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Comparison of Postures from Pen and Mouse Use

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Introduction

There are a variety of possible finger, hand, and arm positions which can occur during input device use. These include:

- rotation of forearm
- hand deviation at the wrist
- extension, flexion, and lateral separation of the fingers
- elbow abduction
- forward rotation of the shoulder

Postures are measured by deviation from a neutral position. A neutral posture is the position that parts of the body assume when completely relaxed, that is, without any intentional bending at the joints. A neutral arm position occurs when:

- the forearm is not rotated
- the hand is not bent at the wrist
- the fingers are not intentionally flexed, extended, or laterally separated
- the elbow is not abducted
- the shoulder is not rotated

Postures are considered excessive when they exceed 30% of maximum deviation (see Table 1). Excessive posture deviation (see Figures 1 and 2) can lead to musculoskeletal disorders if assumed for a prolonged duration (i.e., 20% or more of the task time). For example, recent medical research indicates that excessive and prolonged wrist deviation leads to excessive and problematic biomechanical load and is positively correlated with cumulative trauma disorders of the hand.

Table 1: Postures and deviation from neutral

Posture	**Characteristic**	**Maximum range of deviation from neutral** (95th percentile)		**Excessive deviation** (30% maximum range)	
		male	female	male	female
pronation	rotation of the lower arm toward the center of the body	99°	87°	33	29
extension	bending of the hand at the wrist away from the palm	88	76	29	25
flexion	bending of the hand at the wrist toward the palm	90	85	30	28
ulnar deviation	lateral rotation of the hand at the wrist in the direction of the little finger	37	40	12	13
radial deviation	lateral rotation of the hand at the wrist in the direction of the thumb	37	30	12	10

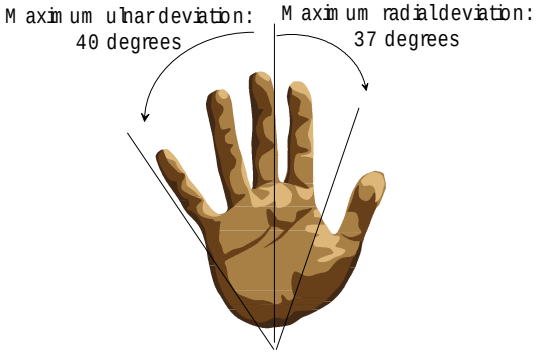


Figure 1: Maximum lateral hand deviation

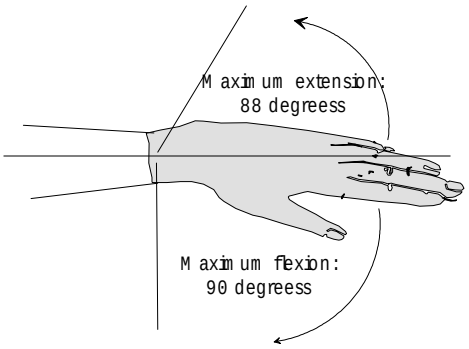


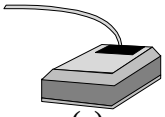
Figure 2: Maximum extension and flexion

Postures assumed during input device use depend on:
- the design of the input device
- the task
- the portion of the body used to control the input device
- the positioning of the device in relation to the user

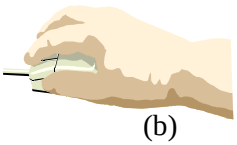
The majority of input devices result in inappropriate postures due to insufficient:
- integration of ergonomic principles into design
- inappropriate height of input devices
- inappropriate distance of input devices from the user
- training of correct postures and input device use techniques

Posture and input device design

The design of certain input devices inherently leads to inappropriate postures as soon as users grasp them. For example, mice that resemble the original mouse design (see Figure 3a) result in hand pronation as soon as a user places the hand on the top surface (see Figure 3b). Traditionally designed pucks also result in hand pronation (see Figure 4).



