

# **An Alternative Keyboard for Typists with Carpal Tunnel Syndrome**

**Peter J. McAlindon**

McAlindon Enterprises, Inc.

**Florian G. Jentsch**

University of Central Florida

## **1 Introduction**

The de-facto standard QWERTY keyboard was developed over a hundred years ago and is one of the few visual display terminal (VDT) workstation components that has not made the same technological strides as the rest of the workstation components. It is this lack of advancement that has caused the QWERTY keyboard to become suspect in causing repetitive strain injuries (RSIs) such as carpal tunnel syndrome (CTS). Keyboard and mouse operations require unnatural physical positioning of the arms, hands, and fingers; in typical operations elbows are flexed and wrists are ulnarly deviated, pronated, and extended (Duncan & Ferguson, 1974). Such positions put operators at risk of developing cumulative trauma disorders (CTDs). CTDs are caused from continuous repetitive motions of the hand, wrist, and arm. In extreme cases, these compromising positions can cause severe wrist trauma such as CTS as well as muscle strains in the shoulders, neck, and arms of the typist.

The purpose of this study was to investigate the ergonomic, biomechanical, and typing performances of a newly designed alphanumeric keyboard called the Alphanumeric Input Device for those with Carpal Tunnel Syndrome (AID-CTS keyboard) – one of the first ergonomically designed keyboards that eliminates finger movement and drastically reduces wrist movement while maximizing typing comfort.

## **2 Method**

### **2.1 Participants**

Forty-four touch typists (40 females and 4 males) between the ages of 18 and 55 (mean = 28, s.d. = 9.9) fulfilled the initial requirements to participate in the research. Pre-experimental typing performances ranged from 32 to 88 GWPM (mean = 49.9, s.d. = 12). An orthopedic surgeon determined the degree of disability for each participant. Based on this classification, the participants were assigned to cohort groups with similar disabilities. Within each disability cohort group, participants were then separated into performance groups. They were then randomly assigned to the six experimental groups: Two groups used the QWERTY keyboard, two used the ergonomic split keyboard, and two used the new AID-CTS keyboard.

## 2.2 Keyboards

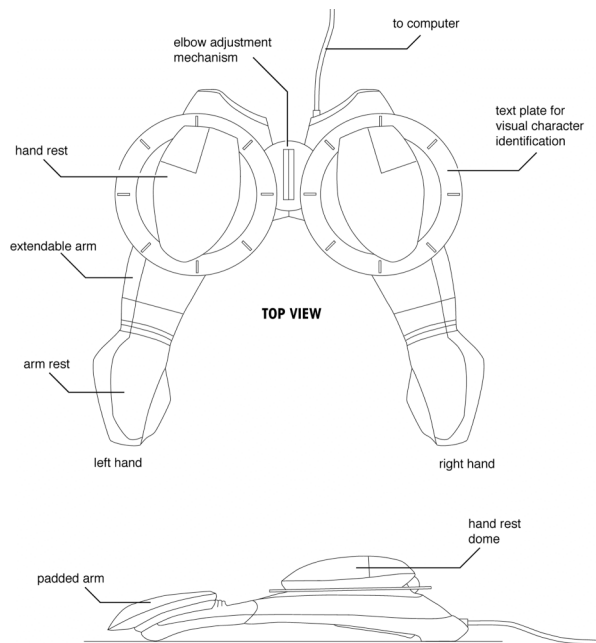
*QWERTY keyboard.* The de-facto alphanumeric input device—the QWERTY keyboard (see Current, 1954, for a complete history of the QWERTY keyboard) has a layout that consists of four parallel rows of keys that in sum comprise the 26 letters of the alphabet, 10 numeric keys, and several other specific symbol or function keys.

*Key contoured, split keyboard.* A number of efforts have been made to improve the ergonomic/biomechanical characteristics of the QWERTY keyboard, while maintaining its basic layout. The basic reason for splitting the keyboard is to eliminate ulnar wrist deviation, a suspect static position in the development of CTS. A number of these keyboards also allow the sections to be tilted outward to pronate the hand. The keyboard used in this study has a sculpted keying surface, separated alphanumeric keypads, thumb keypads, and closely placed function keys. This keyboard uses the QWERTY key layout.

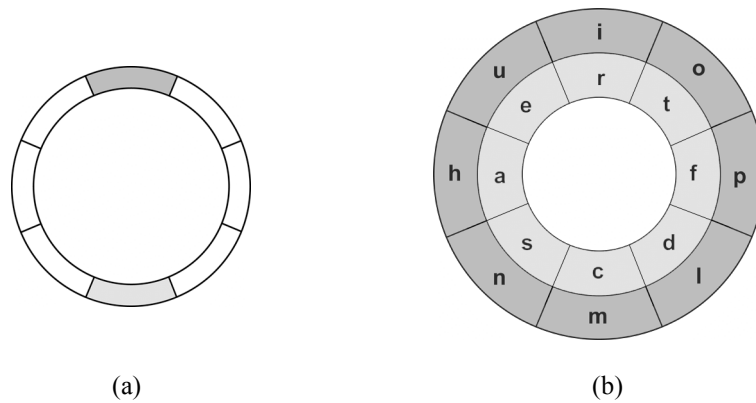
*New AID-CTS keyboard.* A new type of alphanumeric input based on the chording concept was designed to make typing less physically traumatic, increase typing efficiency, and facilitate typing task learning. The AID-CTS keyboard, as depicted in Figure 1, is an alphanumeric input system that uses a pair of devices each comprised of an inverted dome upon which the hands rest. Each dome is flexibly coupled to a base. The design alleviates many of the problems of key spacing, key size, and key force that are part of every traditional QWERTY type keyboard. 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 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 or flat board). 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. For example, referring to Figure 2, moving the selector dome to the "dark gray" position enables access to the "dark gray" concentric circle of the character dome (here shown to contain the letters i, o, p, l, m, n, h, and u). Moving the selector dome to the "light gray" position would enable the character dome to access r, t, f, d, c, s, a, and e. Once a position on the selector dome is selected, the characters on the character dome can be typed by moving the character dome into the direction of the character the user wishes to type. The lateral movements of each dome are the same for all characters (i.e., the characters on the outer character rings require the same lateral displacement as those on the inner ones).



