

Observed finger behaviour during computer mouse use

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Abstract

Two-button computer mouse users may exhibit sustained, static finger lifting behaviours to prevent inadvertent activations by avoiding finger pressure on the buttons, which leads to prolonged, static finger extensor muscle loading. One hundred graduate students were observed during normal computer work in a university computer facility to qualify and quantify the prevalence of lifted finger behaviours and extended finger postures, as well as wrist/forearm and grip behaviour, during specific mouse activities. The highest prevalences observed were 48% of the students lifted their middle finger during mouse drag activities, and 23% extended their middle finger while moving the mouse. In addition, 98% of the students rested their wrist and forearm (77%) or wrist only (21%) on the workstation surface, and 97% had an extended wrist posture (15°–30°) when using the mouse. Potential applications of these findings include future computer input device designs to reduce finger lifting behaviour and exposures to risk factors of hand/forearm musculoskeletal pain.

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1. Introduction

With the advent of graphical user interfaces (GUI), computer mouse use is a ubiquitous activity in personal computing, generally used between one to two-thirds of the time during computer work (Johnson et al., 1993; Keir et al., 1999). Intensive computer mouse use as an input device during computer work is associated with upper extremity pain (Kryger et al., 2003; Lassen et al., 2004). In a large, one-year prospective study among computer workers, Lassen et al. (2004) found positive associations between elbow and wrist/hand pain conditions and self-reported mouse and keyboard usage. In the same study, intensive mouse usage was found to be a major risk factor for forearm pain, as well as intensive keyboard usage, however, to a smaller degree (Kryger et al., 2003).

While the exact mechanism behind the forearm and hand/wrist pain associated with computer mouse use still

remains unclear, a leading hypothesis is that mouse users are exposed to prolonged, static working postures involving hand and wrist extension (Burgess-Limerick et al., 1999; Delisle et al., 2004; Jensen et al., 1998). During keyboarding, maintaining wrist and elbow postures for extended periods during typing creates static loading in the wrist extensors (Keir and Wells, 2002). For the fingers during keyboarding, extensor muscle loading is needed to hold the fingers over the keys (Gerard et al., 1996), and it has been suggested that fingers are maintained in extended postures to prevent inadvertent key activations given the keyswitch sensitivity in modern keyboards (Keir and Wells, 2002).

Since the design of the two-button mouse allows for multiple button activations, mouse users may also be lifting and/or extending their fingers over the buttons to prevent inadvertent button activations by avoiding finger pressure on the buttons (Sogaard et al., 2001). The sustained, static muscular activation patterns of the finger extensor muscles required to lift the fingers during mouse use (Jensen et al., 1998; Sogaard et al., 2001), in combination with extended wrist postures already observed from previous mouse

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studies (Karlqvist et al., 1994; Keir et al., 1999) may play a role in the occurrence of forearm and hand/wrist pain during intensive mouse use. The underlying structures and resultant biomechanics of the finger and hand may also be important factors since the muscle tendons of the extensor digitorum communis (EDC) and flexor digitorum superficialis (FDS) are interconnected extrinsically. Zatsiorsky et al. (2000) demonstrated that during the isometric force production of one or more fingers, an involuntary force production of the other fingers results (enslaving effects), with neighbouring fingers having larger enslaving effects. Index finger left button activations may potentially result in right button inadvertent activations should the enslaving effects to the middle finger on the right button be larger than the switch activation force. Therefore, lifting the middle finger to avoid inadvertent switch activations requires increased extensor activity to overcome enslaving effects during index finger force production.

It has been reported that computer users sustain a lifted finger posture over the mouse buttons during computer work (Sogaard et al., 2001); however, to date no studies have empirically determined the prevalence of such static finger lifting behaviour applied to two-button computer mouse use. Therefore, we sought to determine the prevalence of static finger lifting behaviour and extended finger posture across the range of mouse use activities that may be present to avoid inadvertent button activations. As a first step, an observational field study was carried out in a high-use graduate school computer facility. The purpose of this study was to qualify and quantify finger behaviour during two-button computer mouse use, specifically to determine the prevalence of (1) statically lifted fingers and (2) extended finger postures over the mouse buttons.

