One Hand or Two Hands? 2D Selection Tasks With the Leap Motion Device

Manuel César Bessa Seixas
FEUP,
University of Porto,
Porto, Portugal
ei09011@fe.up.pt

Jorge C. S. Cardoso
CITAR/School of Arts,
Portuguese Catholic University,
Porto, Portugal
jorgecardoso@ieee.org

Maria Teresa Galvão Dias
INESC TEC/FEUP,
University of Porto,
Porto, Portugal
tgalvao@fe.up.pt

***Abstract*—In this paper, we present the results from an experiment designed to compare two selection gestures (hand grab and screen tap) for the Leap Motion controller in 2D pointing tasks. We used the ISO 9241-9 multi-directional tapping test for comparing the devices, and we analyze the results using standard throughput and error rate measures as well as additional accuracy measures. We also present the results from the ISO 9241-9 assessment of comfort questionnaire. To complement this analysis, the computer mouse was also evaluated in order to serve as a comparison. Results indicate that the hand grab gesture performs better than the screen tap.**

Keywords-Interaction Device; Leap Motion; HCI; Pointing devices; Performance evaluation; Selection tasks.

I. INTRODUCTION

The Leap Motion (LM) controller is a 3D sensing device for hand gesture interaction. The LM is a small device that plugs to the computer via USB (it is also sold embedded in the HP ENVY Leap Motion Notebook PC and in the HP Leap Motion keyboard) and is operated by positioning the hands over the device. Through stereoscopic computer vision techniques, it is able to determine the position and orientation of the fingers of the hands, as well as the palm orientation and curvature. The controller can be used to point to a computer screen with a finger or with a tool (a pen or pencil, for example), or perform various hand gestures.

Although not meant to be a replacement of the mouse, many of the interactions with the LM involve pointing at a computer screen. There are situations where users would want or need to perform typical Windows, Icons, Menus, Pointer (WIMP) tasks with the LM, such as selecting buttons, navigating through menus and options or dragging graphical objects. Many applications in the Leap App Store are meant to give users various degrees of control over the computer, from selection and launching predefined applications and settings to scrolling content on webpages. Some applications even emulate the mouse, allowing cursor control and mouse actions [1]–[3]. Most applications that take advantage of the LM device still require users to perform typical WIMP tasks at some point (in many cases giving users the option of using the mouse or the LM device). For example, in many games users still need to select options and activate buttons; some software for surgery rooms also provides cursor control for specific functions [4].

If we assume that the LM device gains commercial traction and becomes embedded in additional laptop computers and desktop keyboards, we must also assume that it will become an additional alternative to typical WIMP tasks. In a situation where the user is operating the LM device in a specific LM task it may be faster to perform a WIMP task also with the LM, instead of moving the hand to operate the mouse.

Previous work [5] has evaluated the LM device for 2D selection tasks using a single hand for both the pointing and target selection actions. The LM performed poorly in that situation. One of the reasons that may justify the poor performance of the LM in that study is the fact that only hand was being used, forcing the user to move the pointer and select with the same hand. This may originate errors and delays in the “clicking” part of the gesture. We hypothesize that using a different hand for performing the selection gesture may improve the task.

In this work, we compare two gestures for selection tasks with the LM. One gesture uses the same hand for pointing and selecting; another uses one hand for pointing and the other hand for selecting. We also compare the selection task made with a traditional computer mouse. We used the standard ISO 9241-9 multi-directional tapping test [6] for pointing devices and calculated various accuracy measures [7] for the various selection gestures and devices. We have also used the ISO 9241-9 assessment of comfort questionnaire to get a subjective device preference, with additional questions regarding the selection gesture preference.

The contributions of this paper are: comparison of two gestures for selecting targets in 2d graphical interfaces with the LM device and a computer mouse; an analysis of the differences between pointing paths for the two LM gestures and the computer mouse; an assessment of the subjective preferences and comfort of the LM device versus the computer mouse; an assessment of the subjective user preference of the selection gesture.

The rest of the paper is organized in the following way. In Section 2, we present work that has used the LM device either to evaluate the device itself, or to evaluate new interaction techniques implemented with the LM. In Section 3, we describe the LM device in more detail. In Section 4,

 ISBN: 978-1-61208-382-7

we describe the experimental setup. In Section 5, we present and discuss the results from the experiment; In Section 6, we conclude.

