

EFFECTS OF A MULTITOUCH KEYBOARD ON WRIST POSTURE, COMFORT AND TYPING PERFORMANCE

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EFFECTS OF A MULTITOUCH KEYBOARD ON WRIST POSTURE, COMFORT AND TYPING PERFORMANCE

Presentation Outline

1. Background
2. Objectives and Hypotheses
3. Methods and Procedure
4. Results
5. Discussion and Research Implications

EFFECTS OF A MULTITOUCH KEYBOARD ON WRIST POSTURE, COMFORT AND TYPING PERFORMANCE

Introduction

Portability has become a prevalent trend of computer design.

Besides decreasing the physical thickness of computer keyboards, efforts have been made to eliminate key travel and the force needed to depress keys.

These forces have been associated with repetitive exertion, extreme wrist postures, and mechanical stress on soft tissue (Tittaronda et al., 1999).

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Key Design

- Key travel is intimately linked to key activation forces, which should range from 0.25 to 1.47 N and total key displacement should be 1-6 mm. However, these parameters, within certain limits, have little effect on experienced typists (Alden et al., 1972).
- By altering key geometry to reduce finger travel between keys, it can be hypothesized that movement time may decrease and user performance in terms of typing speed may increase
- The smallest movement times were found in the instances when the inter-key spacing was approximately the same as finger-pad size while movement time increased with a larger amount of keys moved (Hoffman, Tsang & Mu, 1995).

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Feedback

- Visual feedback helps typists self-detect errors and assists in the location of the home row while touch typing (Klemmer, 1971).
- Elastomer key action and tactile feedback at multiple points of each keystroke improved performance (Brunner and Richardson, 1984).
- Error rates reduced by increasing kinesthetic feedback by adding a 25-30-millisecond lockout to depressions on a membrane keypad (Pollard and Cooper, 1979).
- Addition of metal domes and embossed keys, and a 1000 Hz tone for auditory feedback to a membrane keyboard yielded the best performance and preference scores (Roe, Muto & Cooper, 1984).

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Keyboard Height

- In Burke et al. (1984), skilled typists used 8 eight low profile keyboards that were placed on platforms to simulate keyboard heights of 64 mm, 84 mm, and 104 mm. While performance did not really vary in terms of accuracy and speed, the subject preferred a keyboard height of 84mm.

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MSDs

- Awkward posture, force application and repetitive tasks are noted as the major risk factors contributing to the development of MSDs (NIOSH, 1997).
- Extension, or dorsiflexion, is the wrist deviation most commonly associated with the increased risk of injury (NIOSH, 1997).
- Repeated flexion and extension can cause the sheaths surrounding the flexor tendons can swell, constricting the carpal tunnel, which presses into the median nerve (Sanders & McCormick, 1997).

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MSDs

- Substantial research has indicated a higher incidence rate of MSDs of the upper extremities as computer use, combined with posture issues and repetitive motion, has increased (National Academy of Sciences, 2001).
- To decrease the incidence of risk, a neutral wrist angle of zero degrees of pronation, extension/flexion and radial/ulnar deviation is hypothesized to be the most favorable wrist posture (Zezevic, Miller & Harburn, 2000).

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MultiTouch

This surface uses a capacitive sensor array to create a keying environment that is extremely thin and can be re-arranged in many configurations (Westerman et al., 2001).

Typing is registered by single finger contacts with the surface.

Cursor positioning is detected as two finger contacts, and other gestural commands can control other computer functions by use of a combination of finger movements on the surface.

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Objective

To evaluate the technology of a MultiTouch keyboard in terms of performance and usability as compared to the conventional keyboard.

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Hypotheses:

1. Text-entry will be **faster** and **more accurate** for the MultiTouch keyless keyboard because it does not require key travel.

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Hypotheses:

1. Text-entry will be **faster** and **more accurate** for the MultiTouch keyless keyboard because it does not require key travel.
2. A flat, ultra low-profile MultiTouch keyboard design will **improve wrist posture** during typing, which can **reduce the risk of injury**.
3. There will be a **significant short-term learning effect** on the accuracy and speed of text-entry tasks on the MultiTouch keyless keyboard.

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Subjects

Pilot study conducted

12 subjects, 6 men and 6 women. All were compensated for participation.

Proficient touch typists (defined as being able to type 45 wpm)

Recruited from the Cornell University population (20-28 years old)

Tested independently in laboratory by the same experimenter

Required to come into the lab for 1.5 hours on 2 days (for a total of 3 hours), at the same time of day.

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Sitmatic Boss ergonomic chair

LINAK adjustable table

Dell 20" – 51 cm diameter computer monitor

Wrist goniometer (Greenleaf Medical) worn on right hand.

Each subject positioned himself or herself at the keyboard and sat at distance from monitor that was most comfortable.

