Investigation of Subjective Preferences in Multiple Degrees-of-freedom Inputs

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ABSTRACT
With the rapid proliferation of a wide range of input devices, there are many choices in designing or selecting a 6DOF input device. User perception of the devices is an important aspect of design. We complement existing literature on the influence of grip of dominant hand on performance times with our experiments on the influence of grip of non-dominant hand on perceived ease-of-use, control and fatigue. Our results show that for the non-dominant hand, the finger grip is perceived as being easy to use, less fatiguing and more controllable.

Keywords
Fatigue, Ease of Use, Control, Multiple Degrees of Freedom, 6DOF, 3D interface, Input devices.

INTRODUCTION
Today's market place is filled with a plethora of input devices. These devices range from the simple 2D mouse to different kinds of 3D input devices. While performance measures such as task completion time and root-mean-square error give us first-order cues about the performance of these devices, they do not tell us much about how people feel about these devices. When dealing with high degrees-of-freedom (DOF) input devices or two handed input devices, these measures fail to capture the complete quality of input performance [1]. Ease-of-use, perceived sense of control and fatigue can also be used as indicators in the users' preference for an input device [3].

In [2], Zhai et al investigated the influence of muscle groups of the users dominant hand on task performance times. They compared the task completion times of a precision grip device, "the Fingerball" with a power grip device, "the glove", to show that the Fingerball is significantly better than the glove. However, their subjective evaluations did not reveal any significant difference between the Fingerball and the Glove. The authors point out that this could be attributed to the different look and feel of the two devices. We are not aware of any further scientific investigations to explore the influence of muscle groups on users performance. In this paper, we report the findings of an experiment we conducted to evaluate the users subjective preferences in using three 3D input devices in their non-dominant hand.

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THE EXPERIMENT
THE TASK
The primary task of the user was to dock a cross-section picking prop called the Rigid Intersection Selection Prop (RISP) with a dark gray disk hidden inside a solid 3D model. The location of the disk is not visible through the surface rendering of the 3D model, and so the user has to navigate through the 3D model using the RISP and view the dynamically generated cross-sections of the cut to get to the location of the disk. When the user feels that s/he has successfully docked s/he can call "finished" and move onto the next trial.

INTERFACE DESIGN
The experiment was run on the Visual Interaction Platform [3]. The three different prototypes of the RISP used in this experiment were made un-tethered and non-intrusive by using wireless trackers. The only noticeable difference in the RISPs was in the grip of each prototype. Figure 1, shows the different prototypes. RISP1 has a handle, which can be gripped by the user, allowing them to use the wrist and elbow muscles to position the cutting plane. RISP3 has a tire like ball that can be held by the user between their fingers. This prototype can be handled using the finger, wrist and elbow muscles. RISP2 is in between the RISP1 and RISP3. A constraint in using the RISP is that it should always remain within the line of sight of the tracker sensor.

PERFORMANCE MEASURE
The users had to evaluate the input props based on ease-of-use, control, and fatigue using a post-test questionnaire. For each criterion the user performed three sets of ratings. Firstly, they gave individual rating for each input prop, by answering the questions "How easy was RISPX to use?" "How much control did you have when using RISPX?" "How tired did you feel with using RISPX?". The scale was from 0 to7 (very easy to very hard, total control to no control at all and not tired at all to very tired). Secondly, they did three pair wise comparisons (RISPX vs. RISPY). These two comparisons helped subjects in filling the third

Figure 1: From top to bottom: RISP1, RISP2, RISP3

set where they had to formulate an overall positioning of the three props. This final rating was used in our analysis.

EXPERIMENTAL SETUP

A within subject experiment was conducted with 12 users. The subjects performed a total of 60 tasks, 20 with each prototype. The first two were trial tasks. In order to remove the effect of learning the each subject were presented with different orders of the prototypes. The test took about 1 hour per subject. The first 15 mins were used for learning. The users were shown a video of an expert performing the same task.

RESULTS

Figure 2 shows the histogram of the subjective ranks assigned by the users for each prototype with respect to ease-of-use, fatigue and control. The RISP3 with the Finger grip was rated most easy to use, least fatiguing and most control. Statistical analysis using chi-squared test confirmed that the RISP3 is significantly easier to use (χ^2 = 19.4, p<0.01), less tiring (χ^2 = 14.64, p<0.01) and better to control (χ^2 = 14.04, p<0.01) than RISP1 or RISP2.

CONCLUSIONS AND FUTURE DIRECTIONS

The results of this experiment show that in the non-dominant hand the input prop that uses the fine muscle groups is perceived as being easier to use, less fatiguing and more controllable. This complements the results of Zhai et al [2], which showed that task performance times are better for precision grip devices in the users dominant hand. Our results also suggest that there is a strong correlation between users perceived ease-of-use, fatigue and control. However, we feel that we need more subjects to analyze this. In the future, we plan to run experiment on to gain deeper insights into the use of two-hands in 3D

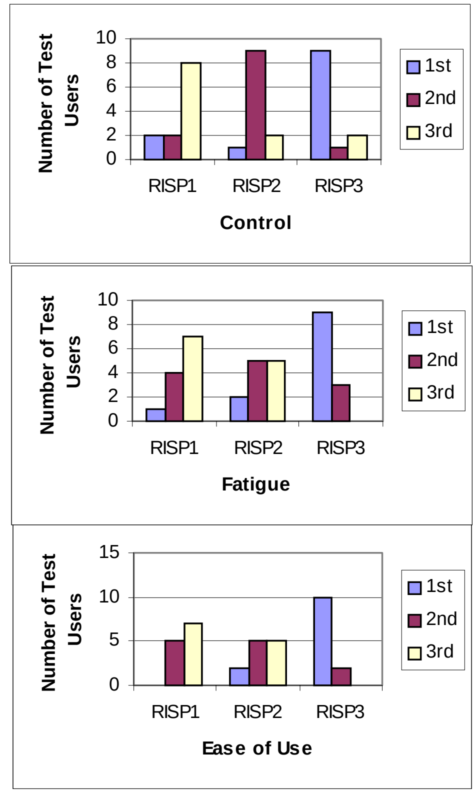

Figure 2: Subjective ranks of each prototype for different criteria

docking experiments. We also hope to be able to compare different subjective and objective performance measures to see if they actually measure different dimensions of the input design space.

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