(a)



(b)

Figure 3: (a) Mouse similar to the original mouse design 20 years ago
(b) User's pronated hand grasping a traditionally designed mouse

Figure 4: User's pronated hand position grasping a puck

In addition, mice with buttons in a flat plane on the top surface (such as in Figure 5a) typically result in finger extension because as users lay the palm of their hand on the mouse top, the button surface keeps their fingers in an extended posture.

Although new designs with sloped sides contoured to the shape of the palm (like the Microsoft *Ergonomic* mouse, the *Contour* mouse, and the Logitech *Mouseman* (see Figures 5-7) are reducing extreme wrist deviations, they continue to occur (see Figure 8).

Figure 5: Microsoft *Ergonomic* mouse Figure 6: Contour mouse Figure 7: Logitech mouse

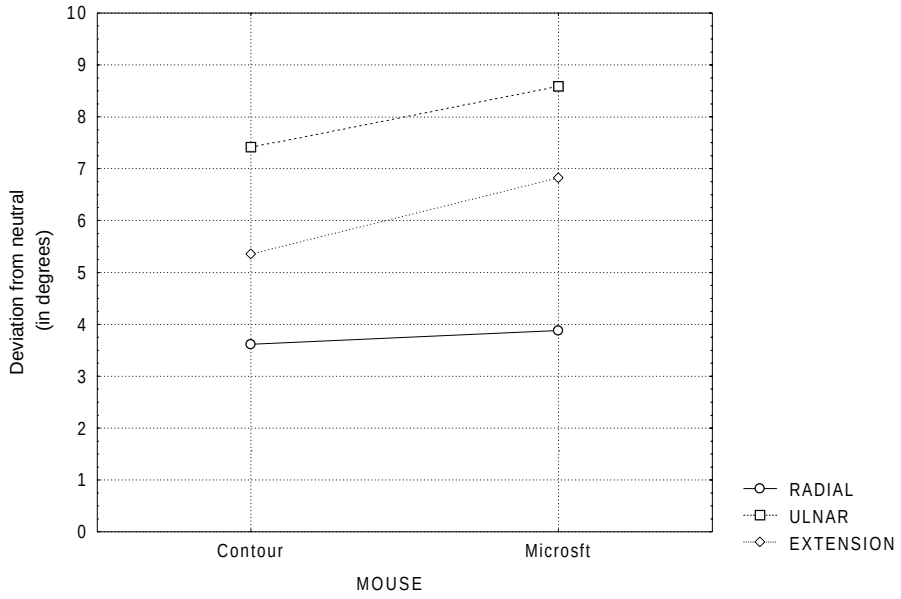


Figure 8: Average wrist deviation for the Contour and Microsoft ergonomic mice
Although deviation for each posture is below the 30% excessive limit,
the maximum deviation was above 30%.

Posture and tasks

Studies have demonstrated that certain tasks (like those requiring lateral movements) more frequently result in extreme postures. For example, mousing tasks requiring cursor movements greater than two lateral screen inches typically result in extreme deviation at the wrist (see Figures 9).

