have attempted to remedy the physically debilitating conditions, called repetitive strain injury (RSI) or cumulative trauma disorders (CTD), associated with using the QWERTY keyboard (Kroemer, K.H.E., 1972; Kroemer, K.H.E., 1992; Lu, H. & Aghazadeh, F., 1992). A dozen or so keyboard redesign attempts have been made to develop a solution to the multi-billion dollar a year problem of repetitive strain injury as it relates to typing (Hobday, S. W., 1988; Fathallah, F., 1988). No one keyboard, however, offers a comprehensive solution to curbing the injuries incurred from repetitive strain. Researchers have addressed several issues related to keyboard design; key arrangement, hand posture, arm posture, key force, key displacement, as well as several other related factors have been investigated in an attempt to eliminate or significantly reduce the trauma caused to the human body (the wrist in particular) (Brunner, H., & Richardson, R. M., 1984; Butterbaugh, L. C., 1982;Nakaseko, M., Grandjean, E., Hunting, W., and Gierer, R., 1985; Norman, D. A. & Fisher, D., 1982; Shiratori, Y. & Obashi, F., 1986). Despite this comprehensive body of knowledge the problem still persists. The elimination of wrist deviation and slight outward rotation of the hand, which are prevalent in almost every newly designed keyboard, address only part of the problem. An equally important, and often overlooked, issue is eliminating or drastically reducing finger movement.

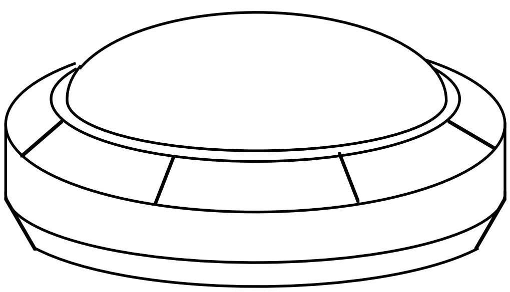
The research described herein is the first in an attempt to provide a more in-depth analysis and evaluation of motion factors that influence typing performance to better understand the capabilities of the human, the keyboard, the typing task, and the way in which they interact. Its purpose is to investigate the ergonomic and biomechanical performances in using a newly designed alphanumeric keyboard called the Keybowl.

Keybowl Description

The Keybowl keyboard was developed to accommodate any user (handicapped users in particular) and to make typing less physically traumatic. It was designed to eliminate finger movement and eliminate or substantially reduce wrist movement. The bowl design was chosen because it approximates closely the at rest posture of the hand, which reduces static muscle fatigue. Other features of the Keybowl include: adjustable bowl movement force and displacement, a built in mouse for complete hands on typing, and complete self containment for use in underwater or hostile environments.

The Keybowl keyboard uses concurrent independent inputs in which two inverted bowls are used to type alphanumeric characters. Concurrent inputs are commonly referred to as chording. Chord keyboards have been gaining greater acceptance as potential alternative devices to replace the standard QWERTY keyboard which is now considered the de-facto standard for alphanumeric input (for more on the QWERTY keyboard see Noyes, J., 1983).

The Keybowl (see Figure 1) is an alphanumeric input system using a pair of devices, each comprised of an inverted bowl upon which the hands comfortably rest, flexibly coupled to a base. The Keybowl is designed to replace the traditional alphanumeric keyboard and mouse. The fully functioning model of the Keybowl has a 64 character capability (an 8 by 8 design) and has been developed to accommodate all the alphanumeric, special characters, as well as several function keys. Both hands are required to type characters, one hand per bowl. A bowl capable of movement in eight directions (note: it may be helpful to think of its movement in a compass rose arrangement: N, S, E, W, NE, SE, NW, SW) is used to activate the different concentric character rings on the other bowl (see Figure 2). The character rings contain eight characters each defined by a discrete movement of the bowl. Each bowl moves into the same 8 compass rose directions. The eight position bowl used for typing the characters will be used by the users dominant hand.


