Effect of VDT Mouse Design on CTD Risk and User Skill

Summary Report

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List of Publications

Barr AE: Effect of VDT mouse design on task and musculoskeletal performance. Marconi Input Device Research Conference '96, January 4 - 7, 1996, Marshall, CA.

Barr AE: Effect of computer mouse design on risk factors for cumulative trauma disorder and on patterns of motor coordination of the forearm and wrist in skilled and novice users. Ph.D. Dissertation, Environmental Health Sciences Program, New York University, January, 1997.

Significant Findings

Mouse use, in general, is associated with activation of the forearm musculature at intensities sufficient to produce muscle fatigue over a period of a few hours. Therefore, mouse users are at risk for developing cumulative trauma disorders (CTDs) of the forearm and wrist with prolonged, daily mouse use.

Use of the common, forearm pronated (FP) mouse design is associated with the following biomechanical constraints and CTD risk factors: 1) mean forearm pronation from 65° beyond neutral to maximum pronation (90°); 2) mean wrist ulnar deviation from 15° to 24°; 3) use of wrist radial-ulnar deviation for device operation with the intermittent occurrence of maximum ulnar deviation angles; and 4) continuous activation of the pronator quadratus (PQ), the pronator teres (PT), the extensor carpi ulnaris (ECU), the extensors carpi radialis longus and brevis (ECR), and the extensor digitorum communis (EDC) at intensities between 8% maximum voluntary contraction (MVC) and 35% MVC at least 40% of the time.

The newly designed, forearm neutral (FN) mouse effectively reduced several of these constraints and risk factors. Forearm pronation was reduced by 50° ($p < 0.001$), and the mean forearm pronation angle of 40° beyond neutral observed by the end of the study has been shown by others to minimize carpal tunnel pressure. Mean wrist ulnar deviation was reduced to approximately neutral ($p < 0.001$), and range of radial-ulnar deviation motion decreased such that intermittent joint angles oscillated $\pm$ 5° about the neutral position. Activation intensities tended toward a lower amplitude for the PQ and the ECU such that the majority of the time these muscles were active at 15% MVC or lower. Findings for the PT were modestly suggestive of a decrease in either activation intensity or in the proportion of time spent at a given activation intensity. The range of wrist flexion-extension motion increased during operation of the FN mouse, thereby transferring the movements required for its operation to the mid-range of the available total range of motion.

The FN mouse design did not reduce mean wrist extension and it appeared to increase ECR activation at higher intensity levels, but both mouse designs were associated with mean wrist extension angles that have been shown by others to minimize carpal tunnel pressure and to reduce cumulative finger flexor tendon travel as compared to more flexed wrist positions. In addition, a mean posture of wrist extension would reduce the electromechanical delay between finger flexor activation and function key depression through passive means, so mouse operators make favorable functional use of wrist extension to improve speed of performance. Both mean wrist extension for both designs and ECR activation intensity for the FN mouse design tended to decrease over

test sessions, which suggest that users became less dependent on the passive postural strategy as skill proficiency improved.

The EDC appears to function as a finger extensor at relatively high activity intensities more than 60% of the time during operation of both mouse designs, but this activation is presumed to be intermittent and, therefore, not necessarily harmful.

The highest speed of performance was attained with the FP mouse design among both skilled and novice users ($p < 0.001$). However, ultimate skill proficiency had not been achieved by the end of the study period, so the extent to which this discrepancy would persist is unknown. Nevertheless, both electromechanical deficiencies of the FN mouse prototype and the restriction of wrist ulnar deviation by the FN mouse housing probably contributed to the limitation of speed of performance as compared to the FP mouse condition.

Novice users demonstrated a similar rate of improvement in speed of performance with both mouse designs regardless of task type or level of difficulty. Therefore, despite the potentially greater complexity in operation of the FN mouse design, skill acquisition does not appear to be adversely affected.

Skilled users demonstrated a remarkable degree of skill transfer when operating the FN mouse design and exceeded the performance of novice users throughout the study period. This was also apparent in wrist flexion-extension and radial-ulnar deviation movements, such that skilled users demonstrated a release in wrist joint degrees of freedom by the end of the study period, whereas novice users were still apparently freezing wrist joint degrees of freedom. Such behaviors are consistent with the Dynamical Systems Model of motor skill acquisition, which suggests that performers search the perceptual-motor work space for effective, new movement strategies with which to solve a goal-oriented task.

Although the zero time lag cross correlation coefficients were not sensitive to improvement in skill proficiency, the wrist flexors and extensors and the wrist radial and ulnar deviators are well coordinated during operation of the FN and FP mouse designs, respectively.

Finally, the majority of both skilled and novice users indicated either a preference for the FN mouse design or no preference for either design in terms of physical comfort by the end of the study period. In terms of function, the FP design was clearly favored throughout the study. The major complaint was the relatively inferior fine positioning control of the FN design, which has already been partly explained by possible hardware limitations of the FN prototype. Future studies should eliminate these hardware discrepancies.

Usefulness of Findings

This study has demonstrated the presence of risk factors during FP mouse use that are associated with the development of forearm and wrist CTD. Modification of the mouse housing for the FN mouse design eliminated the postural and joint motion risk factors and reduced some of the muscular demands associated with the postural risks. Although the FN mouse design may be more difficult to operate initially, the design does not appear to impede the rate of skill acquisition, and there is no reason to predict that the FN design would curtail ultimate skill proficiency among skilled or novice users. This conclusion is based upon the observation that users operating an unfamiliar device show evidence for the use of search strategies with respect to wrist joint motions that

result in more effective movement patterns as is evident from the concomitant improvement in speed of performance.

With regard to further FN mouse design recommendations, of some concern is the intermittent movement of the wrist in the first 5° to 10° of radial deviation, which is within 5° of maximum radial deviation, and the apparent increased demands on the ECR. Although radial deviation would occur intermittently and some of the ECR activation can be attributed to intermittent radial deviation and wrist extension, there is no reason why the wrist should be strictly neutral with respect to radial-ulnar deviation. Therefore, an increase of 5° to 10° in the grip angle of the FN mouse design is proposed so that the mean wrist deviation angle would be offset from neutral to 5° or 10° of ulnar deviation, and movement would oscillate between neutral and 10° or 15° of ulnar deviation (i.e. in the mid-range of total radial-ulnar deviation range of motion). Not only would this reduce the occurrence of high wrist radial deviation angles and the demands on the ECR muscle, but it may improve performance by enabling computer mouse operators to use the combined wrist extension-ulnar deviation postural strategy to enhance finger flexor function.

This study showed that risk factors for forearm and wrist CTD are attributable to mouse operation *per se*. Mouse users may opt for increased risk to musculoskeletal structures to maximize performance, and the FN mouse design effectively reduced some of these risks primarily by limiting the amount of wrist ulnar deviation positions and movements. Thes findings are particularly relevant to the occupational setting, where mouse use may exceed several hours per day. The FN mouse design did not appear to reduce the acquisition of mouse operation skill, which further suggests that changes in mouse design aimed at reducing CTD risk do not impede worker productivity.

Relationship of Publications to Aims of the Project

All of the aims of the project are fully stated and addressed in the enclosed publications. The abstract presented at the Marconi Input Device Conference '96 represents pilot data, which is described in detail in Barr's doctoral dissertation. Ann Barr successfully defended her dissertation on December 9, 1996, thereby fulfilling all requirements for the degree of Doctor of Philosophy in the Environmental Health Sciences Program of New York University.