II. Related Work

Previous work has addressed the LM device from different perspectives.

Weichert et al. [8] analyzed the accuracy and robustness of the leap motion controller. They performed an experiment where a robotic arm would hold a pen in its hand and was programmed to place the tip in several real world known positions. These positions would then be compared to the ones acquired by the LM controller, being the difference between each other the precision. These measures were repeated several times in order to find repeatability, for two cases: static and dynamic (with a moving pen). They found the accuracy of the LM to be less than 0.2mm for the static case and less than 1mm for the dynamic case. Weichert et al. focused on the accuracy of device itself; in this paper, we focus on the accuracy of the user performing a task with the device.

Vikram et al. [9] present a new type of user input for writing, using the LM. Using the finger position data from the LM they are able to identify characters and words written “in the air”. They propose an algorithm that is capable of recognizing gestures without pen down/pen up gestures to mark the beginning and end of a gesture. Although their interaction technique relies on users performing finger gestures, their analysis is concerned with the gesture recognition algorithm. In this paper, we address the issue of the performance of doing the gestures (for simple pointing tasks).

Nabiyouni et al. [10] performed a usability testing in order to find which of the implemented 3D travel techniques was the most efficient in bare-hand interaction. Five techniques were tested in a set of 3 tasks and the interaction was performed through the use of the LM controller. The techniques developed were based on a “Camera-in-hand” metaphor, where the Leap Motion workspace was directly mapped to the virtual world, and an “Airplane” metaphor, that, similar to driving a vehicle, had the camera always moving straightforward being the user responsible for controlling its velocity and orientation (the orientation was the same as the hand). A 3D virtual scenario, modeled as a city, was used to perform the tests. This is an example of a task that is out of the scope of our evaluation since it uses LM-specific features that are outside of the WIMP paradigm.

III. The Leap Motion device

The LM is a small input device (7.6 x 3 x 1.3 cm) developed by Leap Motion Inc., which detects and recognizes users’ hands posture and gestures (Figure 1).

Programmers can use the Leap Motion SDK (available for C++, Java, Objective-C, C#, Python, Javascript, and other programming languages) to develop applications that take advantage of the device’s capabilities.

Currently, the SDK provides high-level functions such as:

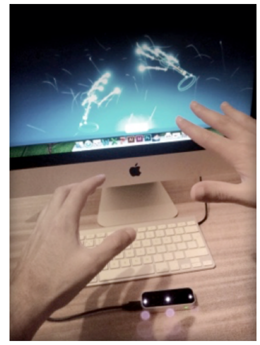


Figure 1. The Leap Motion device.

- Detection of the hands, and their 3D position in space, within the range of the LM.
- Orientation and curvature of the hand’s palm.
- Overall scale, rotation, and translation motions calculated from the movement of the hands.
- 3D orientation and position of individual fingers and normalized 2D pointing position on the screen.

Applications developed for the LM can be distributed via the Airspace store [11], an online store from which users may download applications to use with their device. Several applications are currently available, from games to productivity applications.

The LM controller can be used as a traditional pointing device, but this functionality is not included directly in the driver software. To do this, an application must be used. Touchless [2] is an example of such applications, developed by Leap Motion Inc., with versions for Mac and Windows computers. Touchless provides several ways to interact with the OS:

- By pointing with a finger, users can control the position of the mouse cursor on the screen.
- By making a screen tap gesture (i.e., moving the finger towards the screen quickly), users can perform a mouse click.
- By swiping multiple fingers in the air, users can scroll horizontally or vertically.
- By pinching the fingers, users can zoom in and out.

IV. Experiment

A. LM Gestures

We compared two selection gestures for the LM device: screen tap, and hand grab (Figure 2). The screen tap gesture consists in moving the pointing finger towards the screen and returning the original position, quickly. This gesture is supported directly by the LM SDK that provides functions to configure the gesture’s speed and motion amplitude and is an often-used gesture by applications on the Airspace store. The hand grab gesture requires two hands to point and select: the dominant hand is used for controlling the position of the pointer on the screen; the auxiliary hand is used to perform the selection by closing and opening the hand (i.e., making a fist).