Apparatus and Conditions



Methods and Procedure

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Apparatus and Conditions

Conventional Keyboard (CK)

Dell AT101W Keyboard

Keyswitch make force 0.60-0.82 N

7° slope from front of the keyboard to the back (measured from numberpad)



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Apparatus and Conditions

MultiTouch Keyboard (MTK)

Fingerworks Ultra (prototype)

Keyswitch make force 0 N

0° slope from front of the keyboard to the back



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Tasks

Performed eight 7.5 minute typing tasks on each visit.

Typing tasks consisted of 500-word passages excerpted from general interest magazine articles. Selected for similarity in length and Flesch-Kincaid Grade Level Score of 12.

Subjects typed for entire 7.5 minute duration. Timed by experimenter using stop-watch, which was started as first letter was typed.

Typing software (Typing Quick and Easy 13.0) used to present text passages.

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Questionnaires

Fatigue questionnaire given before and after each typing task

Subjects marked on a 4-point Likert-type scale their feelings of discomfort for:

right hand, right wrist, right forearm, right upper arm, right shoulder, left hand, left wrist, left forearm, left upper arm, left

shoulder, neck, upper back, and lower back.

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Questionnaires

Post-trial questionnaire administered after the last task of the 2nd day of testing.

On a 10 point scale, subjects asked to describe their enjoyment and comfort with each of the keyboards.

Frequency of use of different computing devices, as well as split and conventional keyboards was collected.

Time of day (TOD) preference questionnaire based on Horne and Ostberg's (1976) Morningness and Eveningness assessment was included.

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Procedure

Repeated measures design, with subject participating in both conditions (CK and MTK).

Experiment took place in same lab at the same time of day over 2 days.

Condition order and typing task order were counter-balanced and randomly-assigned to the subjects.

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Procedure

Subject entered lab and adjusted chair and table to his or her own comfort. Table height was recorded and set to same height for second day of testing.

Completed fatigue questionnaire.

Subject donned wrist goniometer on the right arm, which was then calibrated.

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Procedure

Subjects were instructed on the typing tasks and the use of the keyboards.

A 5-minute practice typing task was given.

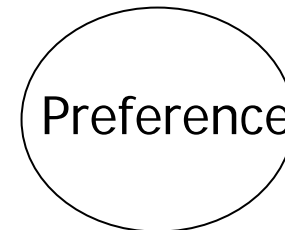
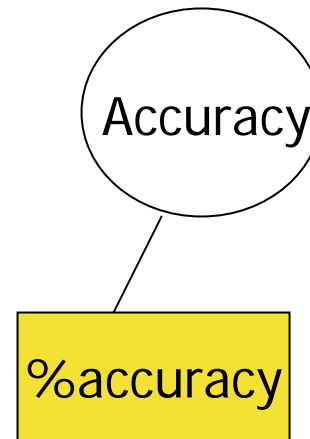
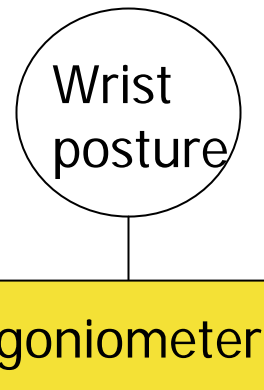
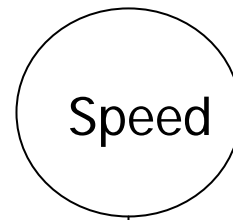
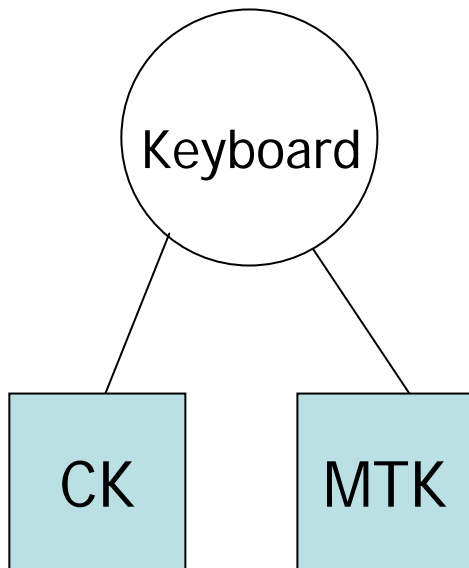
Subjects participated in 8 experimental typing tasks.
Fatigue questionnaire administered between each task.

After the last task on the 2nd day of the experiment, post-trial questionnaire was given.

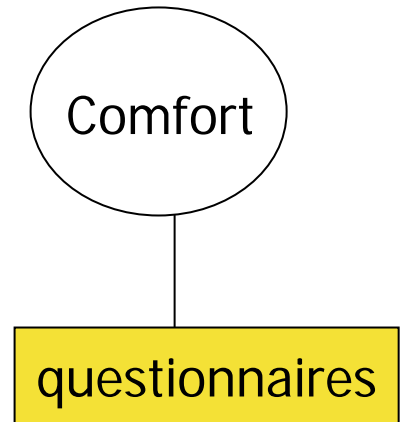
Subject was debriefed at end of the experiment.