2. Method

One hundred graduate students (59 females, 41 males) were observed during computer work in a student micro-laboratory at the Harvard School of Public Health for a period of three weeks during May of 2004. The micro-laboratory contained 20 computers; all computers, computer peripherals, and workstations were identical and height-adjustable for the keyboards, monitors, and chairs. All computer mice were located laterally to the right of the keyboard. The computer mouse at all workstations was a USB-interfaced Optical Wheel Mouse (IBM; Model no.: MO28UO; height: 32 mm × width: 54 mm × depth: 114 mm; 0.094 kg), which had a scroll wheel between the conventional left and right click buttons.

Observations were recorded randomly across workstations throughout the micro-laboratory at random times in the morning, afternoon, and early evening. To minimize intrusiveness, a researcher who was a member of the student body completed all observations on a custom-designed observational checklist without any direct contact or communication with the observed students. The researcher, who was a trained occupational therapist, sat

in an adjacent workstation no more than 1.5 m behind and to the right of the observed student to ensure superior and lateral visibility of all fingers and wrist postures and behaviour during mouse use. The specific parameters recorded on the observational checklist included gender, hand used, specific fingers used on each mouse button, wrist extension levels, level of wrist/forearm support on the workstation surface, overall mouse grip behaviour, finger support during mouse use, and finger postures across finger support during mouse use (Table 1; Fig. 1); other individual features were noted to ensure that each student was not recorded more than once. With use of a visual comparison reference with joint angles, each student was observed for 5 min prior to checklist input to ensure all parameters were observed. Inputting observations into the checklist required an additional 5 min to complete. These procedures were approved by the Harvard School of Public Health Human Subjects Committee.

The 5 min observational period was qualitatively determined from pilot testing on 10 observations prior to actual data collection to determine the amount of time required to fully capture finger behaviour and postures across activities of mouse use (Fig. 2). Lifted fingers were defined as non-physical contact of the palmar surface of the finger distally from the metacarpophalangeal joint (MCP) to the fingertip, and extended finger postures were characterized by a proximal interphalangeal joint (PIP) flexion angle of less than 15°, with a MCP flexion angle greater than 0°. Wrist extension of 15° and 30° were chosen based upon the Rapid Upper Limb Assessment (RULA) (McAtamney and Corlett, 1993) and expected wrist extension during mouse use (Keir et al., 1999), respectively.

Mouse use taxonomy (Fig. 2) and the checklist design were developed from the pilot testing. Mouse use activity was dichotomized as either (1) stationary or (2) dynamic. Stationary usage indicated non-moving, static postures in the fingers and hand during mouse use. Dynamic mouse usage was defined as any movement in the fingers, wrist, or the mouse itself, which was further divided into two categories: (1) moving, with non-activating motions and (2) activating only. Moving actions were defined by non-clicking actions or dragging activity. Activating actions were defined by movement of the fingers to perform left click activations, right click activations, and scrolling only, while keeping the mouse itself stationary. It was assumed that users stopped moving the mouse, albeit instantaneously at times, during button activation. Although dragging requires button activation, it was considered a moving action since the entire mouse itself moves during dragging activities.

