Extending the index finger is worse than sitting:

Posture and minimal objects in 3D pointing interfaces

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***Abstract*— This study examined the relationship between objects of manipulation in interacting with an absolute 3D deictic gesture interface. Participants were given a hand-mounted 3D mouse and pointing movements were tracked by a Kinect sensor. Two experiments were run; the first in which the user either sat or stood while performing the points and the second the user's index finger was either splinted in a pointing position or left free. We found regulating the way the user pointed did not greatly change their behavior, while the seated posture impacted both the angle of the arm when pointing and the experienced fatigue.**

Keywords— "finger extension", "3D mouse", "hand gesture", "fatigue", "user satisfaction", "wearable computing".

I. Introduction

Currently, interacting with 3D visualizations or environments with common interface devices presents a problem to users. Appropriately pointing to objects or areas that may be obscured by depth or occluded by other 3D objects requires manipulation of the viewport, or a more dynamic way of pointing within the space. Common approaches to approach these issues involve additional interface features or changing perspective on top of the standard 2D methods of point and select commonly used.

Despite these shortcomings, communicating about navigation or selection in 3D space is a regularly accomplished task in day-to-day life. Communicating these sorts of tasks is done through verbal descriptions and the use of a series of common gestures; symbolic gestures to describe or demonstrate physical manipulations by performing the operation in the absence of an object, and deictic gestures that indicate the location of things through standard pointing. As consumer-end computers have become powerful enough to process images with sufficient fidelity to recognize these kinds of gestures, gesture based interfaces have begun to appear in consumer devices like the Microsoft Kinect and Leap Motion, but research into the use of these devices into direct 3D manipulation and the human factors involved remains a novel area of research.

This projects looks to explore the user experience of operating gesture based 3D pointing interfaces using some of these technologies with a novel implementation of a deictic gesture recognizer. A series of experiments based on prior work have been run to further explore efficiency of performance and fatigue experienced depending on the posture of the user and the nature of the device used in pointing.

II. Background

Non-verbal communication through gesturing is a core part of most human communication and the gestural theory of sign language and gestures predating spoken language remains a leading glottogonic hypothesis [1]. Hands and arms are perhaps the most important part of such communication and the most commonly used, though factors as minor as eye contact length and frequency [2, 3] convey meaningful information to the interlocutor. These gestures can convey many kinds of information [4]. Symbolic gestures, typically emblematic and common to a shared vocabulary within a given culture (such as a thumbs up, a wave or a salute), are best suited to atomic or specific interactions a computer can interpret and react to, while dynamic gestures performed as part of computer interaction, such as the beat gestures generated to indicate emphasis or deictic references made when referring to location or objects can provide affective information about the user or define more complex and general interactions with a system.

The former of these two approaches, using hand gestures as a command language, is certainly the most common, being moderately easy to recognize and the least ambiguous to perform and interpret. Examples include a system capable of detecting fingertips on a hand and using their relative position to define gestures such as 'grabbing' and 'selecting' objects within a 3-dimensional space for movement and manipulation [5], the use of derived hand gestures like spreading fingers and forming a fist as a replacement for a mouse in a windows operating system [6], and recognition of finger, hand and arm orientation in navigating marking menus on a television set [7]. The benefits of these systems are usually reported as a more immediate and natural method of input when compared to other computing devices, but gesture recognition can serve immediately practical purposes as well; recent research has indicated them as a viable means of input in contexts such as operating theatres [8, 9] where user sterility is a factor in interface design.

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Deictic gestures are of particular interest in gesture capture as they allow a direct and natural way of interacting with a computer screen by indicating through motion regions or locations of interest. The core function of devices like the Wii remote are in performing deictic gestures for interpretation by computers. Bolt's seminal paper of a deictic recognition system [10] describes a way of pointing at a large projected surface to create, select and move entities on the screen. A similar system of pointing capture was achieved by Fukumoto, Suenaga [11] using cameras to determine point direction rather than relying on worn devices like rings or gloves. Relative deictic input can be captured and interpreted as well; one such system includes relative movements on a display surface made by a hand wearing a special glove to determine spatial movement in a 3D display [12], and two-handed movements relative to the body to determine rotation and movement of a camera in a VR environment [13].

Ergonomics are also an important factor in gesture design, due to frequently being cited as causing fatigue but rarely quantified. A short paper by [14] found virtual object manipulation induced more fatigue than performing the same interaction on a real object. Nielsen, Störring [15] describe an approach to producing a gesture vocabulary through iteration, accounting factors such as ergonomics and efficiency of performance. This was extended on further in measuring discomfort in participants, where comfortable positions to the user are preferable to discomforting ones, even if they induce little short-term fatigue [16]. One approach described in generating gestures was providing users with the ability to generate a gesture by moving and controlling a 3D model of a hand to best represent the desired task, then attempting to perform the gesture themselves for a significant period of time in assessing its comfort [17].