To select these gestures for the experiment, we ran a preliminary session where we asked participants to try out

 ISBN: 978-1-61208-382-7

different gestures in the ISO 9241-9 multi-directional tapping test, and then collected their subjective preference regarding the gestures. In this preliminary session, each of the six participants was exposed to the following gestures: screen tap, hand grab, key tap, touch zone entered, and touch zone exited. The key tap gesture is performed with the auxiliary hand by flicking the index finger as if playing a piano key. The touch zone entered gesture uses a virtual vertical plane as a threshold: if the index finger crosses that threshold in the direction of the screen, a touch zone entered gesture is performed. The touch zone exited works in the opposite way to the touch zone entered: if the index finger crosses the threshold in the direction of the screen and than crosses it again in the opposite way, a touch zone exited gesture is performed. Participants experimented with all these five gestures and were then asked to rate them. The preferred gesture was the hand grab gesture, and the least preferred gesture was the screen tap. We thus decided to evaluate the performance of the two gestures that were rated best and worst and compare them to the computer mouse.

B. Setup

The experiment was a 3 × 5 × 7 within-subjects factorial design:

- Device {Mouse, LMScreenTap, LMHandGrab}
- Sequence {1,2,3,4,5}
- Block {1,2,3,4,5,6,7}

We configured the multi-directional tapping test with 16 circular targets, each with 13mm, in a circular layout with diameter of 180mm. The nominal index of difficulty used was 3.8 bits. The experiment was structured in “sequences” and “blocks.” A sequence corresponded to 15 target selections. A block had 5 sequences. Each participant was tested with all devices/gestures. The order of device/gesture differed for each participant according to a balanced Latin square.

We developed an application for collecting the pointer data for all devices/gestures, at 40 samples per second.

At the beginning of the experiment the participants were explained the purpose of the experiment, the task to be performed, and the devices to be used. Participants were also asked to fill in a questionnaire to determine their computer literacy and experience with the devices. Age and gender were also asked.

Participants were asked to perform the selection task as fast as possible without exceeding one error per sequence. Participants were allowed to perform practice trials until they felt ready to start the experiment and could use their preferred hand to operate the devices. Breaks were allowed between sequences.

At the end of each device’s trials we asked participants to fill in the 12 item ISO 9241-9 comfort and effort questionnaire. At the end, we asked participants which device they preferred and several questions about the LM gestures. The experiment lasted about 1 hour and 30 minutes.

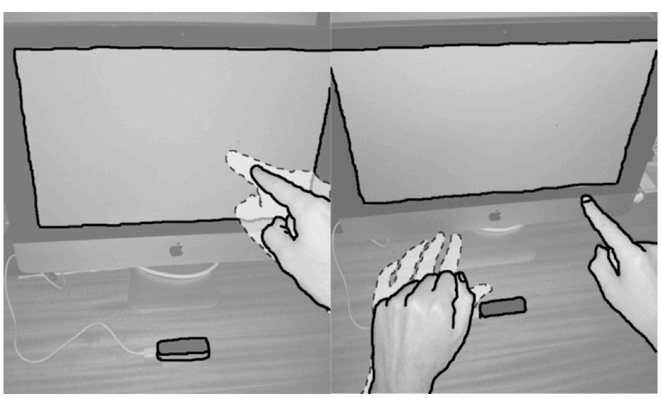
C. Participants

Nine non-paid participants (4 male, 5 female) were recruited. Their ages ranged from 10 to 35 years old. All participants were daily computer and computer mouse users (except one that stated to use the computer/mouse often). No participant had used the LM before.

D. Apparatus

We used the following hardware and software for the experiment:

- Apple Mac Mini (2.5GHz Intel Core i5, with 4GB RAM), running Mac OS X 10.8.3;
- HP L1706 LCD Display, with resolution set to 1280 x 1024;
- Genius Xscroll USB mouse, with the tracking speed set to third tick mark;
- Leap Motion device (commercial version), with tracking priority set to "Balanced";
- The Touchless software [2] for the screen tap gesture.



