Measuring the Performance of Laser Spot Clicking Techniques

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Measuring the Performance of Laser Spot Clicking Techniques

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***Abstract*—Laser spot clicking technique is the term of remote interaction technique between human and computer using a laser pointer as a pointing device. This paper is focused on the performance test of two laser spot clicking techniques. An off-the-shelf laser pointer has a toggle switch to generate a laser spot, the presence (ON) or absence (OFF) of this spot and its combination are the candidates of the interaction technique. We conducted empirical study that compared remote pointing technique performed using combination of ON and OFF of the laser spot, ON-OFF and ON-OFF-ON, and using a desktop mouse as a baseline comparison. We present quantitative performance test based on Fitts' test using a one-direction tapping test in ISO/TS 9241-411 procedure; and assessment of comfort using a questionnaire. We hope this result give contribution to the interaction technique using laser pointer as a pointing device especially in selecting the appropriate clicking technique for real application. Our results suggest ON-OFF technique has positive advantages over ON-OFF-ON technique such as the throughput and comfort.**

I. INTRODUCTION

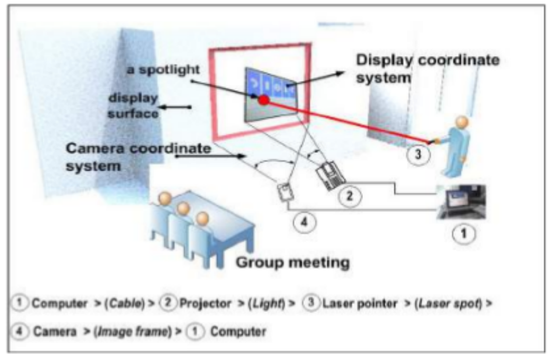
This research presents an opportunity to explore evaluation of interaction technique in laser pointer as a pointing device.

A. Background

In a group-meeting situation where a presenter is required to walk around while access computer applications easily at a distance, a laser pointer (LP) as a pointing device promises movement flexibility. Generally known that a left-clicking of a mouse is the common way to select (mark) an item or open a menu in a desktop application. This paper aims to present the performance test of two candidate laser spot techniques to perform clicking technique for interacting with large display from a distance. Therefore the result of this measurement could be used as a recommendation to select the appropriate laser spot clicking technique for emulating a mouse left-click. Figure 1(a) describes the situation where a laser pointer was used as a pointing device and Fig. 1(b) is off-the-shelf laser pointer.

B. Related Work

The laser pointer as a pointing device has been used for presentation [1]-[3] and large displays interaction system [4]-[11]. Several studies about its evaluation and clicking



(a)

(b)

Fig. 1. Laser pointer as a pointing device.

techniques will be discussed in more detail below.

1) Evaluation of Laser Pointer as a Pointing Device: Some evaluation that compares LP interaction style with another device has been done. Such as evaluation of LP with mouse in [12] showed the throughput of LP is 25% under the throughput of the mouse. In [13], LP compared to touch screen devices (SmartBoard) showed that the LP has movement time and error rate greater than the SmartBoard. Next the other evaluation is between LP and manual (hand) gestures in manipulating graphical objects [14] show that LP is fast but inaccurate in single point. As such, these results should be viewed simply regarding LP have the advantages over mice and touch screen device such as its mobility and the ability to interact with the display from everywhere in the room.

The previous evaluations were using non-standard off-the-shelf laser pointer. In [12], LP was modified by mounted into a small case and installed buttons on top of this case. The interaction techniques by continuously turn the spot on, and clicking signal action by push the button that transmit ultrasound to the PC. Thereafter in [13], a built-in laser pointer scanner in Symbol SPT 1700 Palm was used in the experiment; the spot was turned continuously on and user give click-signal by push buttons on the device. Later on in [14], the experiment conducted using wooden dowel and

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markers to substitute the real laser pointer; to simulate clicking a button on the real LP, the user occluded a smaller marker located near the thumb while image processing software process the occluded marker.

Therefore we consider it is necessary to evaluate a laser pointer using off-the-shelf laser pointer and use the casual interaction, combination of "on and off."

2) Clicking Technique using Laser Pointer: The other issue is the clicking technique in order to emulate the mouse button using spot gestures. Kim et al. in [11] and Ghosh et al. in [15], [16] use clicking techniques, namely: "single-click," "double-click," and "right-click" using the combination of the presence and absence of a laser spot. Other researchers, Kirstein and Heinrich [1], use two types clicking techniques, namely "button press" and "button release." "Button press" operation was recognized when the spot was dwell at a point to signal a press, on the other hand "release button" operation is generated if the spot is turned off for a specified time.

Laser spot was use only on the state ON and OFF to control the direction of a wheelchair to avoid obstacles [17] and to order the robot arm to retrieve certain items for bedridden users [18], respectively. In [4] and [10] there are additional buttons to simulate click action as mentioned earlier, while in [6] such information is transmitted as a mouse click by changing the modulation of the spot, then frequency-demodulation CMOS image sensor is used to translate it.

Generally, the clicking action in laser pointer interaction system was taken from the combination of state ON and OFF, and dwell at the target point. Sometimes by adding specific time after states to recognize the specific event as in [19] using 2 seconds elapsed after laser spot off to recognize "Laser Extended Off" event.