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Independent Variable



Data Analysis



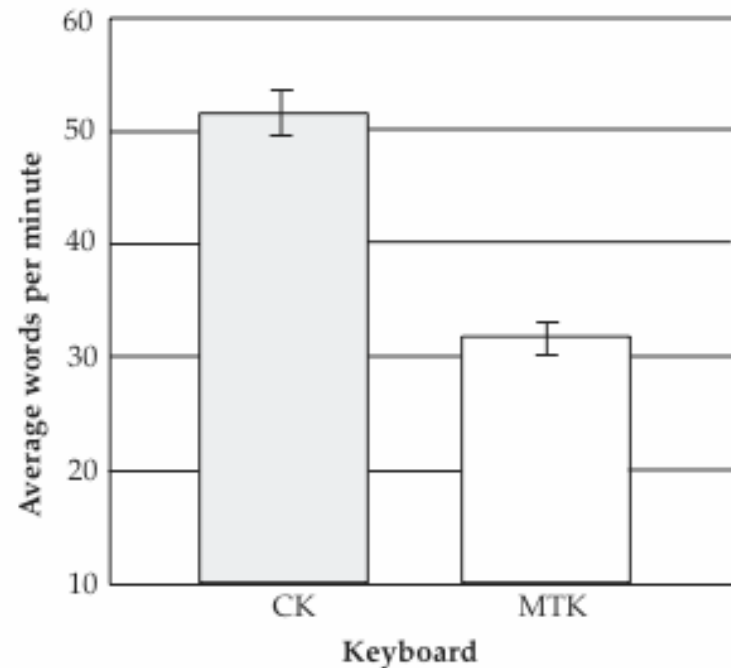
Dependent Variables

Methods and Procedure

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Typing Speed

There was an effect of keyboard on the average words per minute typed during the tasks ($F_{1,11} = 41.86, p=0.000$)

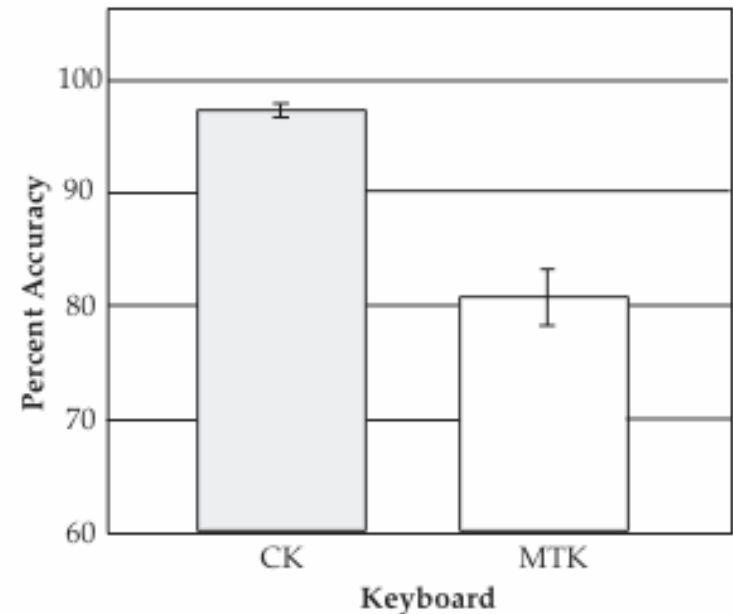


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The keyboard type had an effect on subjects' accuracy during the typing tasks ($F_{1,11} = 23.55$, $p=0.001$).

There was a marginally significant interaction between gender and keyboard type ($F_{1,10} = 4.80$, $p=0.053$).

