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Wrist posture during computer pointing device use

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Abstract

Objective: This research examines individual differences in the wrist postures adopted during the use of two pointing devices (mouse and trackball).

Design: A multiple case study of twelve participants was employed.

Background: The use of pointing devices may lead to musculoskeletal discomfort and injury as a consequence of prolonged exposure to postures involving wrist extension and ulnar deviation.

Methods: Wrist flexion/extension and radial/ulnar deviation was measured while twelve participants completed two standardised tasks involving horizontal and vertical cursor movements respectively.

Results: Exposure to extreme ulnar deviation and wrist extension was observed in the use of computer mouse and trackball. The trackball involved decreased ulnar deviation and increased wrist extension, however considerable individual differences were observed.

Conclusions: Some users may be placed at risk of injury by prolonged exposure to the use of such devices, while others may not. A trackball may reduce the exposure to extreme ulnar deviation, but in some cases, a trackball may increase exposure to extreme wrist extension.

Keywords: Pointing devices; Computer mice; Wrist; Musculoskeletal disorders

1. Introduction

A consequence of the move from command line modes of human–computer interaction to graphical user interfaces has been increasing the use of pointing devices, and particularly the computer mouse. It has been suggested that the use of such devices may lead to musculoskeletal discomfort and injury as a consequence of prolonged exposure to postures involving wrist extension and ulnar deviation [1]. Fogleman and Brogmus [2] examined compensation data from 1986 to 1993 and found that although computer mouse related claims represented a small proportion of claims for cumulative injuries to the upper extremities, the proportion increased rapidly over that period. A variety of alternate pointing devices (e.g., trackball) have been promoted as reducing the likelihood of injury, however no published evaluations are available regarding the wrist postures adopted to use different pointing devices.

Prolonged or repetitive exposure to postures involving deviation from neutral joint positions have been associated with development of musculoskeletal discomfort and injury [3]. Mackinnon and Novak [4] identified three potential mechanisms by which such postures might contribute to the development of musculoskeletal disorders: (i) increased pressure on nerves at entrapment points; (ii) increased neural tension; and (iii) use of muscles while shortened.

Wrist extension and ulnar deviation cause increased pressure on the median nerve by narrowing the carpal tunnel [4–6]. Increased neural tension in the median and radial nerves is caused by extension and ulnar deviation respectively, and both postures necessarily involve activation of forearm muscles while shortened. Postures involving wrist extension and ulnar deviation have been associated with discomfort and the development of musculoskeletal disorders [3,7–9].

In the same way as individual users differ in their anthropometry, individuals also differ in the manner in which tools such as computer pointing devices are used. This research is a preliminary investigation of wrist postures adopted during the use of the mouse, and an

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alternate pointing device (trackball) to perform two standardised tasks.

2. Method

2.1. Participants

Twelve right-handed university students (6 male, 6 female, age 19–31 years) participated in the experiment. All were familiar with the use of computer mice, but had no previous experience with other pointing devices.

2.2. Procedures

Wrist extension and ulnar deviation were measured while participants completed two standardised tasks with each of two pointing devices. The seat height, and location of the pointing devices was individually adjusted to ensure a standardised posture of the upper arm (vertical) and forearm (perpendicular to the upper arm and the sagittal plane). The positions of four infrared emitting diodes (IREDs) placed on the participants' right hands and forearms were measured in three-dimensions at 20 Hz via Optotrak (Northen Digital, CA, USA).

Three IREDs were placed on a rigid flat plastic marker rig taped to each participant's forearm. The marker rig was placed such that the first IRED lay at the midpoint of a line joining radial and ulnar heads, and the second marker was positioned 90 mm from the first on the middle of the dorsal surface of the forearm. The first IRED defined the origin of a local coordinate system embedded in the forearm. The second IRED defined the negative X axis of this coordinate system which coincided with the longitudinal axis of the forearm. The third IRED on the marker frame defined the XY axis (coordinates −45 mm, 12.5 mm). A fourth IRED was placed on the head of the third metacarpal. The Optotrak rigmarker and data analysis package software was used to compute the three-dimensional location of the fourth IRED (metacarpal III) in the local coordinate system of the forearm for each sample, and these coordinates were used to define the extension and ulnar deviation of the wrist.