Data from the checklists were inputted into Microsoft Excel (Microsoft Corp., Redmond, WA, USA), and imported into SAS 8.0 (SAS Institute Inc., Cary, NC, USA). Descriptive summary statistics on individual factors, level of wrist extension, level of wrist/forearm support, and grip behaviour (Table 1) were calculated in SAS through frequency counts (Proc Freq). Descriptive

Table 1
Observational checklist parameters and descriptions

Mouse use parameters	Descriptions
Individual factors	<ul style="list-style-type: none"> ● Gender (male, female) ● Hand used (right hand, left hand) ● Left mouse button click finger (I, M, R, L)^a ● Right mouse button click finger (I, M, R, L)^a ● Scroll wheel finger (I, M, R, L)^a
Level of wrist extension (Fig. 1(A)–(C))	<p>The wrist extension levels examined were</p> <ul style="list-style-type: none"> (A) less than 15° (B) between 15 and 30° (C) greater than 30°
Level of wrist/forearm support on the workstation surface (Fig. 1(D)–(F))	<p>The levels of wrist/forearm support examined were</p> <ul style="list-style-type: none"> (D) forearm and wrist supported on the workstation surface (E) wrist on the edge of the workstation surface (F) forearm and wrist off and above the workstation surface
Grip behaviour (Fig. 1(G)–(H))	<p>The levels of grip behaviour examined were</p> <ul style="list-style-type: none"> (G) appeared relaxed (H) appeared tense <p>Tense grip behaviour was observed when the tendons of the hand and finger extensors were prominent on the dorsal surface of the hand and fingers during mouse use</p>
Finger support across mouse use activity (Fig. 1(I),(J))	<p>Finger support was classified by either being</p> <ul style="list-style-type: none"> (I) <i>Rested</i> on the button or against the mouse, or (J) <i>Lifted</i> up above or off the mouse (non-physical contact)
Finger postures across finger support and mouse use activity (Fig. 1(K)–(N) for rested fingers; Fig. 1(O)–(R) for lifted fingers)	<p>The rested and lifted finger postures examined across finger support were</p> <ul style="list-style-type: none"> (K), (O) <i>Extended posture</i>. Extended postures were characterized by any proximal interphalangeal joint (PIP) flexion angle less than 15°, with a metacarpophalangeal (MCP) flexion angle greater than 0°. (L), (P) <i>Neutral posture</i>. Neutral postures were characterized by finger joints ranging between defined extended and flexed postures. (M), (Q) <i>Flexed posture</i>. Flexed postures were characterized by any PIP flexion angle greater than 60°, with a MCP flexion angle greater than 0°. (N), (R) <i>Clawed posture</i>. Clawed postures were characterized by hyper-extension of the MCP joint and any flexion angle of the interphalangeal (IP) joints.

^aI, Index finger; M, Middle finger; R, Ring finger; L, Little finger.

summary statistics on finger support and finger postures were calculated in SAS through sorting (Proc Sort) by finger (index, middle, ring, and little fingers) and cross-tabulating (Proc Freq, Proc Tabulate) across the various activities of mouse use (Fig. 2). Results are presented in percentages in terms of the prevalence for each mouse use activity examined. Finger support was examined in terms of prevalence of fingers lifted for the index, middle, ring, and little fingers across mouse use activity. Finger posture over the mouse buttons was examined in terms of prevalence of neutral, extended, flexed, and clawed postures for the index and middle fingers across mouse use activity (Table 1).

3. Results

All 100 observed students used the computer mouse with their right hands, and their index fingers for left mouse button activations. Right mouse button clicking was predominantly used by middle fingers at 91%, with 6% using ring fingers, and the remaining 3% with index fingers. Eighty-eight percent of observed students used their index fingers for scrolling, while the remaining 12% used their

middle fingers. The predominant wrist extension posture was observed to be between 15° and 30° of wrist extension among 97% of observed students, with the remaining 2% being less than 15°, and 1% found to be extended greater than 30°. Seventy-seven percent of the forearms and wrists were fully supported by the workstation surface. Twenty-one percent had their wrists supported on the edge of the workstation surface, and the remaining 2% had their forearms and wrists lifted off and above the workstation surface. All students were observed to have their wrist and forearms fully pronated on the workstation surface. The predominant grip behaviour for observed students was a relaxed grip at 97%, as compared to the tense grip found at 3% during computer mouse use.