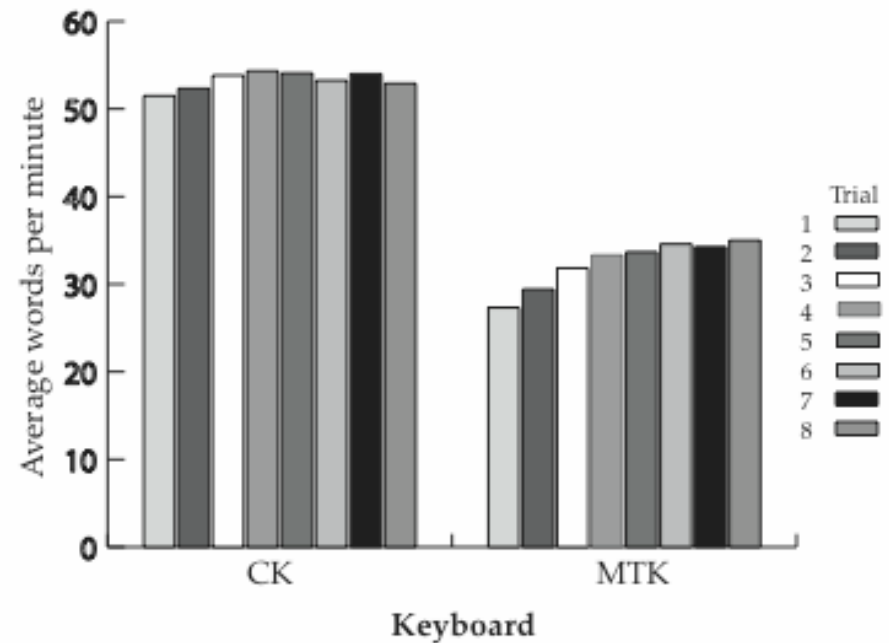
Percent Accuracy



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Learning Effects

Tests of within-subject contrasts of the subjects' average words per minute typed showed a significant linear pattern with the interaction between keyboard and trial ($F_{1,11} = 9.308$, $p=0.011$).

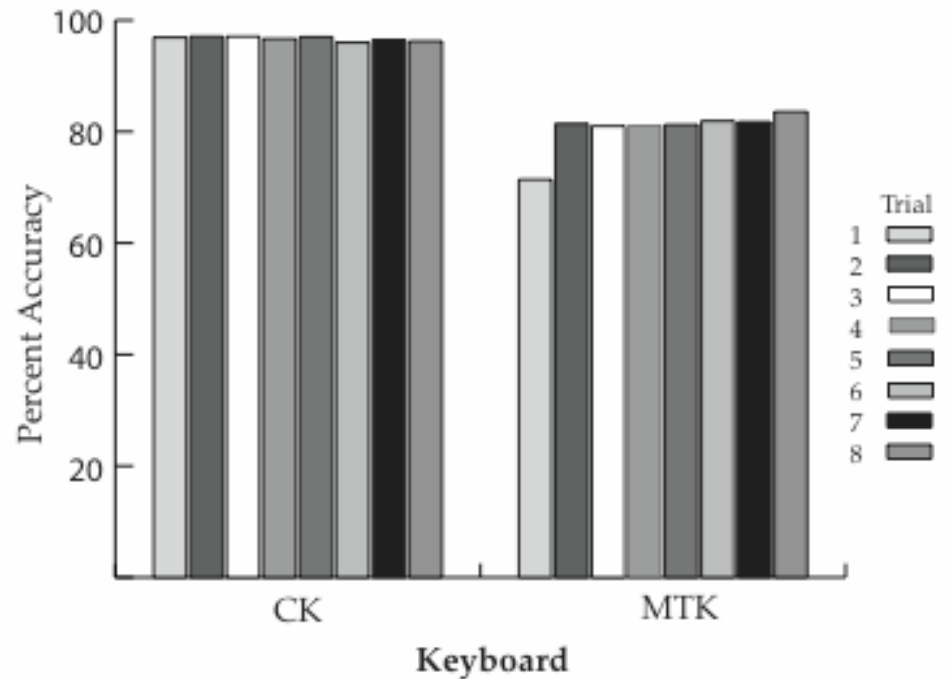


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Learning Effects

Accuracy scores also revealed a significant linear pattern in the interaction between keyboard and trial

($F_{1,11} = 11.903, p = 0.005$).

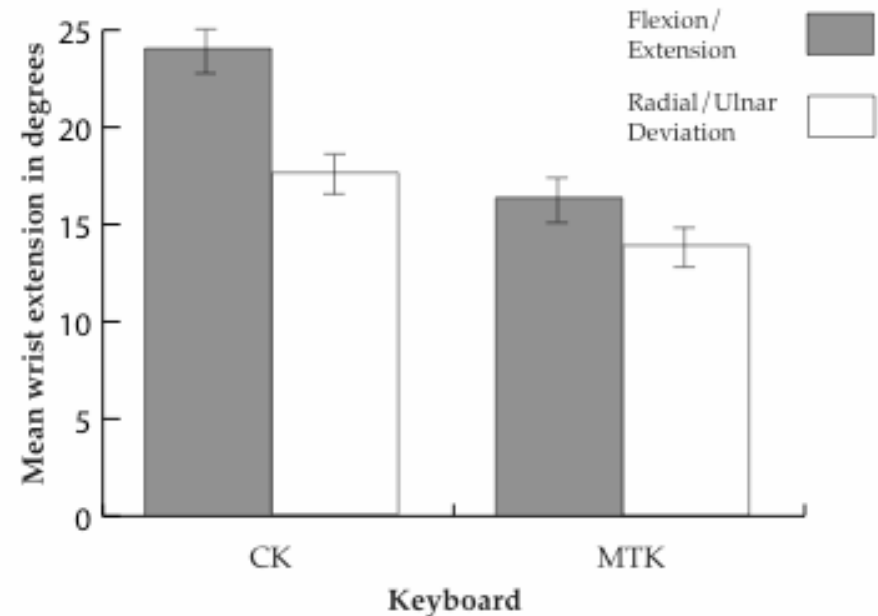


Results

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There was an effect of keyboard on flexion and extension ($F_{1,11} = 10.205$, $p = 0.000$).