(a)

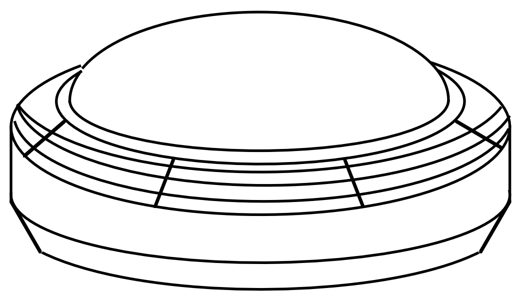

(b)

Figure 1: The Keybowl (profile view)

The Keybowl typing methodology entails creating a keystroke via a combination of positions of the two bowls. For instance, referring to Figure 2, moving the left-hand bowl to the "hatched" position enables access to the "hatched concentric circle" of the right-hand bowl (here shown to contain the letters a, e, i, o, u, y, r, and t). Moving the 8 position bowl to the "gray" position would enable the left hand to access space, semicolon, b, c, k, p, w, and n. Once a position on the selector bowl is selected the characters on the character bowl can be typed by moving the right bowl into the character position that the user wishes to type. The lateral movements of bowl is the same for all characters (i.e., characters on the outer character rings require the same lateral displacement as those on the inner ones).

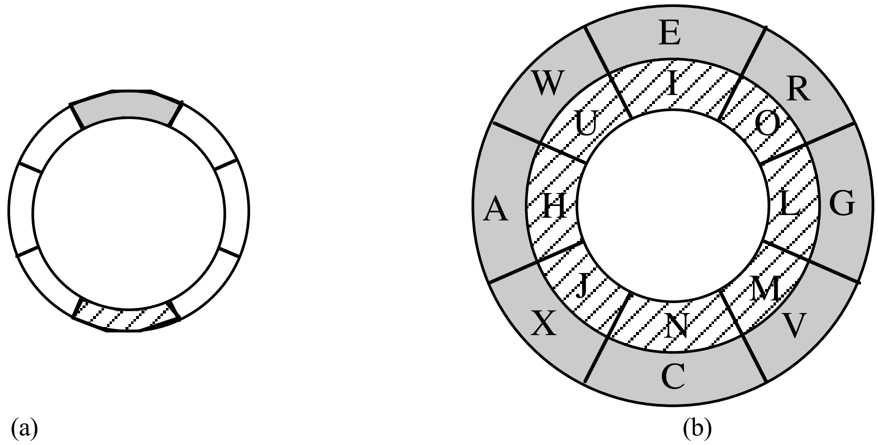


Figure 2: Top view of (a) Selector Keybowl (b) Character Keybowl: An example key chording activation scheme. (Note: six more selector positions on the Selector Keybowl exist and six more concentric circles need to be added to the Character Keybowl to allow for 64 'keys'.)

Motor skill requirements are also of great interest. A finger tapping motor skill (QWERTY) versus a lateral hand motion skill (Keybowl) is the essence of the difference in typing with the two keyboards. No applicable research has been uncovered in reference to a lateral hand motion vs. a perpendicular to key finger movement. One of the goals of the study was to identify and quantify such movements.

Method

An experimental comparison of the Keybowl keyboard to the QWERTY keyboard was conducted to evaluate the Keybowl as a viable alternative to typing. It investigated how the two groups of 15 subjects compared in typing speed and accuracy and how ergonomic performances, in terms wrist movements, compared on the Keybowl and QWERTY keyboards.

Performance data on the number of characters typed, number of errors, and times between key presses was recorded for each of 16 sessions. A reduced set of characters was used because of time and monetary constraints; the set was comprised of the 16 most common letters of the English alphabet. Also during each session, left and right hand wrist deviation data (flexion & extension and ulnar & radial deviation) was collected by way of electrogoniometers.

Performance Considerations

The 15 Keybowl subjects had memorized the locations of all 16 characters in the first 4 sessions of testing (1 hour 15 minutes). The subjects averaged 24 WPM (16-40 WPM range) after using the Keybowl for 5 hours. QWERTY typing speeds for the Keybowl group averaged 40 WPM in a one minute typing test. In comparison, the subjects in the QWERTY keyboard group typed an average of 46 WPM in the study and an average of 42 WPM in the one minute typing test. The disparity between the study's typing rate and timed test rate can be attributed to having the subjects type using the full character set after typing 16 sessions of 16 characters.

The performance data indicate that relearning the type with the Keybowl can be done fairly quickly. After five hours of using the Keybowl, 52% of QWERTY keyboard typing speed was realized. In addition, learning curve analysis was used to gain insight as to how long it make take a proficient typist to gain 60 wpm QWERTY speeds on the Keybowl. Learning rates were calculated using a log linear model proposed by Hancock and Bayha (1982). The analysis consisted of doubling the output and computing the word per cycle increase. The analysis revealed that an average of approximately 140 hours was needed to reach 60 wpm in typing with the Keybowl. For the QWERTY group, 36 additional hours of training were needed to reach 60 wpm. The differential would therefore be equal to 140-36 or 104 hours of total training time to reach 60 wpm when typing with the Keybowl (for the given subject group). Longer term studies are needed to determine the exact variation of how performances differ over time.