3.1. Finger support across mouse use activity

Computer users were found to exhibit finger lifting behaviour with a prevalence of up to 48% in the middle finger during dragging activities (Table 2). The middle finger was found to be lifted at a greater prevalence than the index finger across mouse use activity. During stationary mouse activity, a prevalence of 30% of observed

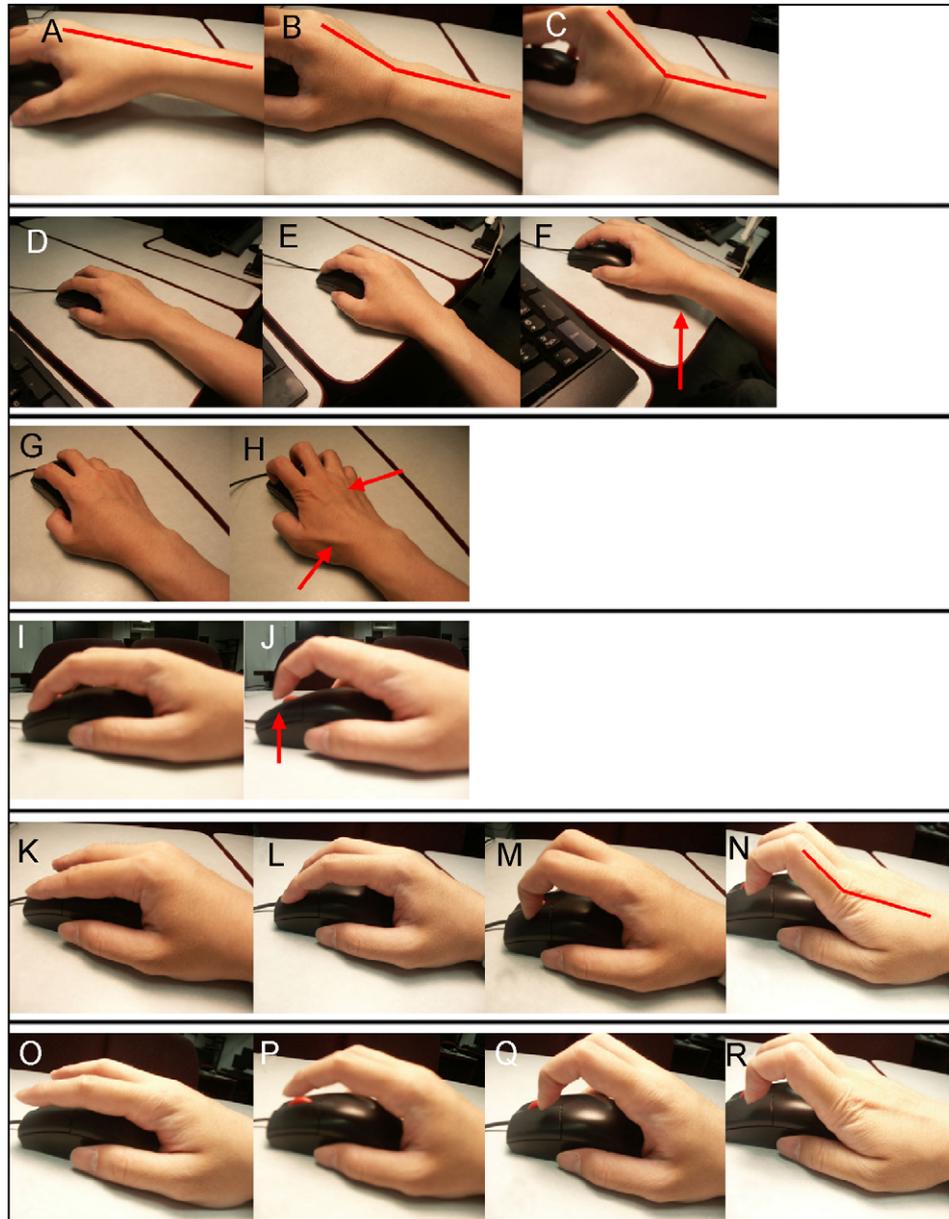


Fig. 1. The illustrations of the parameters examined in the study, which corresponds to [Table 1](#): wrist extension postures ((A)–(C)), wrist support on workstation surface ((D)–(F)), grip behaviour ((G),(H)), finger support ((I),(J)), rested finger postures ((K)–(N)), and lifted finger postures ((O)–(R)). The arrows and lines are added to highlight specific features unique to the parameter observed.