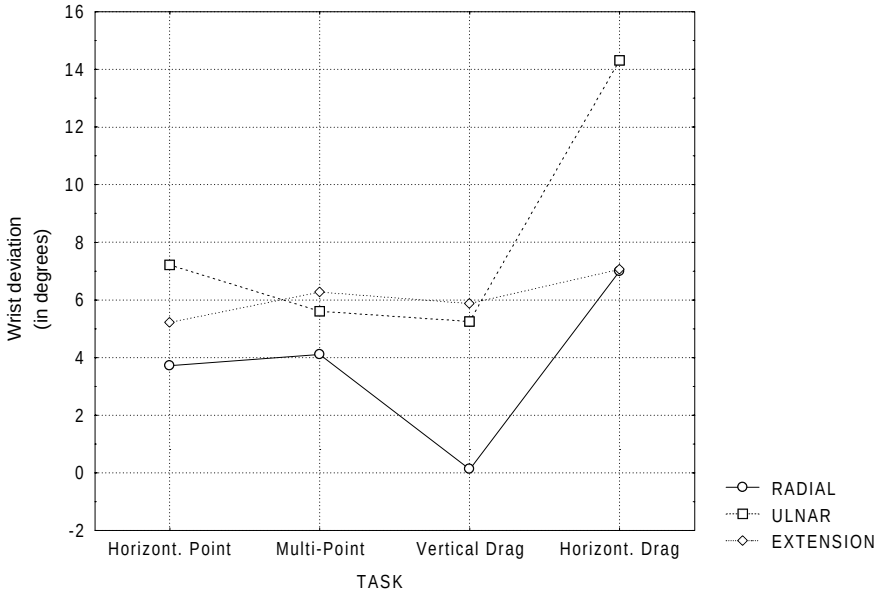


Figure 9: Comparison of average hand deviation
for lateral vs. vertical cursor movement tasks

Posture and portion of the body used during the task

Users who move an input device with their hand rather than their arm movement typically demonstrate more extreme postures at the wrist. In the previous example of pointing to screen images more than two inches apart, users who move their mouse with their hand cause significantly more wrist deviation than those who move the mouse with their whole arm (see section on Pen Movement Control).

Posture and surface height

Most users place their input device on a surface of an inappropriate height. Mice higher than elbow height typically result in unconsciously lifting the shoulder for prolonged duration. This results in frequently reported problems with shoulder pain.

Mice lower than elbow height results in excessive hand extension due to the elbow being higher than the wrist.

Posture and distance of input device

Most users place input devices used with keyboards to the right of the keyboard (see Figure 10). This results in excessive reach, arm abduction at the elbow, shoulder pain, and often long term musculoskeletal problems. Excessive distance placement exacerbates biomechanical problems that occur with certain tasks and inappropriate mouse location.

Figure 10: Example of typical mouse placement when used with a keyboard

Wacom Pen Study

In a previous report for Wacom - *Ergonomic Comparison of Stylus Tablet Systems and Mice* – it was stated that no studies could be found measuring user hand postures during use of a pen with a tablet. As a result of this finding, an ergonomic test was conducted of subjects using Wacom pens to assess a variety of usability measures including hand postures. The evaluation consisted of eight subjects using two different model pens for tasks typical of pen use. The tasks, movements, and activations included those listed in Table 2.

Table 2: Wacom test tasks, pen movements, and actions

Task	Pen movement	Pen action
one direction tapping	lateral pen movements	clicking
multi-directional tapping	sideways, forward, and backward pen movements	clicking
lateral tracing	lateral pen movements	dragging
circular tracing	circular pen movements	dragging
circle drawing	circular pen movements	dragging
cross hatch drawing	forward and backward pen movements	clicking & dragging
square drawing	forward and backward pen	dragging
diagonal drawing	diagonal	clicking & dragging
erasing	sideways	clicking & dragging
masking		dragging

Each task required the use of the pen tip, side switch, or eraser. Observations and measures were made of user's hand and arm postures and movements during pen use.

Posture measures were taken of ulnar and radial deviation and pronation. Measures of posture deviation were made from neutral reference marks on the subjects' arm and hand. The number of posture measures varied between tasks (see Table 3). Recordings were collected of hand and arm movements.

Table 3: Wacom test tasks and measurement occurrence and frequency

Task	Measurement occurrence	Number of measures/pen
lateral tapping	when user clicked on a target	20
multi-directional tapping	when user clicked on a target	48
lateral tracing	at start and end of track	20
circular tracing	at quarter positions of the circle	20
circle drawing	at quarter positions of the circle	20
cross hatch drawing	at the end of each stroke	🌡
cross hatch erase	at the end of each stroke	🌡
square drawing	at each corner	4
cross hatch drawing	at the end of each stroke	🌡
cross hatch erase	at the end of each stroke	🌡
erasing	at the end of each stroke	🌡
masking	at intervals during the task	1/sec.

🌡 Frequency depended on the number of crosshatch lines drawn.

Comparison of Wacom Pen Study Results with Results of Mouse Studies

Mouse studies have shown that posture deviation from neutral (i.e., excessive pronation, extension, ulnar and radial deviation) during mouse use is often excessive. Most of the postures observed during the Wacom Pen study were either neutral or slightly deviated from neutral (less than 3° deviation) from neutral. Some subjects occasionally exhibited extreme deviations but deviation was significantly less than 20% of the task time.