III. Experimental Design

A. Research Basis

This research is based derived from the findings of a previously published paper [18] examining the relationship between the user and device in 3D deictic gesture interfaces. This previous study found that depending on the device being held in performing pointing gestures (regardless of how the gesture is being captured by the system), users will perform the gesture with a different posture and motion. Devices that the user holds that already resemble pointing devices, in this case a Wiimote encourage the user to adopt a more at rest stance and use the length of the controller to aid in the gesture. Conversely a device that does not perform this role and has no ability to be used directly in pointing, in the previous experiment a P5 Wired Glove, the user will rely on their arm and hand more heavily on ensuring the gesture is precise and on target. This occurred regardless of the form of tracking being employed; even though both approaches were tracked using camera and the users arm rather than the device itself, this trend still appeared. As a consequence, the level of fatigue participants experienced when operating the different interfaces and the speed and accuracy with which they could perform tasks was also impacted.

This led to asking the question, what factors of the design of the device and the manner with which it was presented to users actively impacted this phenomenon? In providing hypotheses to these questions, we identified the following areas to investigate:

- Controlling the posture of the user, by requiring them to either be seated or standing and seeing how this impacts the movement of their arms
- Controlling the position of the fingers on the hand, specifically when pointing with a bare hand or non-constricting device. Determining if having the index finger outstretched in the typical posture for full-arm pointing changes the way the user observes the devices.

These two questions formed the basis of the experimental trials run in this paper.

B. Setup

Our experimental setup made use of a gesture capture system designed to detect and react to absolute 3D pointing gestures; the user was placed 1.2m from a large-screen display and where they pointed at the screen would be the region of the screen they could select or manipulate.

This system was implemented using a Microsoft Kinect camera placed at the base of the display. The system made use of the Kinect's skeleton capture feature to determine the world coordinates of the users elbow and wrist joints, and used these coordinates to create a directional vector of where the user's arm is pointing. The program then calculated the point at which the vector intercepted the plane on which the Kinect camera rested, and thus where the user is pointing. The screen position was calibrated beforehand to determine exactly what position on the screen the user was pointing to; this is accomplished by the user pointing to each of the four corners of the screen. The design allowed for multiple postures and interpretations of how pointing in 3D could be accomplished while still functioning correctly; if the user preferred to calibrate the display to be larger or smaller than it actually was, the device would still recognize their method of pointing provided it remained consistent during the trial. As absolute coordinates were used, the user could operate the interface from any location as well, provided it remained within the sensors field of vision.

In our previous experiment we had used a wired glove to emulate a hands free interface; however we found that the glove was cumbersome for many users and did not fit all hands appropriately, making it a poor substitute for true hand-free experience. It was replaced in this experiment with a Neo Reflection Wireless 3D Finger Mouse, a small device worn on the side of the index finger and manipulated by pressing buttons on its outside face with the thumb of the same hand. The device includes both optical and gyroscopic mouse pointer features, but in our experiment only the mouse buttons were used, as both other features offer relative pointing rather than absolute. Determining the position of the deictic point was determined by the Kinect. This device being much smaller and not encumbering the hand was considered a close equivalent to a hands-free device, and fit a wider range of finger sizes.

The experiment itself involved performing a series of tasks in a virtual 3D environment. The simulation was designed take place in the environs of a gothic castle, with tasks themed around performing magical spells when pointing at the screen. The cursor was denoted with a small trail of stars and a larger burst would appear whenever the user attempted to select a region of the screen. There were a total of 3 kinds of task performed by users:

- The simple selection task involved simply pointing at an object displayed on the screen and selecting it by pressing the left (lower) button on the finger mouse. The objects were ghosts, which appeared in a variety of sizes and positions on the screen.
- The grab task involved picking up a metal key on a table by selecting it in the same way ghosts were in the previous trial, the holding the right (upper) button on the mouse to drag it over a lock. Once it passed in front of the lock, the object disappeared and the user would perform the task again on a different lock. The key and locks stayed the same size but moved to different positions on the screen.
- The drag and drop task involved selecting and grabbing fireflies floating in the sky, and then dropping them in a cage in the center of the screen. The fireflies appeared at different places on the screen.

While running the trials, the system recorded the speed and accuracy with which users performed the tasks presented. The recordings also captured the angle between the forearm and upper arm of the participant to measure how directly towards the screen the user was pointing- the smaller the angle, the greater the bend in the elbow and the more relaxed the users posture.

C. *Finger Splint Experiment*

The first experimental variation sought to determine whether or not controlling the manner with which users pointed with their hand but otherwise gave them free movement of their arm would change the way they choose to point. Wearing or operating a device that implies direct pointing we predicted would have the user rely on that implication and adopt a less 'direct' and more relaxed posture for pointing. Conversely, being given a less restrictive system with no such implications would encourage users to point in a more direct and less relaxed fashion due to the greater ambiguity of how the system works. These hypotheses are informed by the findings of our previous experiment.