**Figure 1:** The AID CTS keyboard for use by individuals with upper extremity disability (Model shown for illustration purposes only. Experimental models were simplified prototypes).



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

The AID-CTS keyboard design was kept as close to QWERTY specification to control for statistical confounding. In addition to force and displacement considerations, character size and font was the same for each keyboard for easy visual 'key' activation reference.

### **3 Results**

AID-CTS keyboard users' absolute flexion/extension wrist acceleration movements, when compared to QWERTY movements, were reduced by an average of 70% whereas absolute acceleration in the ulnar/radial plane were reduced by an average of 43%.

In regard to typing performance, results indicate that users of the AID-CTS keyboard typed an average of 30% of their regular QWERTY keyboard speed in as little as three hours. Split keyboard typists typed an average of 75% of their regular QWERTY keyboard speed.

Mental workload measures were significantly higher for the AID-CTS keyboard group for the first few sessions of testing due to adaptation to the AID-CTS keyboard method of typing. Otherwise, they were not significantly different between the groups.

In terms of subjective comfort in using the keyboards, the AID-CTS keyboard was found to have less wrist and finger fatigue when compared to the split keyboard and QWERTY keyboards. There were no significant differences between the split keyboard and the QWERTY keyboards with respect to fatigue.

Character error analysis revealed that the eight positions of dome movement were for the most part proportionally balanced. This finding indicates that of the eight positions, no one position was more difficult to actuate than any other position.

#### **3.1 Acquisition/learning curves**

The main effect of session was found to be statistically significant,  $F(8,54) = 3.91$ ,  $p < 0.0001$ . Gaining proficiency was much more pronounced in the split keyboard and AID-CTS groups, however. Figure 3 indicates a linear performance improvement for the AID-CTS typists with no apparent asymptote. This suggests that AID-CTS typists had not reached a performance plateau after nine sessions (or 3 hours of using the device). The split keyboard typists showed signs of leveling off at session 10 or after approximately two hours of using the device. The "learning curve" for QWERTY group was substantially flatter, with only slight improvements over the same 3-hour period.

### **4 Discussion**

The objective of this study was to determine how the AID-CTS keyboard compared to the traditional QWERTY keyboard and its "ergonomic" derivative, the split keyboard. The results of this study support the notion that the AID-CTS keyboard has the potential to become an effective alternative device. The results indicated a clear ergonomic advantage of the AID-CTS device when compared to keyboards using the traditional QWERTY key layout. In addition to completely eliminating finger movements, the AID-CTS device also led to a marked reduction in wrist motions. In the planes of flexion/extension and ulnar/radial motion, significantly less movement was recorded when using the AID-CTS device than when using traditional keyboards. Further, subjective perceptions of pain and discomfort in the hand/wrist/arm system were

significantly lower for participants who used the AID-CTS devices than for those who used keyboards based on the QWERTY layout. In fact, two participants (or about 12% of the group) who used the traditional QWERTY keyboards had to be excused from the study prematurely because their condition did no longer allow them to continue their participation. In contrast, no participant from the group using the AID-CTS devices showed similar deterioration that required termination of their participation. This suggests that while the use of the AID-CTS keyboard comes (at lease initially) at a performance price, it does offer promise for those who can not use QWERTY keyboards or must avoid wrist and finger movements.

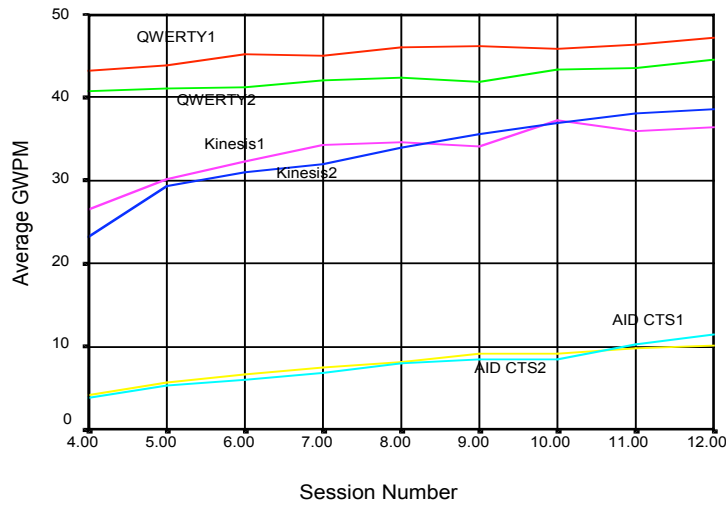


Figure 3. Average gross words per minute as a function of keyboard and session.

## 5 References

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