Wrist posture was defined by expressing the three-dimensional location of metacarpal III in terms of the angular deviation from neutral in XY and XZ planes. Neutral wrist posture (zero flexion/extension and radial/ulnar deviation) was defined as when the third metacarpal was parallel to the long axis of the forearm [10]. Hence the neutral posture occurred when the Y and Z coordinates of the Metacarpal III IRED were zero. Extension and ulnar deviation were defined positive, and flexion and radial deviation were negative. Angular extension was calculated as the inverse sine of the Z coordinate of the Metacarpal III IRED divided by the absolute length of the position vector of the Metacarpal III IRED. Similarly the angular deviation of the wrist in the ulnar direction was calculated as the inverse sine of the Y coordinate of the Metacarpal III IRED divided by the absolute length of the position vector of the Metacarpal III IRED (in this case the result was multiplied by negative 1 to obtain the desired sign convention).

Two standardised tasks were performed involving either horizontal or vertical movements between 12 circular targets (8 mm diameter) drawn on alternate sides of the computer screen. The "vertical" trials required continuous alternate up and down vertical cursor movements to targets at the top and bottom of the screen, while the "horizontal" trials required continuous alternate left and right horizontal cursor movements to each of 10 targets at the left and right screen edges. A click of the pointing device was required at each target to leave a black dot (3 mm diameter) within the area defined by the target. Instructions to the participants emphasised both accuracy and speed. Two devices were used to perform both tasks, a Mouse (Apple Desktop Bus Mouse II) and a Trackball (Kensington Turbo Mouse). The sensitivity (speed) of both devices were set to default values.

Three practice trials were completed with each device in each trial direction. Blocks of six trials of each task were then performed, and data were collected from the first 10 seconds of the last three trials in each block.

2.3. Analysis

Wrist flexion/extension and radial/ulnar deviation data were recorded at 20 Hz for the first 10 seconds of three repetitions of each task for each pointing device. For each trial the maximum and average extension and ulnar deviation was recorded. Average values for horizontal and vertical trials were calculated for each participant, and the Mean and Standard Deviation for horizontal and vertical trials were then calculated using participant average data. Data from both horizontal and vertical trials were combined to calculate the effect size (d) associated with differences in device and trial direction [11].

Individual subject data were examined by constructing frequency distributions for extension and ulnar deviation using 5° bins for the 200 data points in each trial, summing these distributions across the three repetitions of each task, and expressing them as a percentage of trial duration.

3. Results and discussion

Figure 1 presents maximum and average wrist posture data broken down by trial direction and device, and