Wrist Extension

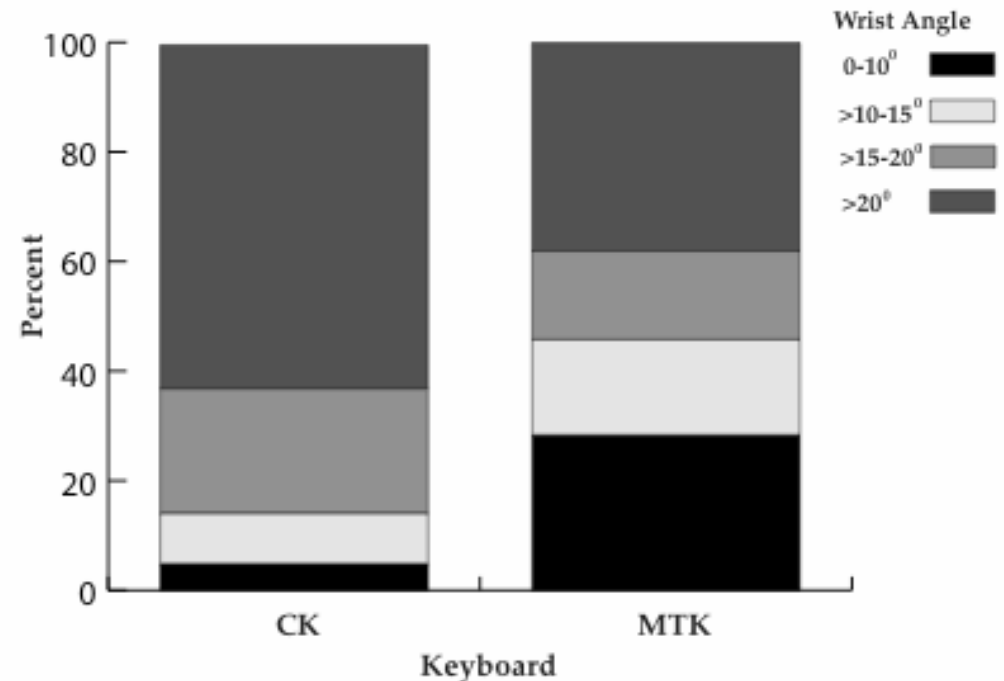


Results

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Wrist Extension: Flexion/Extension

There was an effect of keyboard on the percentage of flexion and extension angles in the 0 to 10 degree range ($F_{1,11} = 12.947$, $p=0.004$).

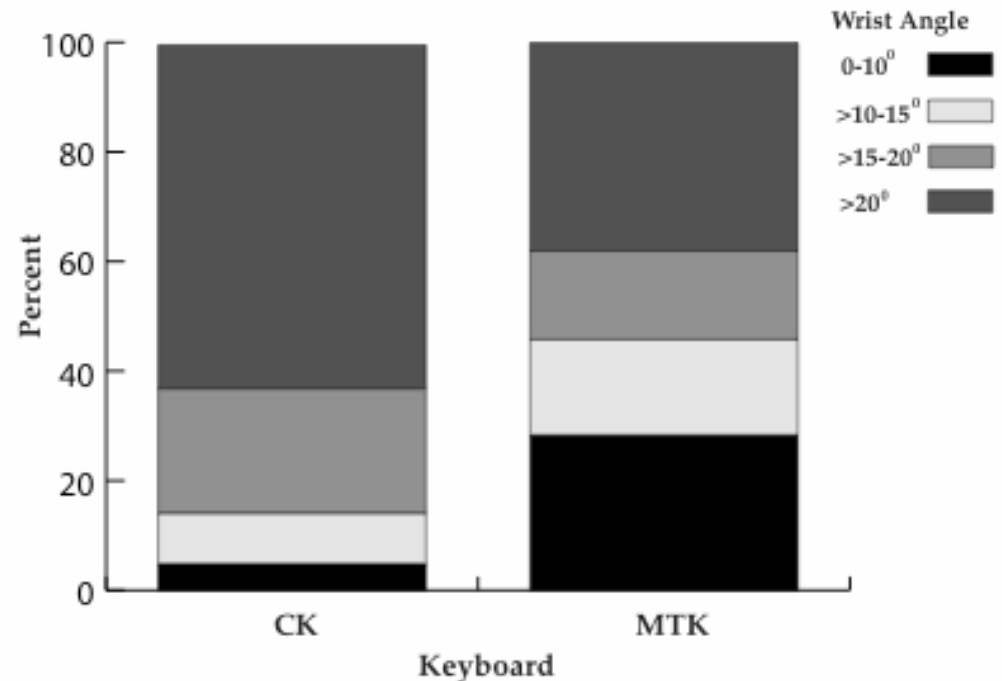


Results

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Wrist Extension: Flexion/Extension

There was an almost significant effect of keyboard on the percentage of flexion and extension angles in the 10 to 15 degree range ($F_{1,11} = 3.933$, $p=0.073$).

