Haptic Manipulation of Objects on Multitouch Screens:

Effects of screen elevation, inclination and task requirements on posture and fatigue

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***Abstract*—Application of multi-touch screen interfaces is desired by manufacturers of measuring instruments to follow the current trend of consumer products. This study is a first approach to determine the influence of screen location and orientation on upper limb movements and posture. Neck and wrist posture, as well as finger movements and subjective perception of discomfort were evaluated in simple tasks simulating the placement and scaling of objects using a multi-touch interface placed on a computer screen of the same size. The results show that wrist and neck postures are generally affected by an interaction between screen height and inclination. They also suggest that precision requirements associated with measuring instruments may not be compatible with simple transfer of manipulation methods from consumer products.**

Natural gestures; finger movements; wrist posture; discomfort

I. Introduction

Natural user Interface technologies based on multi-touch displays have been successfully implemented in a variety of consumer devices. This success has lead to the adoption of these technologies for work applications. However, most work instruments are designed to sit on a bench or cart, have vertically mounted screens and may require precise manipulations. Gestures such as the “pinch”, used to zoom in and out, may require awkward wrist and upper limb postures when performed on a vertically mounted screen. Posture and repetition are known risk factors [1-3] commonly associated with localized muscle fatigue [4-6] and upper limb musculoskeletal disorders [7-8]. Furthermore, movement precision required to set specific values of gesture-controlled functions may increase repetition and muscle co-contraction activities. Hence, simply using the methods designed for mobile devices on vertically mounted screens may create rather than solve problems.

The present study investigated the influence of screen height (elevation) and inclination (relative to the vertical direction) on wrist posture and finger movements during object manipulation tasks using simple natural gestures. The level of required precision varied between tasks.

II. Material and Methods

A. Participants

Ten right-handed young adults aged 20-31 years (5 males, 5 females) participated in the experiment as volunteers. All were free from upper limb neurological and musculoskeletal disorders that might have impaired their performance. Their visual acuity was 20/20 or better, with or without correction.

B. Experimental setup and conditions

An instrument screen was simulated on a computer screen, onto which a matched size multi-touch screen was adapted. LED markers were placed on the thumb and index fingers, the wrist, elbow and shoulder of the right limb and head to record their movements with an active motion capture system (Optotrack™). The participants were facing the screen seated on a comfortable office chair adjusted to their anthropometry to obtain a 90° knee angle with feet flat on the ground. Three screen heights (1.25, 1.5 and 1.75 seated height- measured to the bottom of the screen) combined with three screen inclinations (10, 15, 20° relative to the vertical direction) were tested in random order. The tasks to be performed simulated real instrument operations. They included adjusting both the vertical and horizontal position of an object, scaling the horizontal and vertical dimensions of the object to specified values and switching the primary object to be

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manipulated. Numerical values and grid scales were displayed on the screen.

C. *Procedure*

The duration of each of the five tasks varied between 30 s and 2 min. A brief 10-20 s rest separated two consecutive tasks. A longer 2 min rest was provided between conditions while the experimenter adjusted the screen. Between trials, participants were allowed to relax their arm on the arm rest and between conditions they could stand or move away from the work station. The motion signals associated with each marker were sampled at 100Hz.

D. *Measures*

Discomfort was evaluated on a category scale (0= no discomfort, 1= barely perceptible, …, 5 = extreme pain) for each of the following body parts: finger, wrist, elbow, shoulder, neck, back). The magnitude of selected angular displacements (wrist flexion-extension; wrist pronation-supination; neck flexion-extension) and thumb-index finger “pinch” opening indicated by the maximum distance between the respective finger tips distance were computed from the recorded motion of the respective markers. Observations by the experimenter about task execution and comments from participants were recorded for each experiment for association with quantitative data

III. Results

A. *Discomfort rating*

No major discomfort or fatigue was reported in the context of our experiment. Ratings were rather low; however neck and shoulder discomforts were higher for the 20° screen inclination and were also generally higher for the highest screen elevation. The average peak discomfort corresponded to a value of 2 on the 0-5 scale and discomfort tended to increase with the chronologic order of experimental conditions.

B. *Wrist, head and finger movements*

Wrist extension increased primarily with screen verticality (low inclination), as illustrated in Fig.1. The order of screen height indicates that wrist extension tend to be affected also by screen elevation. However, a higher elevation may reduce wrist extension induced by screen inclination, as indicated by a significant elevation-inclination interaction.

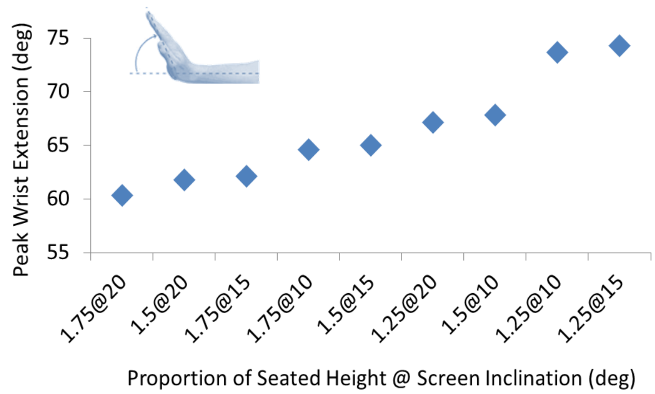

Figure 1. Wrist extension as a function of experimental conditions (screen elevation and inclination).

Wrist rotation tended to increase primarily as a function of screen height, as illustrated in Fig.2.