The following is a summary of mouse studies and the Wacom pen test addressing pronation, hand extension, flexion, ulnar deviation, radial deviation, finger extension, flexion and abduction.

Pronation

Rotation of the lower arm toward the center of the body (see Figure 11) is mostly dependent on the design of the input device. Devices like mice with a grasp surface parallel to the work surface typically result in pronation. Pronation typically occurs during mouse use as soon as users place their hand over the mouse (see Figure __) and remains throughout mouse use.

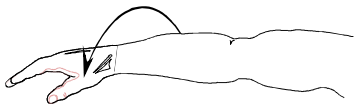


Figure 11: Pronated arm

Figure 12: Pronated hand on mouse

Recently, several mice have been designed with the grasp surface sloped to the side to encourage the hand to be in a more neutral position. These mice include the *Contour* (see Figure 5), *Logitech* (see Figure 6), and *Coloni*.

Mouse test results:

Observations during mouse studies demonstrate that maximum pronation typically occurs during mouse use. However, the amount of pronation depends on the placement of the user's hand on the top of the mouse. Most users center their hand on the mouse making it parallel to the work surface (see 12). Some users place their hand along the side of the mouse. However, this results in the edge of the mouse creating a pressure point on the inside of the palm unless the side of the mouse is contoured.

Pen test results:

In the Wacom pen study, no pronation was observed. Pen users typically held the pen as they would a writing implement – in a non-pronated posture (see Figure 13).

Figure 13: Holding of pen with hand in a non-pronated posture

Extension

Bending the hand at the wrist away from the palm (see Figure _) is mainly dependent upon the design of an input device and how the task is performed. For example, high profile mice result in the most hand extension. In addition, when users slide the mouse toward them without moving their arm, excessive extension can result.

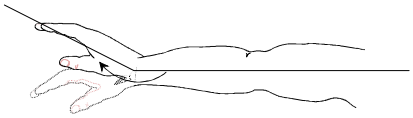


Figure 14: Extended hand

Mouse test results:

Measurements of extension during tests of mice demonstrate average extension of between 8 to 12 degrees (see Figure 15).

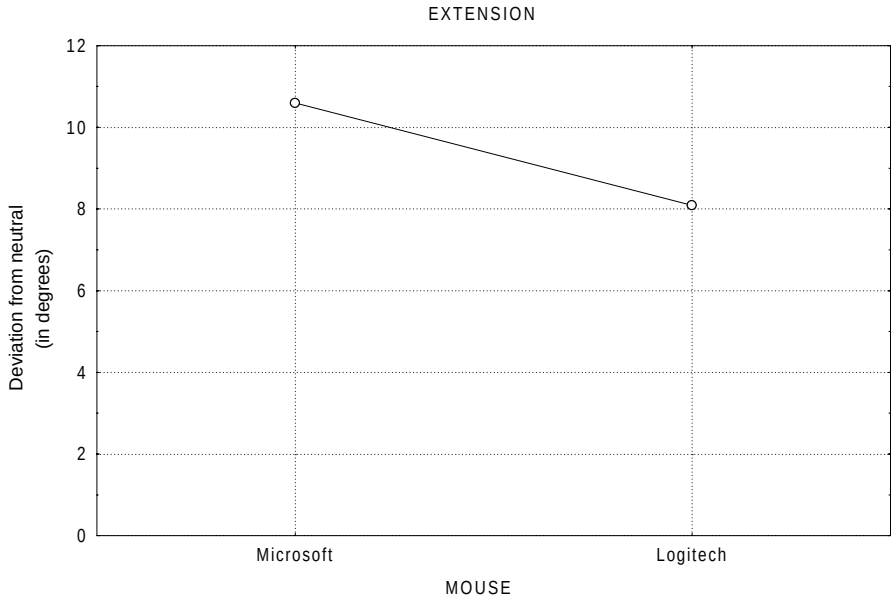


Figure 15: Hand extension during mouse use

Pen test results:

Although extension was not measured during Wacom pen test, almost none of the subjects showed any extension. The only subject that showed any hand extension was the left handed subject; most of the time no extension was observed for this subject

Flexion

Bending of the hand at the wrist toward the palm (see Figure 16) is dependent upon input device height in relation to the user's elbow. Flexion does not usually occur with input devices used with the palm parallel to the support surface (such as mice, pucks, and trackballs). Flexion more frequently occurs with input devices like pens and joysticks, which are held with the palm vertical to the support surface. Input devices placed on support surfaces significantly higher than the elbow can result in flexion.