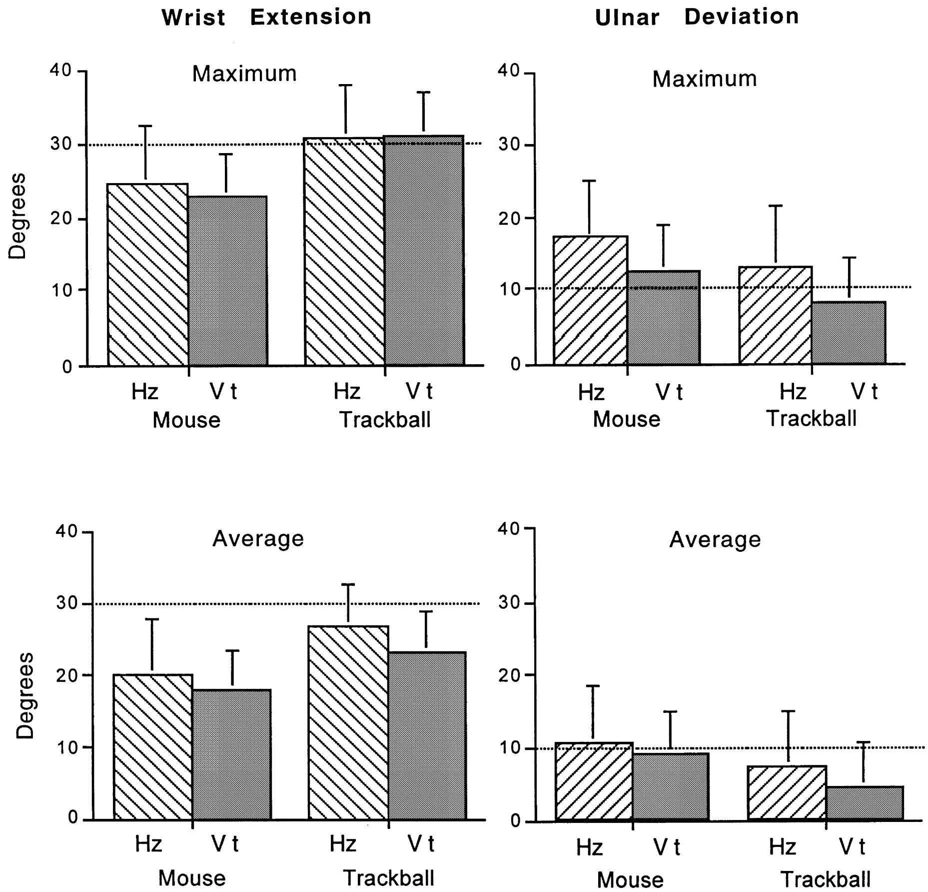

Fig. 1. Maximum and average wrist extension and ulnar deviation in horizontal (Hz) and vertical (Vt) trials performed with mouse and trackball. Error bars indicate between participant standard deviations. Dotted lines indicate extreme wrist extension (30°) and extreme ulnar deviation (10°).

Table 1
Effect sizes and summary statistics for the two-way ANOVA for maximum and average wrist extension and ulnar deviation as a function of device and cursor direction[a]

Dependent variable	Main effect of device			Main effect of direction			Interaction	
	d	*F*	*P*	*d*	*F*	*P*	*F*	*P*
Maximum wrist extension	1.0	20.2	<0.001	0.1	0.392	= 0.544	0.783	= 0.395
Maximum ulnar deviation	0.6	10.0	= 0.009	0.7	16.9	= 0.002	0.024	= 0.880
Average wrist extension	0.9	15.9	= 0.002	0.4	5.90	= 0.033	0.285	= 0.604
Average ulnar deviation	0.6	10.2	= 0.009	0.3	4.35	= 0.061	0.694	= 0.423

[a] Note: degrees of freedom for ANOVA = (1,11).

Table 1 contains effect sizes and summary statistics for the associated two-way ANOVA. Some exposure to extreme wrist extension and ulnar deviation was observed for both the mouse and trackball. The trackball increased wrist extension and decreased ulnar deviation, and this effect was consistent across trial direction. The average wrist posture adopted across horizontal and vertical trials performed with the mouse was 19.1° of extension from neutral (s.d. = 6.8°) and 10° of ulnar deviation (s.d. = 6.9°). The average wrist posture adopted to perform the same tasks using a trackball was 25.1° of extension (s.d. = 5.8°) and 6° of ulnar deviation (s.d. = 7°). The trackball induced an average increase in wrist extension of 6°, and a decrease on ulnar deviation of 4°. These results represent medium to large effect sizes ($d = 0.6$ to 1.0) and were statistically significant (Table 1). Horizontal trials involved greater maximum and average ulnar deviation, and also involved greater average wrist extension although, with the exception of maximum ulnar deviation, these effects were small ($d = 0.4$ or less). The effects of direction and device were independent (all interactions were not statistically significant).

On the basis of this analysis it might be concluded that mouse use typically involves considerable exposure to extreme ulnar deviation (defined as postures involving ulnar deviation greater than 10°) and some exposure to extreme wrist extension (defined as postures involving wrist extension greater than 30°). It might also be concluded that the trackball reduced exposure to postures involving extreme ulnar deviation, but that the benefit may be offset to some extent by an increase in exposure to postures involving extreme wrist extension. These are appropriate conclusions (given appropriate caveats), however considerable individual variability is evidenced by the magnitude of the error bars (standard deviations) included on Fig. 1. Additional insight can be gained by examining data from individual participants.