students demonstrated lifted middle finger behaviour. For dynamic movements the lifting prevalence increased for all fingers. Moving activity (non-clicking mouse movements or dragging actions) were found to have the highest prevalence of fingers lifted, increasing 9% to 15% across all fingers compared to stationary mouse activity. The prevalence of fingers lifted during mouse button activations was lower compared to moving activity, but higher compared to stationary mouse activity. Of the possible button activations (left button clicking, right button clicking, and scrolling), scrolling resulted in the highest prevalence of fingers lifted. During scrolling, 41% of index fingers were lifted, 46% of middle fingers were lifted, 15% of ring fingers were lifted, and 8% of little fingers were

lifted. This results in increases of 21% and 10% in prevalence greater than the right button click activations for the index and middle fingers, respectively, and an increase of 15% and 3% in prevalence greater than left button click activations for the index and middle fingers, respectively.

Males were found to demonstrate a higher prevalence (23%) of lifted finger behaviour more than females during stationary mouse activity, but a similar prevalence during moving or button activating (non-scrolling) activities. Forty-nine percent of males lifted their index or middle fingers during stationary activity, and 59% during moving or button activating (non-scrolling) activities. Females lifted their index or middle fingers at a prevalence of

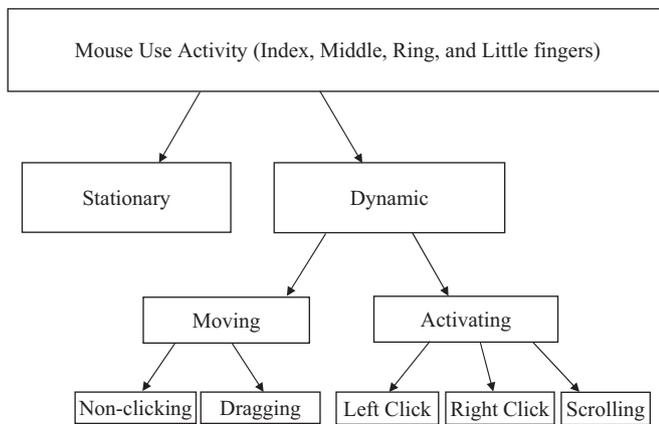


Fig. 2. The taxonomy of mouse use activity developed for this study. Finger behaviour was characterized depending on the stationary or dynamic activity of mouse use. Dynamic mouse use was further divided into either moving or activating activity, in which both were further characterized by the activity of the finger.

Table 2
Summary of lifted fingers (in percentages) across mouse use activity

Mouse use activity		Index finger	Middle finger	Ring finger	Little finger	
Stationary		19	30	4	0	
Dynamic	Moving	Non-clicking	28	45	15	10
		Dragging	0	48	14	11
	Activating	Left click	26	43	9	2
		Right click	20	36	10	1

26% during stationary activity, and 61% during moving or button activating (non-scrolling) activities.

Finger lifting behaviour was exhibited across all activities of mouse use. In terms of examining finger support between stationary and dynamic mouse use, 21% of index fingers and 25% of middle fingers were rested on the left mouse button during stationary activity and lifted during moving and button activating (non-scrolling) activities. Sixteen percent of both index and middle fingers were rested on the mouse buttons during stationary activity and lifted during moving and button activating (non-scrolling) activities. Conversely, a smaller prevalence of fingers (7% for both index and middle fingers) were found to be lifted off the mouse button during stationary activity and rested on the mouse buttons during moving and button activating (non-scrolling) activities.