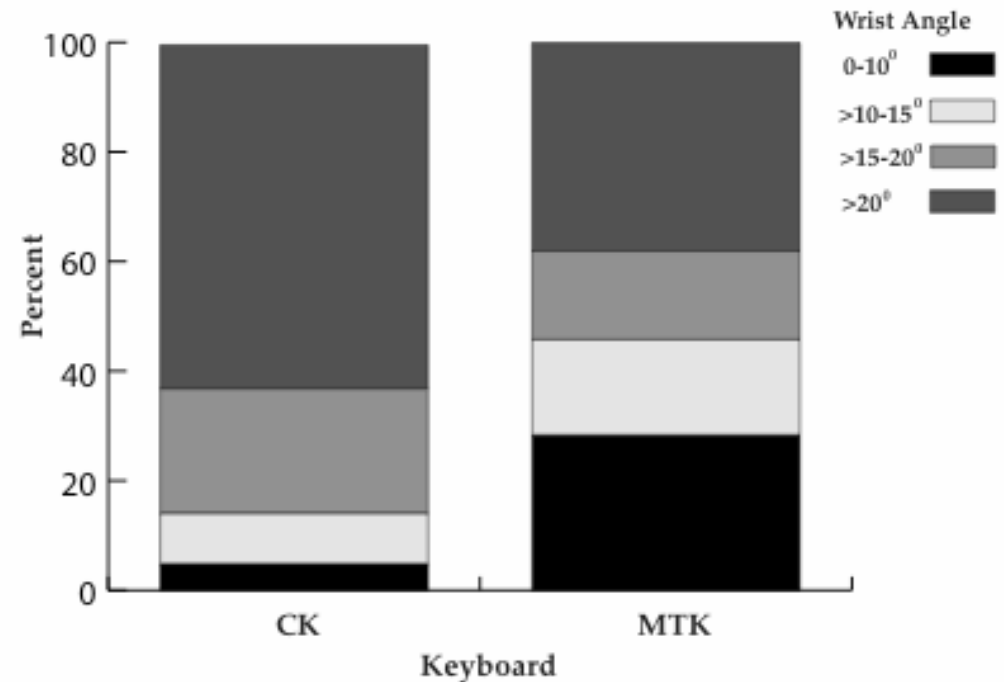


Results

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Wrist Extension: Flexion/Extension

There was an effect of keyboard on the percentage of flexion and extension angles in the **above 20** degree range ($F_{1,11} = 6.437$, $p=0.028$).

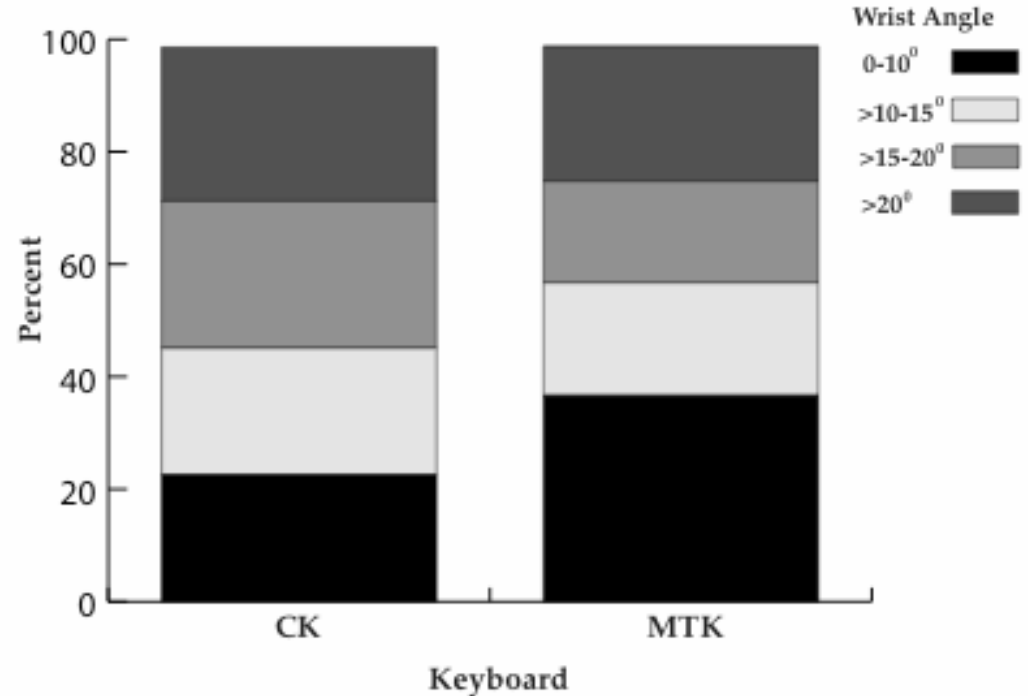


Results

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Wrist Extension: Radial/Ulnar Deviation

Keyboard type did not affect the percentage of radial and ulnar deviation for the four zones of radial and ulnar deviation.