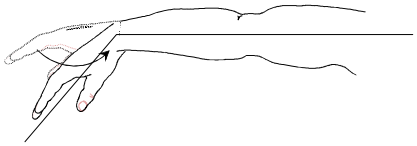


Figure 16: Hand flexion

Mouse test results:

None of the mouse studies measured flexion.

Pen test results:

Flexion was observed when subjects were drawing small lines (like crosshatch in one-inch circles and squares).

Ulnar deviation

Rotation of the hand in the direction of the little finger (see Figure 17) is dependent on the task.

Figure 17: Ulnar deviation

Mouse test results:

Excessive ulnar deviations (12° and greater) have been found in studies of mice use. One study found *average* ulnar deviation between 11° to 12° for Microsoft and Logitech mice (see Figure 18a). In this study: almost half (46%) of the time, subjects using the Microsoft mouse exhibited hand extension greater than the excessive level (12°) (see Figure 18b); slightly more than half of the time (51%) subjects using the Logitech mouse exhibited hand extension greater than the excessive level (see Figure 18b).

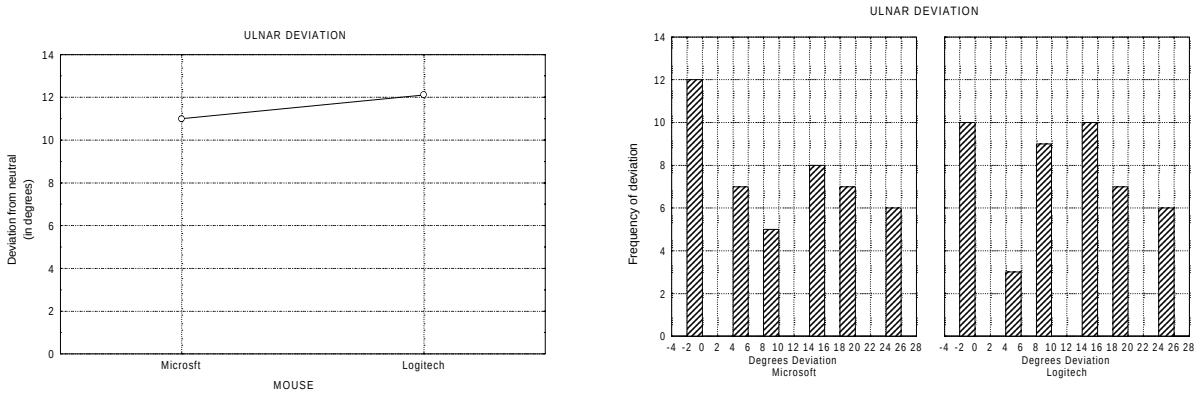


Figure 18: a) Average and b) frequency of ulnar deviation

Pen test results:

Average ulnar deviation during the Wacom pen test was less than 4° for all tasks (see Figure 19). All but two tasks (laterally pointing to large squares and multidirectional pointing) resulted in an average deviation across subjects of less than 1.5°.