3.2. Finger postures across mouse use activity

Computer users were found to exhibit extended finger postures during mouse use with a prevalence of 23% for the middle finger during moving activities (non-clicking and dragging) (Table 3). The prevalence of extended finger postures was found to be similar across mouse use activity between the index and middle fingers (19–23%). The

predominant finger posture across the index and middle fingers was neutral (65–79%), with extended postures being the next most prevalent posture (19–23%) across mouse use activity. Only the middle finger demonstrated a clawed posture, with the greatest prevalence at 4% during left button activations. For the middle finger during moving activities, there was a 4% increase in extended postures found compared to stationary mouse activity. And middle finger postures during left button activations (66% neutral, 22% extended) were similar in prevalence across activities of mouse use to the moving activities, whereas the right button activations were similar to stationary mouse activity (71% neutral, 19% extended).

Males were found to demonstrate greater than 10% increase in prevalence of extended finger posture more than females across mouse use activity. Thirty-four percent of males demonstrated extended finger postures in their index or middle fingers during stationary mouse activity, and 41% during moving or button activating (non-scrolling) activities. For females, 20% demonstrated extended finger postures in their index or middle fingers during stationary mouse activity, and 31% lifted during moving or button activating (non-scrolling) activities.

Computer users were found to exhibit both lifted finger behaviours and extended finger postures concurrently during mouse use. During stationary mouse activity, a prevalence of 10% and 8% of index and middle fingers, respectively, was found to be both lifted and extended. During dynamic mouse activity, a prevalence of 13% and 17% was found to be both lifted and extended for the index and middle fingers, respectively.

4. Discussion

The purpose of this paper was to qualify and quantify the prevalence of finger behaviour and postures during computer mouse use. The major finding of this study was that computer users exhibit finger lifting behaviours and extended finger postures across activities of both stationary and dynamic mouse use. Overall, a prevalence of up to 48% of observed students' finger was found to be lifted across mouse use activity, up to 23% in extended postures, and up to 17% in both lifted and extended postures. The middle finger was found to be lifted at a greater prevalence than the index finger across mouse use activity, and dynamic movements tended to increase finger lifting behaviour.

Depending on the level of intensity and duration of exposure to mouse use, prolonged static lifting behaviour and extended postures of the fingers may put intensive computer mouse users at a level of risk for musculoskeletal pain to the forearm, wrist, or hand (Kryger et al., 2003; Lassen et al., 2004). Lifting finger behaviour is only one of many human computer interactions that have been hypothesized as potential risk factors. Hence, the results should be taken within the context of a much larger environment. Other factors such as the awkward postures

Table 3
Summary of index and middle finger postures (in percentages) across mouse use activity

Mouse use activity			Index finger				Middle finger			
			Neutral	Extended	Flexed	Clawed	Neutral	Extended	Flexed	Clawed
Stationary			78	20	2	0	71	19	8	2
Dynamic	Moving	Non-clicking	77	21	2	0	66	23	8	3
		Dragging	78	19	3	0	65	23	9	3
	Activating	Left click	79	20	1	0	66	22	8	4
		Right click	78	20	2	0	71	19	9	1

associated with various workstation setups (Sauter et al., 1991; Simoneau and Marklin, 2001), individual anthropometry (Karlqvist et al., 1998) and job strain for computer workers (Hannan et al., 2005) can be present and may be independent or interact with the finger behaviour observed in this study. Nonetheless, preventative measures can be taken to reduce exposures to statically lifted and extended finger behaviour through ergonomic interventions, such as engineering designs (i.e. mouse button redesign), personal controls (i.e. alternating hands during mouse use; use of alternative input methods during intensive computer work), or administrative controls (i.e. setting a daily intensive computer mouse use limit); however, further research is needed to examine the effectiveness of these possible controls in reducing the prolonged, static lifted and extended finger behaviours during mouse use.