An examination of frequency distributions for each participant reveals that individuals differed in the wrist postures adopted, and the consequences of providing an alternate pointing device. As suggested by the nomothetic analysis, the majority of participants exhibited some exposure to extreme ulnar deviation during use of the mouse and, for most, this was reduced by use of the trackball. For example, Fig. 2 illustrates data from one participant (R) for whom this is an accurate description. Performance of horizontal cursor movements with the mouse was associated with extreme ulnar deviation, and

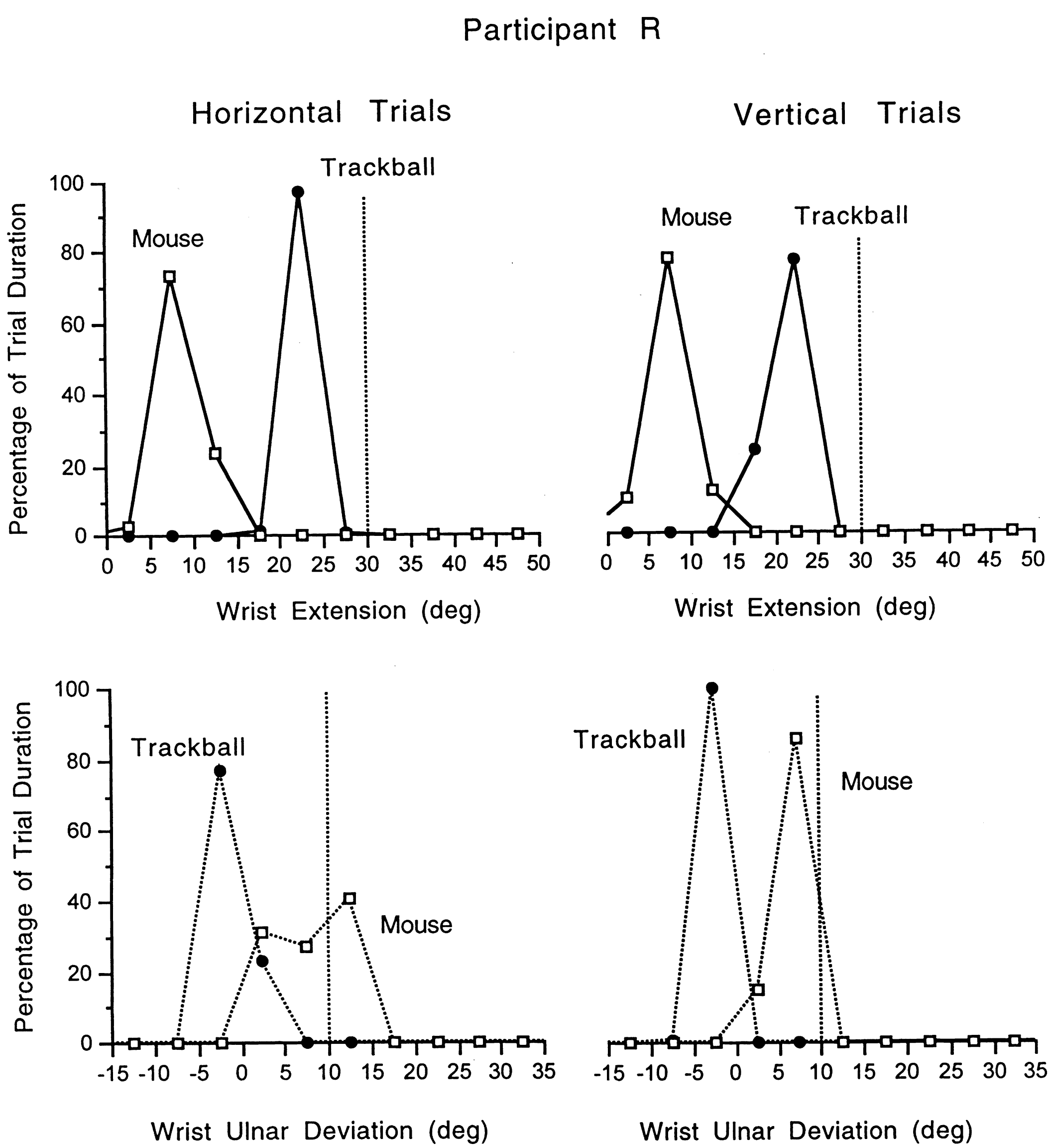

Fig. 2. Frequency distribution of wrist extension and ulnar deviation (average of three trials) for horizontal and vertical trials performed by participant R. Performance of horizontal cursor movements (but not vertical cursor movements) with the mouse was associated with extreme ulnar deviation. This exposure was reduced by the use of the trackball, and although wrist extension was increased, there was no exposure to extension greater than 30°. The use of the trackball might be beneficial for this participant.