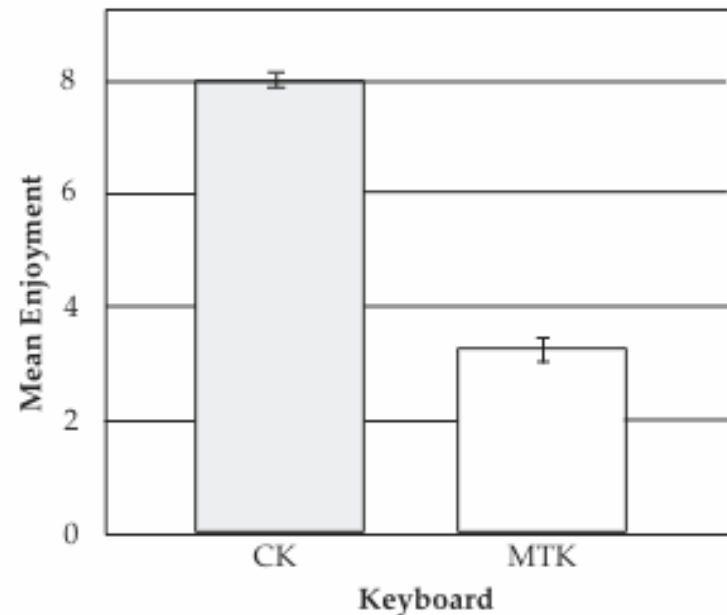


Results

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Enjoyment

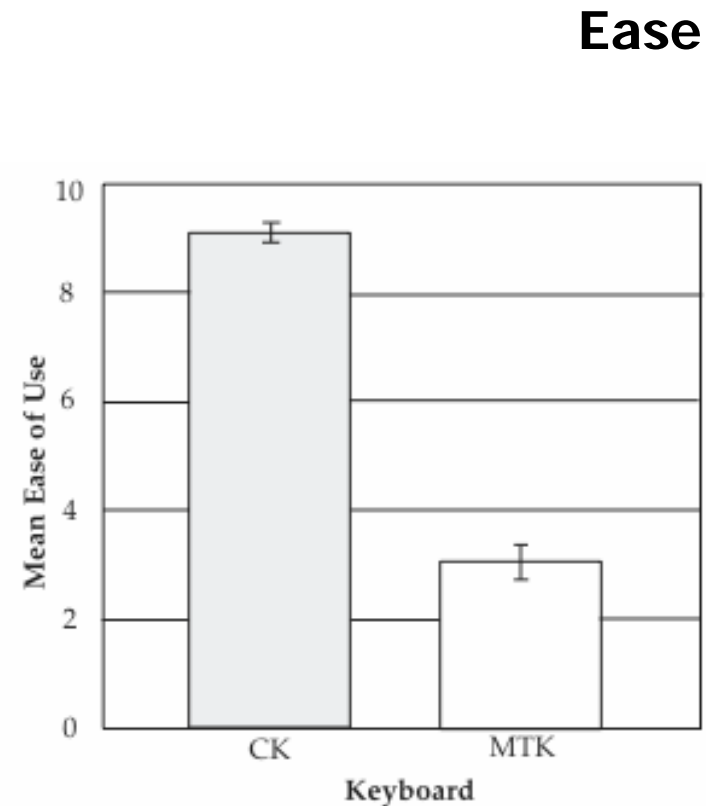
Subjects expressed more enjoyment using the conventional keyboard rather than the MTK for the typing tasks ($F_{1,11} = 51.120$, $p = 0.000$).



Results

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Subjects reported that it was easier to use the conventional keyboard than the MTK to complete the typing tasks ($F_{1,11}=49.732, p=0.000$).



Results

EFFECTS OF A MULTITOUCH KEYBOARD ON WRIST POSTURE, COMFORT AND TYPING PERFORMANCE

Fatigue

There was no significant effect of keyboard on fatigue.

There was a significant effect of trial in fatigue levels for almost all body parts queried, suggesting a fatigue effect as subjects progressed through the typing tasks for each condition.

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- H1:** Text-entry will be **faster** and **more accurate** for the MultiTouch keyless keyboard because it does not require key travel.
- Text-entry using the MTK did not prove to be faster than text entry using the conventional keyboard.
 - May contradict the belief that key force and displacement may not have an effect on the throughput of experienced touch typists, such as the present subjects.
 - Difference in typing speeds may stem from other factors, such as learning, practice and feedback.