In addition to the abovementioned human–computer interaction risk factors, another factor of consideration is forearm support. Several studies have found that support of the forearm during computer work reduces discomfort and muscle loading of the upper back and extremities (Aaras et al., 1997; Rempel et al., 2006; Visser et al., 2000). However, the use of wrist and forearm supports during computer input device usage is mixed among practitioners due to the concern of direct contact pressure on the underlying soft tissue structures. Ninety-eight percent of the students in this study were observed to rest their wrist and forearm (77%) or wrist only (21%) on the workstation surface proximal to the computer mouse. The high prevalence observed in this study could be a result of the mouse not being on an adjustable height surface and above elbow height; however, specific factors such as workstation surface height and other workstation design features influencing the use of forearm supports needs to be further examined in future research.

Students were observed to demonstrate alternating, reciprocal finger movements during mouse use, supporting the idea of computer mouse users actively lifting their fingers against enslaving effects (Zatsiorsky et al., 2000) to avoid inadvertent button activations. Reciprocal finger movements during mouse use are defined by simultaneous opposite movements between neighbouring fingers during button activations, such as the upward lifting of the middle

finger during downward button activations by the index finger. Across all observed subjects, given that both the index and middle fingers were rested during stationary times, 12% of middle fingers were lifted during left button activations by the index finger, and 6% of index fingers were lifted during right button activations by the middle finger. Computer mouse users may be actively lifting or extending neighbouring fingers in order to counteract possible enslaving effects from neighbouring fingers during force production for button activation, and thereby reducing potential inadvertent button switch activations. Since most of the button activations during computer work occur with the left mouse button, and that the index finger was found to be the finger used for left button activations across all observed subjects, this may partially explain why the middle finger was found to be the most prevalent finger lifted across mouse use.

Some limitations inherent in the study design place the findings in specific context. Only graduate students completing computer work in an academic setting were examined. A larger age range and contextual environment (i.e. home and occupational exposure to computer work) may provide further generalizability of the finger behaviours during mouse use. Another limitation is that the findings from this study apply to a specific two-button mouse design with a scroll wheel in between; alternative (i.e. trackball) and one-button mouse users may exhibit different finger behaviours. In addition, this study primarily focused on finger behaviour over the left and right mouse buttons, and secondarily on scrolling and gender differences. Scrolling appeared to increase the finger lifting prevalence, and therefore, further research on the postures associated with scrolling and the influence on neighbouring fingers is warranted. Males were found to exhibit a higher prevalence in lifting and extending finger behaviour than females; however, these gender differences may be confounded by hand anthropometry, mouse use intensity, and other psychosocial variables (i.e. stress), which should be further examined in future research. Furthermore, one researcher completed all observations. Future research can be conducted to quantify the reliability of the researcher and for multiple raters using the observational checklist through test–retest and interrater reliability testing, respectively.

The findings of this study are presented in the context of finger behaviour across mouse use activity, and do not provide indication on the duration of exposure, such as the proportion of time each posture was found across these activities during the observational period. Future research can be conducted to empirically validate the observed prevalence of finger lifting behaviour and finger postures through the use of biomechanical and motion analysis instrumentation. Jindrich et al. (2004) measured finger joint kinematics during voluntary finger tapping on a keyboard keyswitch with the use of miniature electro-goniometers and high-speed photography, which could be used for mouse button switch activations in determining the level of joint flexion angles during lifted and extended finger postures. Johnson et al. (2000) measured finger force exposures during regular computer work and simulated mouse use with a button and grip force-sensing mouse, which could be used in conjunction with the above-mentioned motion analysis instrumentation to empirically examine the timing and durations of index and middle finger lifting behaviours over the mouse buttons. Furthermore, the proportion of time spent lifted or rested in their respective finger postures across periods of mouse use activity could also be determined. However, such instrumentation under experimental conditions may have an effect on the true finger behaviour during mouse use. Observational field studies elicit information about normal human–computer interaction in representative environments, which cannot be gained from laboratory studies.

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