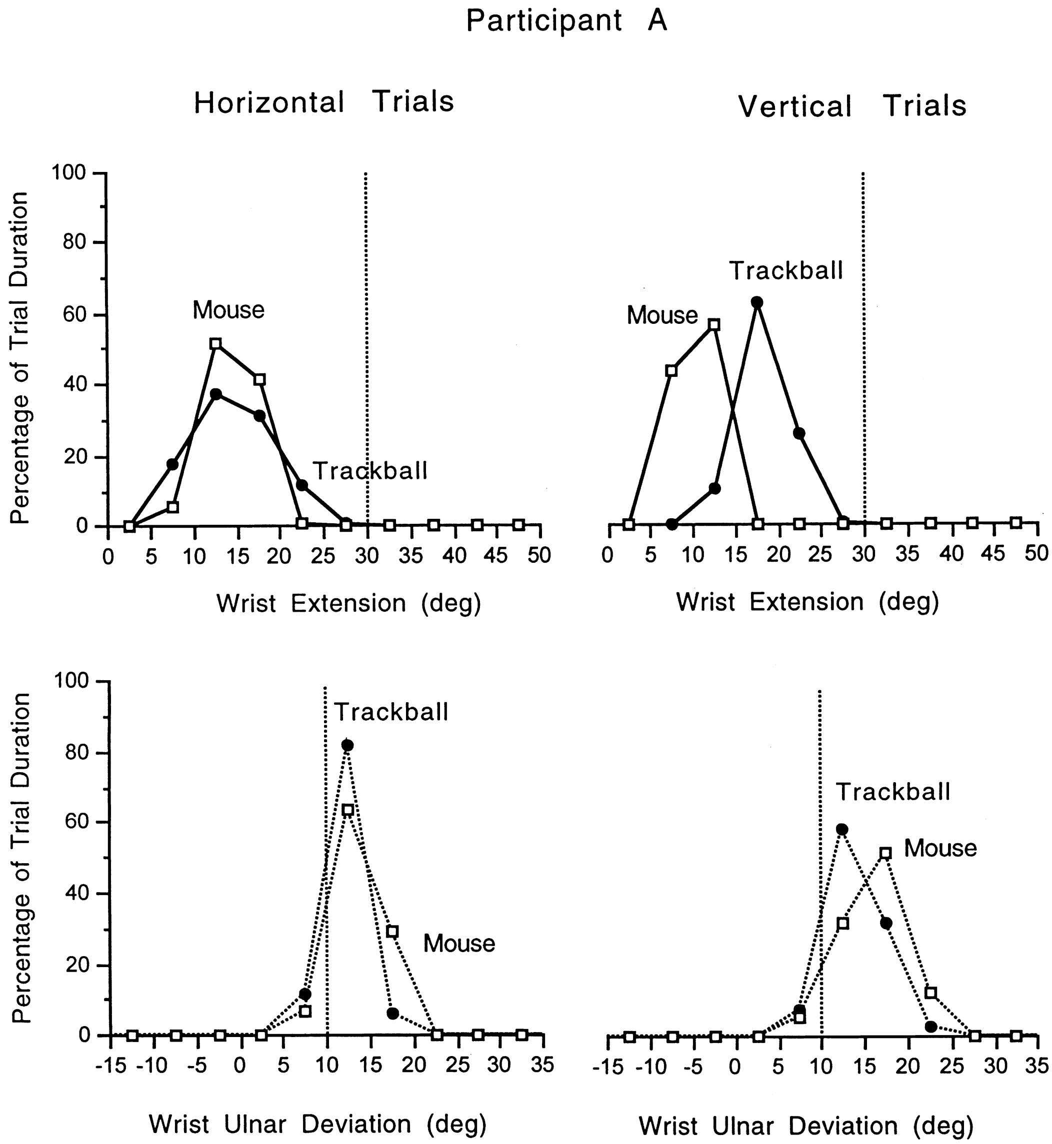

Fig. 3. Frequency distribution of wrist extension and ulnar deviation (average of three trials) for horizontal and vertical trials performed by participant A. Use of the mouse was associated with extreme ulnar deviation, however this exposure was not reduced when a trackball was provided. This participant may be at risk of injury, but the provision of a trackball may have little effect on wrist posture.

this exposure was reduced by the use of the trackball. Although wrist extension was increased, there was no exposure to extension greater than 30°, and the use of the trackball might be beneficial for this person.

This was not true for all participants however. Figure 3 illustrates data for another participant (A) In this case, use of the mouse was associated with extreme ulnar deviation, however this exposure was not reduced when a trackball was provided. This participant may be at risk of injury if mouse use is prolonged, but these data suggest that provision of a trackball may not be beneficial.

For other people, while decreasing ulnar deviation, the trackball may increase exposure to extreme wrist extension. The data presented in Fig. 4 illustrate a participant (N) for whom use of the mouse was associated with extreme ulnar deviation, and this exposure was reduced by the use of the trackball. However, exposure to wrist extension greater than 30° was increased with the trackball. While this participant may be at risk of injury if mouse use is excessive, and the trackball may reduce exposure to extreme ulnar deviation, the benefits may be offset by an increase in exposure to extreme wrist extension.

On the basis of this research it appears that considerable individual differences exist in the wrist postures adopted by users of computer pointing devices, even when performing standardised cursor movements. These data suggest that some users may be placed at risk of injury by prolonged exposure to the use of such devices,