Screen tap   Hand grab

Figure 2. Evaluated LM gestures.

V. Results and Discussion

Raw data from the experiment and R [12] analysis scripts are available at [13].

A. Movement time, Throughput and Error rate

Figure 3 shows the movement time (in seconds) as a function of block.

To estimate the learning effect, we ran pairwise t-tests for average throughput per block (considering all devices) with a significance level of 5%. The results indicate a clear learning effect in blocks 1 to 3, so these blocks are discarded in subsequent results.

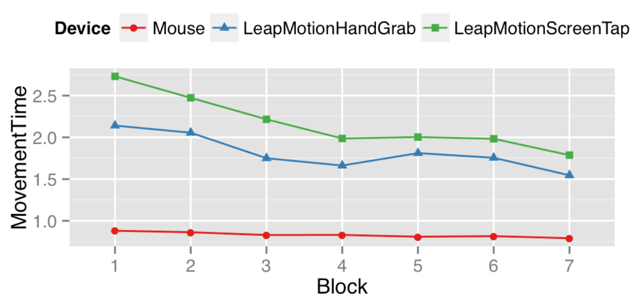


Figure 3. Movement time as a function of block.

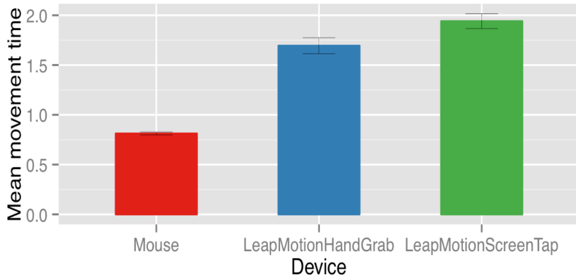


Figure 4. Mean movement time for each device/gesture.

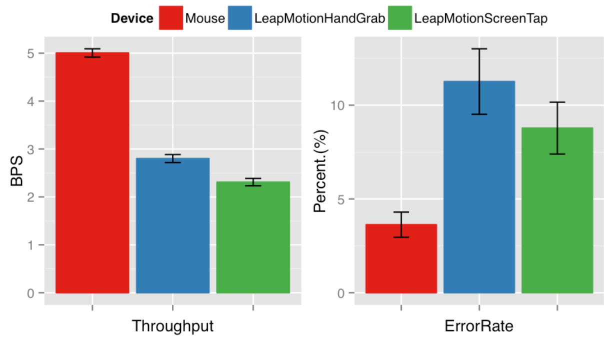


Figure 5. Throughput and error rate.

It is obvious that the mouse outperforms the LM in either gesture. The average movement time is 812 ms for the mouse, 1694 ms for the LM HandGrab gesture, and 1940 ms for the LM Screen Tap gesture (Figure 4). The average movement time for the mouse is less than half than for the LM device. Accordingly, the throughput of the mouse (Figure 5) is much higher than either LM gesture. However, it is also interesting to note that the hand grab gesture results in a faster overall movement time. A paired t-test comparing the two LM gestures shows significant differences in movement time (*t(179)=-6.0954, p-value = 6.539e-09*). The LM hand grab gesture represents a reduction in movement time of over 12% relative to the LM screen tap gesture.

The error rate for the mouse was also lower than the error rate for both the LM gestures. The differences between the two LM gestures were not statistically significant so, although the hand grab gesture seems to decrease the time needed to select an object, it does not appear to contribute to a less error-prone selection.

B. MacKenzie's accuracy measures

The Mackenzie's accuracy measures (see [7] for a description of the measures) allow us to see the differences between the devices/gestures in greater detail. Figure 6 and Table 1 shows the means, standard deviations, and F statistic for all accuracy measures. It also shows the *t* statistic comparing both LM gestures. Analysis of variance indicates that there are significant differences between devices for all measures except Movement Offset (MO). Student's t test comparing both LM gestures indicates significant differences in Task Axis Crossing (TAC), Movement Direction Change (MDC), Orthogonal Direction Change (ODC), Movement Variability (MV), and Movement Error (ME) measures.

As expected, the mouse outperforms the LM device in various measures (TRE, TAC, MDC, and ODC).