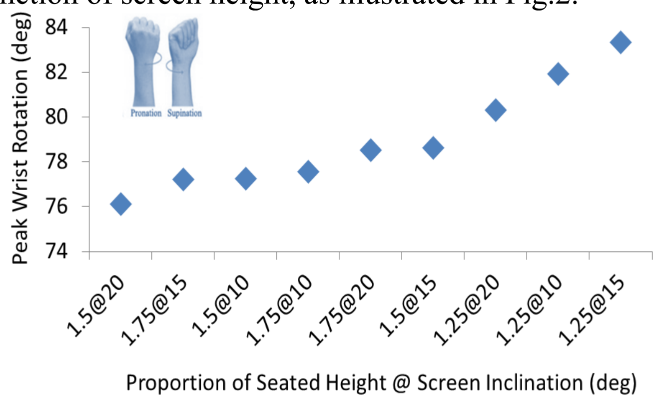

Figure 2. Wrist rotation as a function of experimental conditions.

Neck flexion seems to be higher for the lower screen inclinations (more vertical), particularly for the lower screen elevation as illustrated in Fig.3.

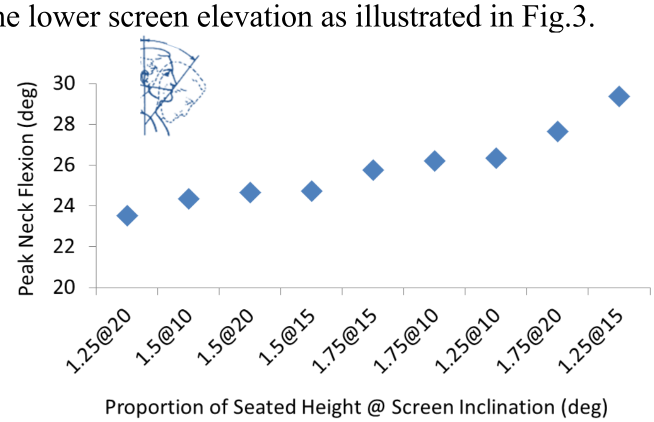

Figure 3. Neck flexion as a function of experimental conditions.

Index finger displacement relative to the thumb ranged from 11.75 cm to 12.9 cm; however,

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movement patterns did not appear to be associated with specific experimental conditions (Fig.4). Furthermore, task duration and thus movement repetition increased significantly (up to 5 fold) when position and scaling precision were required.

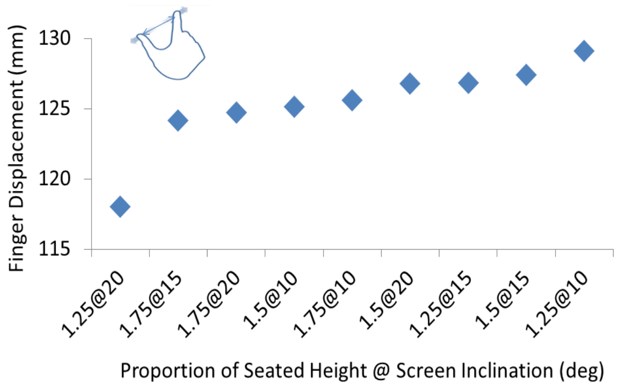

Figure 4. Thumb-index finger maximum distance as a function of experimental conditions.

C. *Survey*

Comments from the participants indicated that object placement and size scaling were very/extremely difficult to achieve when high precision was required (100% of participants). In addition, a delay between finger movements and object movements, as well as parallax associated with the distance (although only a few mm) between the touch screen and computer screen were frequently cited (70% of participants) as factors affecting performance.

IV. DISCUSSION

The results indicate that discomfort was not an issue in the context of our experiment; however, the influence of screen elevation and inclination on wrist posture was significant and showed expected interactions. In addition, delay and the need for precise manipulation contribute to an increase in the number of movements necessary to complete the tasks. Furthermore, multi-touch operations, such as size adjustment, frequently required hand repositioning to re-initiate a gesture.

Discomfort (or muscle fatigue) was moderate in the present context; however the tendency of discomfort to increase with time, as indicated by a sequential order effect suggests that prolonged “manipulations” may lead to the development of fatigue, even if finger forces required to move the fingers are very low [9]. In this experiment, the participants could rest their arm on the armrest at anytime. They could also use the bottom edge of the screen as a wrist support (1) in between tasks, (2) when manipulation of the object did not necessitate vertical displacement of the wrist, or (3) when inclination of the screen permitted such posture / use of support reaction forces. No specific instruction was provided; hence the participants adopted strategies associated with muscular effort minimization, as is the case in posture control [10]. However, these “support/anchoring” strategies are highly dependent on the availability of support and environmental context in which the instrument is used. Furthermore, the participants were not time constrained and benefited from rest periods while the screen position was adjusted for each condition.

Not surprisingly, wrist extension and rotation were influenced by both screen elevation and inclination. In addition, it may be assumed that influences from task specificities are very likely since different gestures (finger movements) require wrist and arm coordination as a function of the direction of the movement. A more detailed analysis based on a larger number of repetitions for each task would be necessary to determine more precisely optimal screen location to minimize large deviations from neutral joint postures. Nevertheless, the present results indicate that touch screen manipulations on vertically mounted instruments may induce significant wrist deviations, which are considered a risk factor, especially when sustained or combined with high repetition [7]. Furthermore, repetition seems to be promoted by accuracy requirements, at least when simply duplicating manipulation methods used to operate hand held devices.

Variations in neck flexion with screen elevation and inclination have been associated with maintaining the line of sight in computer tasks [11-13]. However, in the present context, these variations may reflect an optimization of head orientation to improve visual guidance of hand movements [14].

Overall, postural adjustments seem to be driven by the environmental conditions and the manual task to be performed, which differ from classic visual capture of information from a video screen.

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