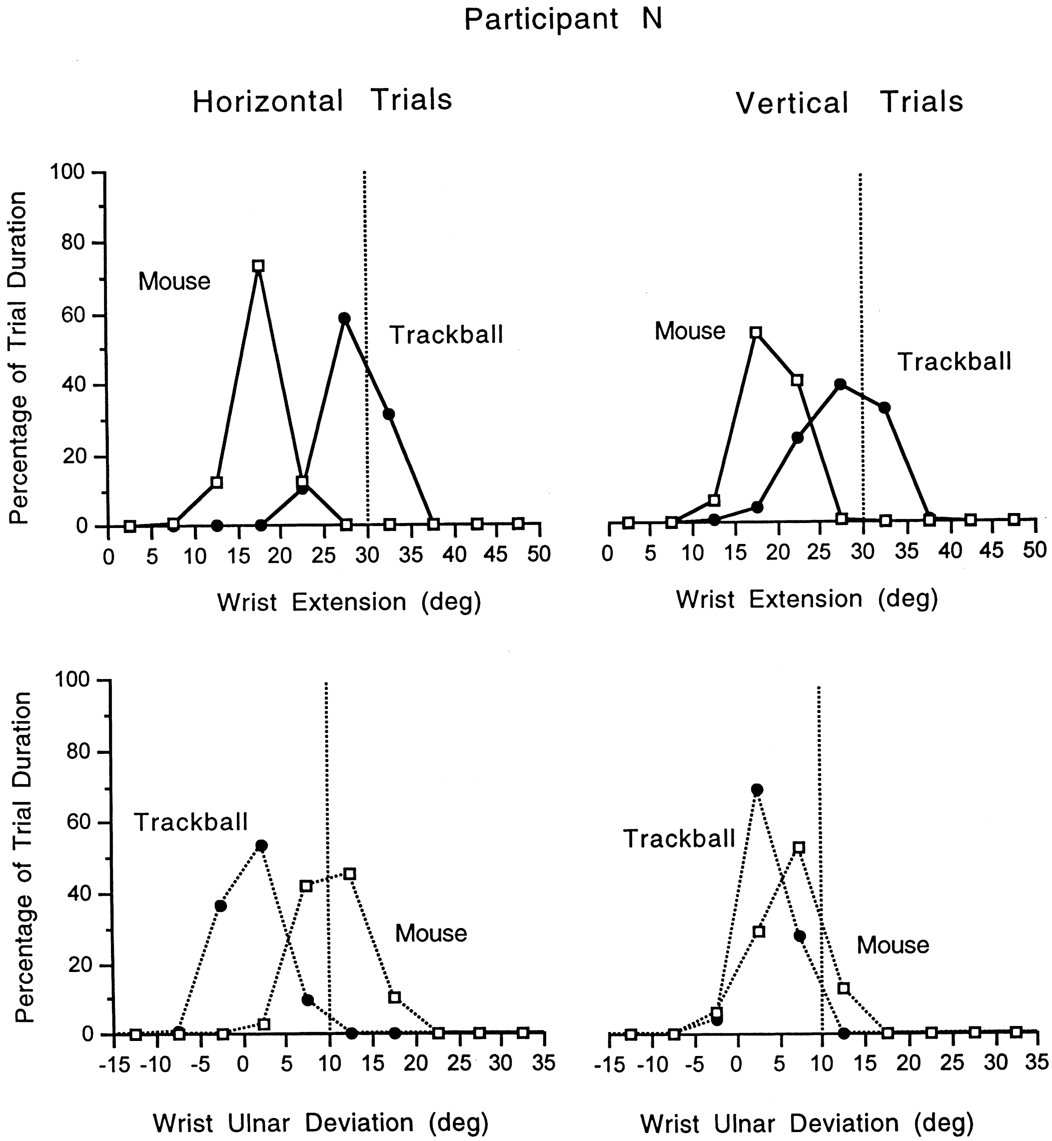

Fig. 4. Frequency distribution of wrist extension and ulnar deviation (average of three trials) for horizontal and vertical trials performed by participant N. Use of the mouse was associated with extreme ulnar deviation, and this exposure was reduced by the use of the trackball. However, exposure to wrist extension greater than 30° occurred with the trackball. While this participant may be at risk of injury if mouse use is excessive, and the trackball may reduce exposure to extreme ulnar deviation, the benefits may be offset by an increase in exposure to extreme wrist extension.

while others may not. Alternative pointing devices may alter the exposure to extreme wrist postures for some users, but not for others.

One implication of these data is that the introduction of an alternate pointing device such as a trackball should be considered as an intervention to alleviate wrist symptoms associated with mouse use, but that any such intervention should involve a subsequent evaluation of the postures adopted to use the alternate device.

The reasons for the individual differences remain unknown. It may be that the variability is simply the consequence of the participants not being familiar with the trackball, and that given sufficient practice the variability would be reduced. Alternately, it may be that design of the trackball allows qualitatively different patterns of use to achieve the same outcome, and the differences observed would persist after practice. Other questions which deserve investigation include: Can the postures adopted be changed with training? What influence does the relationship between pointing device movement and cursor movement (the "speed" of the device) have on wrist postures? Does the type of software (CAD, Wordprocessing, Operating system) influence the postures adopted? What about the many other pointing devices available?

A more comprehensive examination of these issues is justified. Such an investigation should encompass a larger number of participants performing both constrained and naturalistic tasks, and involve a substantial period of familiarisation. Further investigations also need to consider the range of individual differences observed here.

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