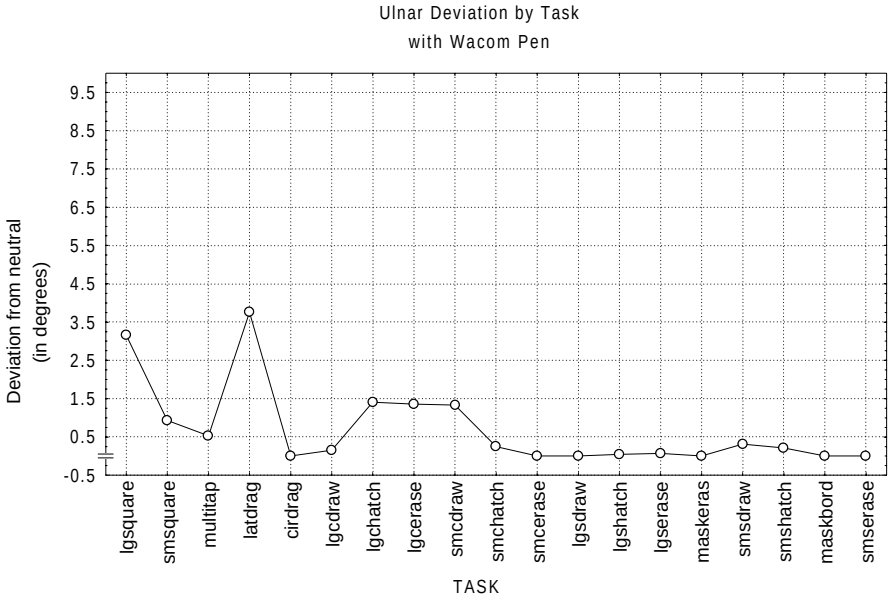


Figure 19: Ulnar deviation by task

Radial deviation

Radial deviation - lateral rotation of the hand at the wrist in the direction of the thumb – is most dependent on the task and usually occurs with input devices held with the palm parallel to the support surface.

Mouse test result:

Radial deviations during mice use have not been shown to be excessive. One study found *average* radial deviation between 2° to 3° for Microsoft and Logitech mice (see Figure 20).

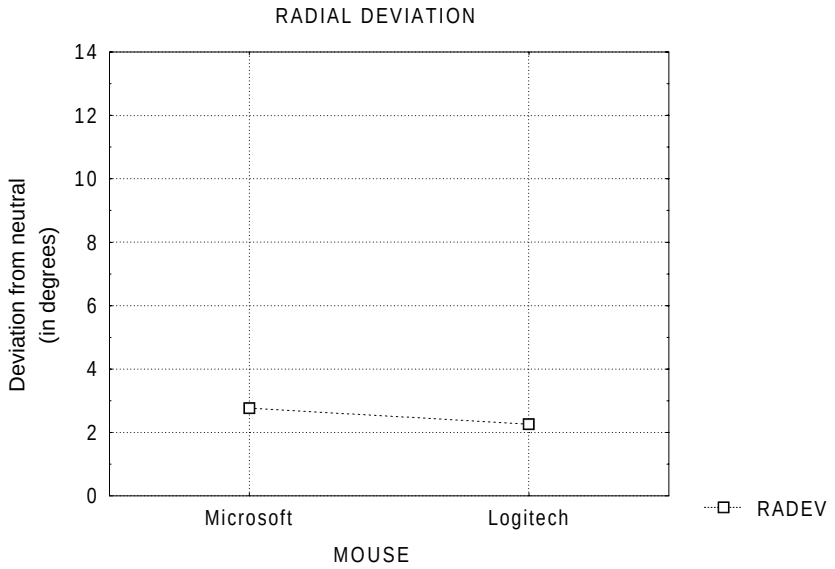


Figure 20: Average radial deviation

Pen test results:

Average radial deviation during the Wacom pen test was less than 2.5° for all tasks. All but two tasks (large square cross hatch and masking erase) resulted in an average deviation across subjects of less than 1.0° (see Figure 21).