We can observe that, based in MV, ME and MO, the movement of the pointer when being controlled by the LM is quite similar to the movement of the pointer when controlled by the computer mouse. When comparing only the LM gestures, however, a few observations stand out as unexpected. The target re-entry measure (TRE), which measures the number of times the pointer re-entries the target before the selection is made, is equivalent in both LM gestures. We expected that the hand grab gesture would result in a lower TRE since the selection gesture is made with the auxiliary hand so selecting the target would not

TABLE I. MEANS AND STANDARD DEVIATIONS OF ACCURACY MEASURES FOR EACH DEVICE/GESTURE.

	Mouse		*LMHandGrab*		*LMScreenTap*			
Accuracy measure	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*F*	*t(179)*
Target re-entry (TRE)	0.10	0.08	0.37	0.25	0.37	0.30	78.4*	-0.0317
Task axis crossing (TAC)	1.61	0.34	1.92	0.67	2.24	0.67	53.1*	-5.338*
Movement direction change (MDC)	4.26	0.85	7.33	2.48	8.37	2.76	170*	-4.507*
Orthogonal direction change (ODC)	1.17	0.53	3.61	1.78	4.20	2.27	161*	-3.177*
Movement variability (MV)	20.62	7.08	26.40	13.37	21.87	7.01	11.4*	4.222*
Movement Error (ME)	20.09	5.56	21.11	10.79	17.73	5.48	9.16*	3.828*
Movement Offset (MO)	-2.46	6.63	-1.57	8.06	-1.81	5.18	0.85	0.335

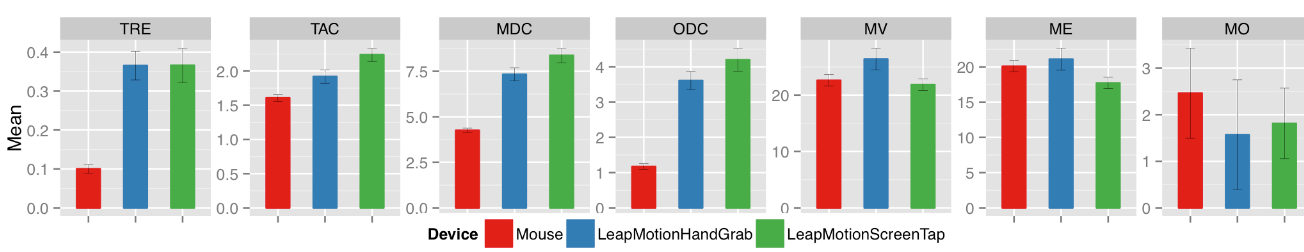


Figure 6. Accuracy measures for the three devices.

 ISBN: 978-1-61208-382-7

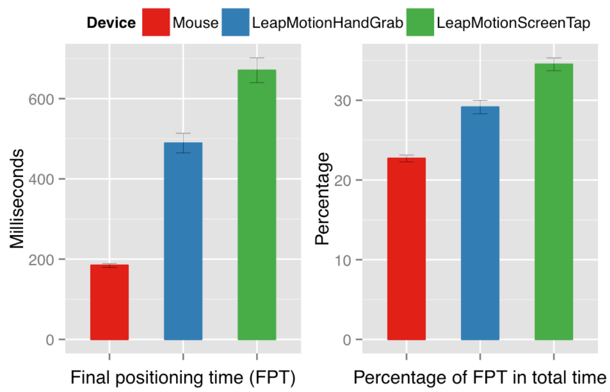


Figure 7. Final positioning time.

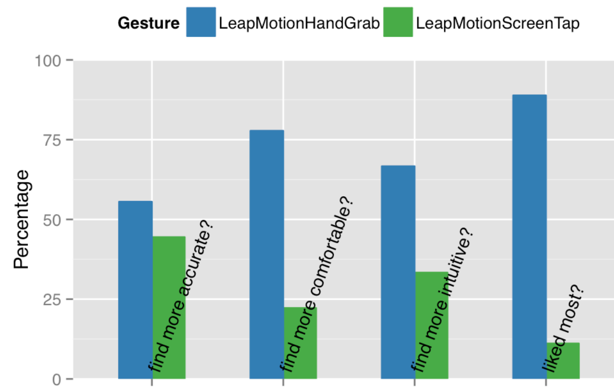


Figure 9. Gesture preference.

influence the pointer movement (as we expected to happen with the screen tap gesture). However, the results show no difference in TRE, indicating that maybe the selection gesture has little influence on the target re-entry measure, and that the higher TRE compared to the mouse is due to the pointer movement itself and not to the final selection gesture.