Biomechanical Considerations

As mentioned earlier, ergonomic evaluation of the Keybowl and QWERTY keyboard was performed by measuring left and right hand wrist deviations using electrogoniometers. Goniometer data was recorded for each of the 16 sessions. The Keybowl user's wrist deviations averaged 3 degrees in the flexion and extension plane and 2 degrees in the ulnar and radial deviation plane. The keyboard user's wrist deviations averaged 15 degrees in the flexion and extension plane and 6 degrees in the ulnar and radial deviation plane. Based on these findings, the Keybowl has demonstrated an adeptness in providing a solution to curbing the common cumulative trauma aspects of typing. This was made possible through the elimination of finger motion and unique dome movement. By eliminating finger motion and drastically reducing wrist motion, the forces used by the upper extremity are theorized to be relocated from the fingers and wrist to the forearm and shoulder with the latter being the most used in typing with the Keybowl. As such, the shoulder was studied biomechanically to determine its ability to perform Keybowl actuation.

The shoulder's range of motion and mobility do not appear to impede the arm's ability to effectively and efficiently type using the Keybowl. In typing with the Keybowl, motions are gross motions (compared to the motions associated with the fingers) which are expected to reduce performance when compared to fine motor skills of finger tapping (as is the case when typing with the QWERTY keyboard). It is a widely held belief that the more gross the motion the more it degrades performance. Similarly, as a task that requires a high level of manual dexterity, typing has traditionally been viewed as a highly coordinated motor task skill. In an attempt to disprove these widely held beliefs, the Keybowl was designed to convert the shoulders gross motor capabilities into the high dexterity motions needed to attain high typing speeds while at the same time offering greater ergonomic benefit. In order for this conversion to occur, the Keybowl was design to have an adjustable dome force and displacement characteristic. It is through these characteristics that the motor skills of the shoulder may offer performances equal to the highly dexterous finger motions. As an example, consider a Keybowl configured with a dome of lower force and displacement than that of the standard key on the QWERTY keyboard. It may be feasible for the arm with its reduced motor capabilities, comparatively speaking, to compete with the finer skills of the hand and fingers in terms of typing performance.

Studies on how the different characteristics of Keybowl force and displacement affect typing performance need to be performed. With the shoulders muscle structure and higher resistance to the effects of cumulative trauma (when compared to the wrist) the effects of Keybowl typing are expected to be fatiguing not traumatic. Further research, however, needs to be performed to qualify this claim.

References

Brunner, H., & Richardson, R. M. (1984). Effects of keyboard design and typing skill on user keyboard preferences and throughput performance. Proceedings of the Human Factors Society 28th Annual Meeting, Santa Monica, CA: Human Factors Society, 267-271.

Butterbaugh, L. C. (1982). Keying logic's for alphanumeric keyboards and human performance. Proceedings of the Human Factors Society 26th Annual Meeting, Santa Monica, CA: Human Factors Society, 634-638.

Fathallah, F. (1988). An experimental comparison of a ternary chord keyboard with the QWERTY keyboard. Unpublished masters thesis, Virginia Polytechnic Institute and State University, Blacksburg, VA.

Hobday, S. W. (1988). A keyboard to increase productivity and reduce postural stress. In F. Aghazadeh (Ed.), Trends in Ergonomics/Human Factors V. New York: North-Holland. 321-330.

Kroemer, K.H.E. (1972). Human engineering the keyboard. Human Factors, 14, 51-63.

Kroemer, K. H. E. (1992). Use and research issues of a new computer keyboard. Proceedings of the Human Factors Society 36th Annual Meeting, Santa Monica, CA: Human Factors Society, 272-275.

Lu, H. & Aghazadeh, F. (1992). Infogrip chordic keyboard evaluation. Proceedings of the Human Factors Society 36th Annual Meeting, Santa Monica, CA: Human Factors Society, 268-271.

Nakaseko, M., Grandjean, E., Hunting, W., and Gierer, R. (1985). Studies on ergonomically designed alphanumeric keyboards. Human Factors, 27(2), 175-187.

Norman, D. A. & Fisher, D. (1982). Why alphabetic keyboards are not easy to use: Keyboard layout doesn't much matter. Human Factors, 24(5), 509-519.

Noyes, J. (1983). The QWERTY keyboard: A review. International Journal of Man-Machine Studies, 18, 265-281.

Shiratori, Y. & Obashi, F. (1986). Optimum keyboard layout design and evaluation of its operation. Contemporary Ergonomics, Taylor and Francis, London, UK.