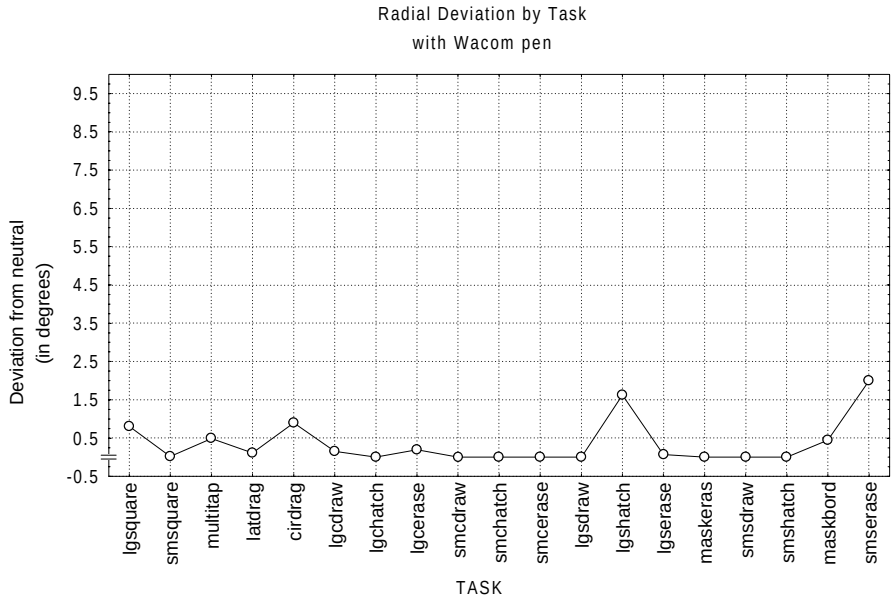
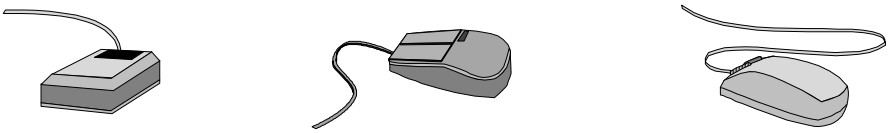


Figure 21: Radial deviation with pen use by task

Finger extension

Straightening the fingers away from the palm usually occurs when buttons or keys are on the same plane as the palm support. Traditional mice have buttons parallel to the support surface (see Figure 22a). Mouse design has been evolving to having buttons slope downward (see Figure 22b). to buttons curving around the front of the mouse (see Figure 22c).



(a) (b) (c)

Figure 22: Evolution of button placement on mice

Mouse test results:

Observations during mouse studies show that most users locate their fingers at an angle that matches the angle of the buttons. Flat buttons result in finger extension; buttons sloped toward the front edge of a mouse result in more neutral finger flexion.

Pen test results:

No finger extension was observed in the Wacom pen study.

Finger Flexion

Finger flexion - bending the fingers in the direction of the palm – is dependent on the size of the device grasped and location of actuators.

Mouse test results:

Finger flexion is frequently observed during mouse use, particularly when the hand of the user is too large for the mouse. This occurs as the user pulls the fingers toward the palm to activate buttons on the top surface of the mouse. Mice that have a finger wheel incorporated into the top surface also result in finger flexion as the finger rotates the wheel toward the palm.

Pen test results:

Pen use resulted in finger flexion while grasping the device and during activation of the switch. The amount of flexion appeared to depend on location of the fingers along the pen and the size of the hand. Users who held the pen closer to the tip (see Figure 23a) flexed their fingers to operate the switch more than users who located their fingers closer to the center of the pen (see Figure23_b).

(a) (b)

Figure 23: Finger posture while holding the pen

Finger Abduction

Finger Abduction - lateral separation of the fingers - is dependent on the size and spacing of buttons (see Figure 24).

Figure 24: Lateral abduction of the first and second fingers.

Mouse test results:

Studies demonstrate excessive finger abduction during mouse use. Use of a mouse often results in excessive lateral abduction of the fingers during button operation due to the width of the buttons. Mice with narrow buttons exhibit less finger abduction than mice with wide buttons.

Pen test results:

Observations of pen use did not demonstrate finger abduction.

Pen movement control

The use of hand and arm depended on the type of task and thus the type of movement required. The pen was typically moved with the arm for tasks requiring large cursor movements; the pen was moved with the hand for tasks requiring small cursor movements (see Figure 25). The majority of the time subjects moved the pen with their whole arm rather than their hand (see Figure 26).