We also expected lower movement variability (MV) (and movement error – both are highly correlated) with the hand grab gesture than with the screen tap gesture. Again, we reasoned that because participants had separate control over the movement of the pointer and the selection of the target with the hand grab gesture it would result in more control over the pointer movement. However, the opposite seems to be true, having both hands over the LM seems to make it more difficult to control the pointer movement, resulting in a higher movement variability.

C. *Final positioning time*

To better understand the differences in the movement between the various devices/gestures, we analyzed the final positioning time (FPT) [14] for the selection task. The FPT measures the time it takes since the moment the cursor enters the target to the moment the user selects the target - we consider only the last target (re-)entry. Figure 7 shows the average FPT for the various devices/gestures in milliseconds, and the percentage that the FPT represents in the overall movement time. Again, it is clear that the mouse outperforms the LM, but more interesting to the current study it the fact that the hand grab gesture clearly reduces the FPT of the selection task ($t(179)= -10.73$, $p\text{-value}<2.2e\text{-}16$). However, it is also clear that the FPT for the LM device is still higher than that of the mouse. The difference in FPT of the two LM gestures explains most of the different in the overall movement time for the two gestures.

D. *Effort and comfort*

We also collected subjective device preferences and comfort through the ISO 9241-9 assessment of comfort questionnaire. Figure 8 shows the average scores for each question. As expected, for the evaluated task, the mouse was, in general, rated higher by participants.

E. *Users' opinion on the LM gestures*

At the end of the experiment participants were asked to indicate which device they liked best for performing this type of tasks. All the participants answer the computer mouse. We then asked participants to indicate which LM gesture they preferred by answering the following questions:

- Of the used gestures which one did you find more accurate?
- Of the used gestures which one did you find more comfortable?
- Of the used gestures which one did you find more intuitive?
- Of the used gestures which one did you like more?

Results are show in Figure 9 as the percentage of participants that preferred each gesture for each question. The results indicate a clear preference for the hand grab gesture, with only one participant saying he liked the screen tap the most.

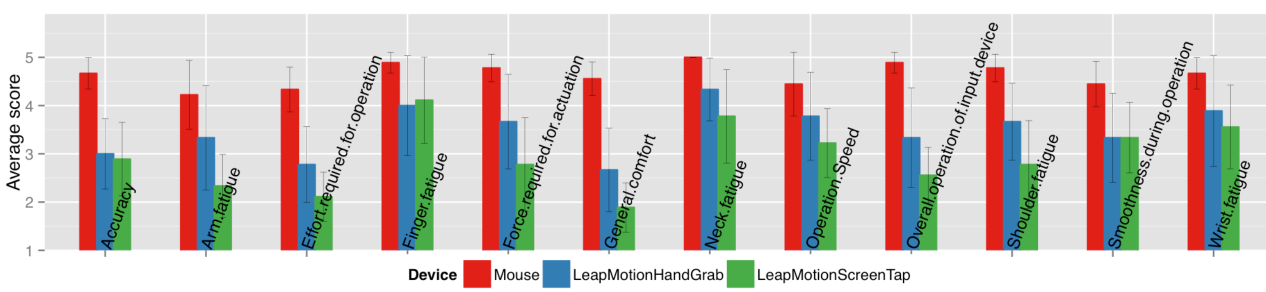


Figure 8. Average scores for the various comfort questions.

In general, participants also seem to find the hand grab gesture more comfortable and intuitive, but were more divided regarding whether any of the gestures was more accurate than the other.

VI. CONCLUSIONS

We have presented the results from an experiment designed to compare two selection gestures for 2D interfaces for the Leap Motion device. We compared the screen tap gesture to the hand grab gesture, in addition to the computer mouse.