The experiment was run with two trials. In one trial, the user would use the finger mouse while standing and without encumbrance. In the other, a splint of roughly finger-width was attached to the index finger and tied to both ends with a piece of wire. The splint held the index finger outstretched, but all other aspects of the experiment were controlled.

A total of 6 participants were run through this experiment, 5 male and 1 female between the ages of 18 and 22. All were university students, with high computer literacy, but only one reported experience with gesture-based interfaces.

D. *Standing and Sitting Experiment*

The second experiment looked to test whether or not actively controlling or modifying the users posture would impact the way they used the system. We had expected to see decreases in perceived fatigue of use and a more relaxed posture, but also a decrease in performance on account of the added constraints of movement.

In testing this, a similar setup was used as in the previous experiment. In one trial the user would be standing and operate the interface as normal, and in the second they were seated. In measuring fatigue for this experiment, users were queried about the level of perceived discomfort they felt after each trial. A hand dynamometer was also used at the end of each trial to see if there was noticeable variation in their arm strength.

A total of 6 participants participated in this trial. All were male between 18 and 29 years of age, reporting regular computer use. Two of the participants had notable experience with gesture-based interfaces.

IV. RESULTS

A. *Finger Splint Experiment*

In determining if there was a significant difference in the way the finger splint was used, a rolling average of each users arm angle was generated to determine what form of pointing was most predominant. The angles were measured and normalized on the largest and smallest angle all participants exhibited.

TABLE I. DIFFERENCE IN NORMALIZED ARM ANGLE BETWEEN FINGER SPLINT TRIALS

Participant	*Without Splint*	*With Splint*	*Difference*
1	0.479929	0.585284	0.105354
2	0.882051	0.860367	-0.02168
3	0.618639	0.657432	0.038793
4	0.898231	0.884259	-0.01397
5	0.89681	0.859148	-0.03766
6	0.530339	0.61404	0.083701

Overall, the results did not show a consistent trend for any particular orientation of the arm between the trials, but there was considerable variation in the sample ($\mu = 0.0257$, $\sigma = 0.0543$).

B. *Standing and Sitting Experiment*

A similar analysis was performed on the participants in the standing and sitting trials:

TABLE II. DIFFERENCE IN NORMALIZED ARM ANGLE BETWEEN STANDING/SITTING TRIALS

Participant	*Standing*	*Seated*	*Difference*
1	0.830808	0.766563	-0.06425
2	0.822841	0.637888	-0.18495
3	0.711392	0.697496	-0.0139
4	0.647317	0.76847	0.121154
5	0.752027	0.595249	-0.15678
6	0.583414	0.498825	-0.08459

These results showed that users had a smaller angle in their arm when seated compared to standing, hence their arms were further extended.

Fatigue of participants was also measured at the end of each trial with a rating of discomfort in the arm on a Likert scale. The scale showed in almost all cases users either experiencing no increase in fatigue or a decrease in fatigue when being seated, with an increase or no change when standing up.

TABLE III. CHANGE IN REPORTED FATIGUE AFTER STANDING AND SITTING TRIALS

Participant	*Seated Fatigue Increase (per minute)*	*Standing Fatigue Increase (per minute)*
1	-0.857143	0.25316
2	0	0
3	-2.089552	0.73171
4	-0.727273	0.27273
5	0	-0.872727
6	-1.096606	1.49254

V. DISCUSSION AND CONCLUSION

The findings of the finger split experiment suggested that users all interpreted hands-free pointing independently from the suggestion given by splinting the finger, with a wide spectrum of different pointing styles. When compared to the much more stark distinction between the hands free and wand trials from the previously run experiment, this suggests that the way the device is physically *held* seems to have a much greater impact, with a device attached to a finger not being interpreted as holding a device.

For the sitting versus standing experiment, we found that standing participants experienced more fatigue than when seated. We found that the mean angle of the elbow in pointing increased on sitting and arm was more extended. This is attributed to issues with the encumbrance of the posture. Sitting down seemed to make it harder to point both directly and casually, so users stretched their arms out to make their pointing less ambiguous. Unexpectedly, we recorded a decrease in fatigue on sitting. While we would expect less fatigue in general on sitting versus standing, as arm fatigue was being measured, we expected to see the longer and less ambiguous deictic gestures users perform in this position increase fatigue.

Our results produced two unexpected outcomes. We found no significant variation in behavior between participants in having a restrained index finger or a free to move index finger, suggesting the impact on how we position the body did not make an extensive difference into how the user viewed the interface, at least on this particular instance. By contrast, the sitting participants having a significant variation in the way they performed their points and this was inversely proportional to the level of fatigue experienced.

It can be concluded from these findings that the user's posture and body position does have an impact on how they use an interface but this depends on the nature of the constraints the device or environment place on the user. The user was able to assume the position, and may have chosen to do so when their finger was free in the split experiment, which was not the case with the sitting experiment.

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