EFFECTS OF A MULTITOUCH KEYBOARD ON WRIST POSTURE, COMFORT AND TYPING PERFORMANCE

- H1:** Text-entry will be **faster** and **more accurate** for the MultiTouch keyless keyboard because it does not require key travel.
- Subjects were significantly more accurate on the typing tasks during the conventional keyboard condition, despite the presence of key travel.
 - Consistent with past research suggesting that light resistance, low-hysteresis linear-spring keyboards with less key travel are prone to inadvertent errors by typists (Brunner & Richardson, 1984).

EFFECTS OF A MULTITOUCH KEYBOARD ON WRIST POSTURE, COMFORT AND TYPING PERFORMANCE

- H1:** Text-entry will be **faster** and **more accurate** for the MultiTouch keyless keyboard because it does not require key travel.
- Software display that presented the typing task did offer visual cues of screen font color when a user mistake was made.
 - Subjects were told, however, that they should try not to correct their errors, which makes the relationship between visual feedback and error self-detection difficult to ascertain in this study.
 - It is possible the cognitive load of using a new device may have caused subjects to look down at the MTK during the keyless keyboard conditions.

EFFECTS OF A MULTITOUCH KEYBOARD ON WRIST POSTURE, COMFORT AND TYPING PERFORMANCE

- H1:** Text-entry will be **faster** and **more accurate** for the MultiTouch keyless keyboard because it does not require key travel.
- Subjects did not prefer the lack of auditory feedback on the MTK.
 - Unclear whether additional electronically generated feedback would produce as much of a performance benefit as the naturally occurring sounds of conventional keys being pressed (Pollard & Cooper, 1979).

EFFECTS OF A MULTITOUCH KEYBOARD ON WRIST POSTURE, COMFORT AND TYPING PERFORMANCE

- H1:** Text-entry will be **faster** and **more accurate** for the MultiTouch keyless keyboard because it does not require key travel.
- Subjects did not prefer the lack of kinesthetic feedback offered by the MTK.
 - Lack of feedback may have contributed to the lower speed and accuracy scores, a finding that would be consistent with Roe et al.'s (1984) research stating the performance benefits of pairing auditory and kinesthetic feedback.

EFFECTS OF A MULTITOUCH KEYBOARD ON WRIST POSTURE, COMFORT AND TYPING PERFORMANCE

- H2:** A flat, ultra low-profile MultiTouch keyboard design will **improve wrist posture** during typing, which can **reduce the risk of injury**.
- Mean wrist extension was significantly lower for the MTK, which suggests that the ultra low-profile design of the keyless keyboard may reduce wrist extension.
 - Flexion decreases in an almost linear pattern as keyboard slope increases (Woldstad & Jedriewski, 1993). The 0° degree slope of the MTK may have contributed to the difference in flexion between the keyboard conditions.

EFFECTS OF A MULTITOUCH KEYBOARD ON WRIST POSTURE, COMFORT AND TYPING PERFORMANCE

- H2:** A flat, ultra low-profile MultiTouch keyboard design will **improve wrist posture** during typing, which can **reduce the risk of injury**.
- Subjects during the MTK condition spent significantly less time in risky (above 15°) flexion and extension wrist postures, and conversely were more likely to have flexion and extension wrist postures in the safer zone of 0° to 15°.
 - The MTK may help to decrease the likelihood of MSDs by reducing the amount of time spent in awkward wrist postures while engaged in repetitive work, a guideline endorsed in previous research .

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H3: There will be a **significant short-term learning effect** on the accuracy and speed of text-entry tasks on the MultiTouch keyless keyboard.

- Linear trend consistent with MacKenzie and Zhang's (2001) investigation of a soft keyboard, where the familiar keyboard did not show improvement over trials but the unfamiliar input device resulted in more dramatic increases in performance.
- In a follow-up study using 7 of the 12 subjects from an original study about the MultiTouch surface as a gestural input, text-editing time decreased an average of 39.6% on the fourth time using MultiTouch during the second experiment (Shanis, 2002) .

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Limitations of Present Study

- Additional measures of dependent variables, such as EMG as an objective measure of user fatigue. Also, key force.
- Using a wrist goniometer to monitor wrist postures on the left-hand side of the body.
- Reluctance to adapt to a new technology. Resulting user frustration may have affected user perception (Alden et al., 1972)
- Prototype may have led to equipment error due to an unreliable driver and increased lag between key strike and feedback.

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Future Research and Design Directions

- Subjects' unfamiliarity with the MultiTouch surface of the MTK remains one of the most important factors in the interpretation of the results (Detwiler, 2001).
- Tradeoff between sensitivity and user frustration should be examined by the designers.
- Integration of typing and gestural commands for future study.

EFFECTS OF A MULTITOUCH KEYBOARD ON WRIST POSTURE, COMFORT AND TYPING PERFORMANCE

Future Research and Design Directions

- Material scalability and flexibility offers a wealth of design possibilities. Larger collaborative workspaces have been explored (Browne et al., 2001).
- Special user groups may benefit from the no-force aspects of the MultiTouch surface.