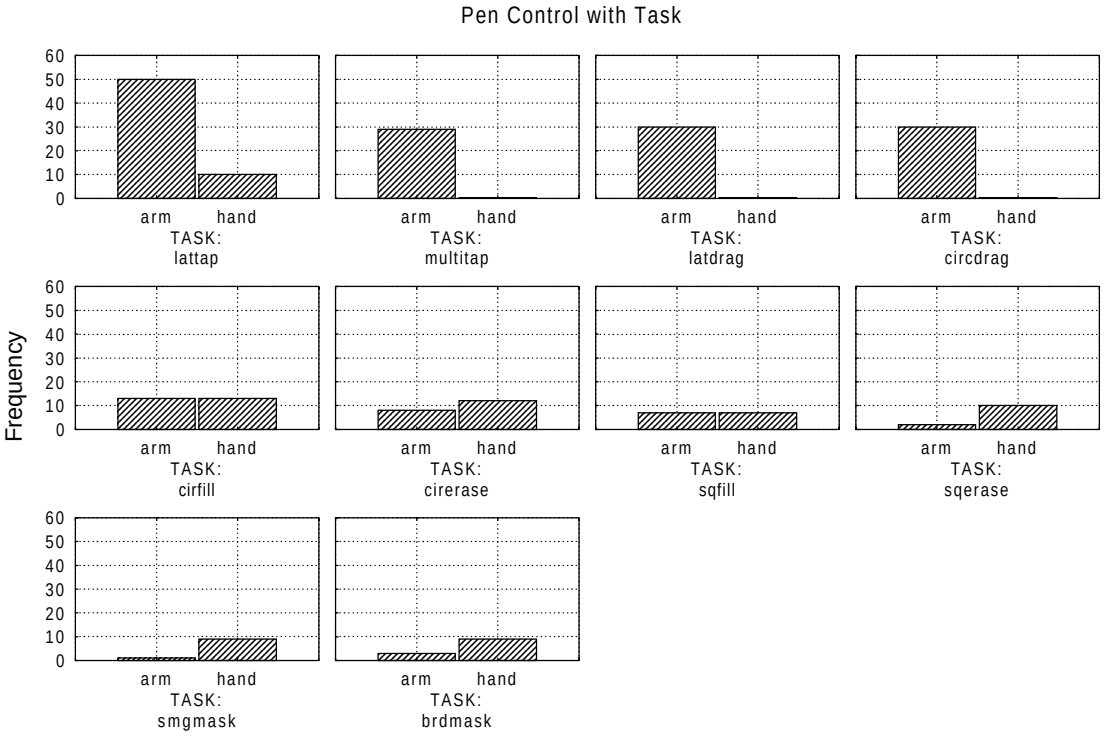


Figure 25: Frequency of arm and hand control during pen use

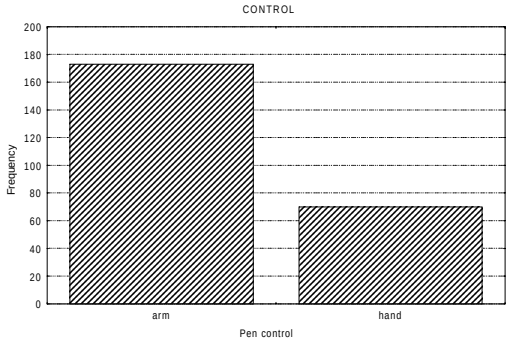


Figure 26: Frequency of arm and hand use

Summary

Results from the Wacom pen test demonstrated less posture deviation from neutral during pen use than during mouse use. Mice studies have demonstrated excessive deviation from neutral. Excessive hand pronation and extension, as well as ulnar deviation and radial deviation have been observed of subject using mice. No pronation was observed of subject using the Wacom pen. Although extension and flexion was not measured, it was observed in only one subject who used the left hand; but the extension and flexion of this subject was not excessive nor prolonged. Average ulnar deviation during pen use was substantially less than during mouse use. Radial deviation for both pen and mouse use has been demonstrated to be low, but average radial deviation with pen use was less than with mouse use. In conclusion, pen use results in a posture more neutral than during mouse use and thus appears to be a biomechanically superior input device.