Results indicate that the hand grab gesture that uses two hands improves the performance of the selection task when compared with the screen tap gesture. Movement time using the hand grab gesture is roughly 12% faster than using the screen tap gesture. This different is mostly accounted for by the lower final positioning time achieved when using the hand grab.

These results can be used when designing the interaction for the LM device, providing additional design options: one hand vs two hands, slower vs faster selection.

It is important to note that the comparison between the mouse and the LM is not completely fair. The mouse uses a non-linear mapping between device displacement and cursor displacement: faster movements translate to greater cursor displacement. This does not currently occur with the LM, but it would be interesting to try to implement a similar technique for the LM. It would also be interesting to evaluate and compare further selection gestures.

We should stress out that this study must be interpreted with care. We performed an evaluation of a very specific graphical interaction 2d task, for which the LM was not specifically designed. We believe that the LM may be used for these tasks, and hence it is important to know how it performs, but it is more suited for general gestural interactions, which was not the focus of the current experiment.

ACKNOWLEDGMENT

This paper was financially supported by the Foundation for Science and Technology — FCT — in the scope of project PEst-OE/EAT/UI0622/2014. We would like to thank all the participants in this experiment for their time and collaboration.

REFERENCES

[1] P. Lab, “Pointable,” 2014. [Online]. Available: https://apps.leapmotion.com/apps/pointable/windows. [retrieved: December, 2014].

[2] Leap Motion Inc., “Touchless for Mac.” [Online]. Available: https://airspace.leapmotion.com/apps/touchless-for-mac/osx. [retrieved: December, 2014].

[3] Nu-Tech, “Mudra Mouse,” 2014. [Online]. Available: https://apps.leapmotion.com/apps/mudra-mouse/osx. [retrieved: December, 2014].

[4] A. Manolova, “System for touchless interaction with medical images in surgery using Leap Motion,” in Proceedings og the 9th INTERNATIONAL CONFERENCE on Communications, Electromagnetics and Medical Applications, October, 2014, pp: 2-6.

[5] M. Seixas, J. Cardoso, and M. T. G. Dias, “The Leap Motion movement for 2D pointing tasks: Characterisation and comparison to other devices,” In Proceedings of the 5th International Conference on Pervasive and Embedded Computing and Communication Systems. Angers, France. 2015. (in press).

[6] International Organization for Standardization, “Ergonomic Requirements for Office Work with Visual Display Terminals (VDTs): Requirements for non-keyboard input devices,” ISO, 2000.

[7] I. S. MacKenzie, T. Kauppinen, and M. Silfverberg, “Accuracy measures for evaluating computer pointing devices,” in Proceedings of the SIGCHI conference on Human factors in computing systems - CHI ’01, 2001, pp. 9–16.

[8] F. Weichert, D. Bachmann, B. Rudak, and D. Fisseler, “Analysis of the accuracy and robustness of the leap motion controller.,” Sensors (Basel)., vol. 13, no. 5, Jan. 2013. pp. 6380–93.

[9] S. Vikram, L. Li, and S. Russell, “Handwriting and Gestures in the Air, Recognizing on the Fly,” CHI 2013 Ext. Abstr., 2013.

[10] M. Nabiyouni, B. Laha, and D. A. Bowman, “Poster: Designing Effective Travel Techniques with Bare-hand Interaction,” in EEE Symposium on 3D User Interfaces (3DUI), 2014. pp. 139-140.

[11] Leap Motion Inc., “Airspace store,” 2014. [Online]. Available: https://airspace.leapmotion.com/. [retrieved: December, 2014]

[12] R Core Team, “R: A Language and Environment for Statistical Computing,” Vienna, Austria, 2014.

[13] J. C. S. Cardoso and M. Seixas, “Leap Motion experiment raw data and analysis scripts - FEUP,” 2014. [Online]. Available: http://dx.doi.org/10.6084/m9.figshare.1263636. [retrieved: December, 2014]

[14] M. Akamatsu, I. S. MacKenzie, and T. Hasbroucq, “A comparison of tactile, auditory, and visual feedback in a pointing task using a mouse-type device.,” Ergonomics, vol. 38, 1995. pp. 816–827.

 ISBN: 978-1-61208-382-7