II. Evaluation of ON-OFF and ON-OFF-ON Clicking Technique

An ordinary laser pointer which is used for pointing device only has a toggle switch to generate a laser spot, therefore casually there are only spot ON and spot OFF combination could be used for interaction as proposed on [1],[11],[15], and [16]. The other technique is dwell at a point, but in [13] it was mentioned that the experiment showed the dwell time to signal a location needed to be at least one second, which would make it inappropriate for use in a timed test.

Since left-clicking is used for many common computer tasks, it needs an efficient substitute technique from LP spot. In the pilot evaluation, we have three candidate techniques: OFF-ON, ON-OFF, and ON-OFF-ON. We saw that OFF-ON technique prone to error as user could not turn the spot on the target clicked-point before visual feedback (laser spot) appear on the display surface. Finally, we elected to use ON-OFF and ON-OFF-ON technique in further studies and experiment because those two techniques ensure visual feedback for user. We will test the performance of the ON-OFF and ON-OFF-ON technique as candidates for substitute a left-clicking button of a mouse. An ON-OFF technique is done by turning on the LP and then turning off the LP on the desired items or position. In case of ON-OFF-ON technique, user turns on the LP and turns it off on the desired position and turns it on again as long as the spot is still on the tolerance area near the last off position.

We hypothesized that ON-OFF technique would be preferred over ON-OFF-ON technique. Our expectation lower at ON-OFF-ON technique because it needs pressing button twice, prone to finger fatigue, and probably there is much more hand-jitter than using ON-OFF technique.

A. *ISO/TS 9241-411*

An ISO standard exists to assist in evaluating pointing devices, ISO 9241 is a multi-part standard covering ergonomics of human-system interaction, and there are nine series: 100 to 900 series. Series 400 is the only series that discusses the physical input device. Series 400 part 411 (ISO/TS 9241-411) includes evaluation methods for the design of physical input devices. This standard describes evaluation procedures for measuring user performance for evaluating the efficiency and effectiveness of existing or new input devices, as well as suggests using a comfort-rating scale to assess comfort.

Performance is measured by task primitives on any five tasks: pointing, selecting, dragging, tracing, and free-hand input. ISO presented four tests: a one-direction tapping test; multi-directional tapping test; dragging test; and tracing test. It is not necessary for an input device to be tested on all task primitives; it is determined by the intended use of the device. However valid comparisons between two or more devices can only be achieved if the same method is used on each device [20].

Since the mouse is one of the common pointing devices, demonstrates a narrow range of reported throughput values (3.7 to 4.9 bps) [21] and is used as a baseline condition in many studies about evaluation of user input devices [12],[13],[22],[23], we will use a standard mouse as a baseline condition of this evaluation. Since the LP intended to use for pointing and selecting an item, we consider using a one-direction tapping test because this is suitable for evaluating a pointing movement along one axis and its application for selecting information in columns or rows.

The primary ISO dependent measure is *Throughput* (TP). TP is rate of information transfer when a user is operating an input device to control a pointer on a display (1). TP is expressed in bits per second (bps), and it concludes speed and accuracy measurement of a device in one dimension.

$$TP = \frac{ID_e}{t_m} \tag{1}$$

$$ID_e = \log_2 \frac{d + w_e}{w_e}; \quad w_e = 4.133 \cdot s_x \tag{2}$$

Where t_m is movement time, t_m was calculated from the initiation of movement of the input device to target selection. ID_e is an effective index of difficulty, which measures user precision required in a task, is measured in bits, and calculated from d, the distance of movement to the target and w_e, the effective target width. The w_e is the distribution of selection coordinates made by a participant during a

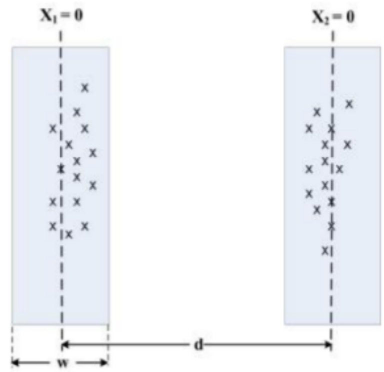

Fig. 2.The clicked-coordinate spreading.

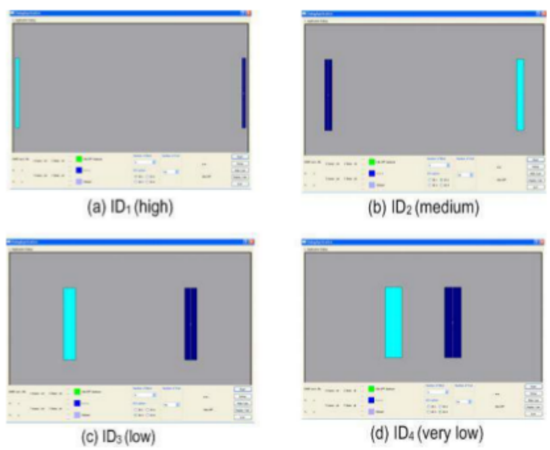

Fig. 3.Test application display.

pointing/tapping test. The s_x is the standard deviation of the tapping coordinates in the direction where movement proceeds (e.g. x-axis in a horizontal tapping test) as illustrated in Fig. 2 as a spreading tapping coordinates by a participant. In figure 2, the participants' tapping is symbolized by *x* was spread around the X_1 and X_2 axis.

ISO suggests that the test should include a variety of task precision or range of difficulty that matches the expected use of the input device. There are four precision levels based on the I_D (index of difficulty), high, medium, low, and very low, and the I_D value is $I_D > 6$, $4 < I_D \leq 6$, $3 < I_D \leq 4$, and $I_D \leq 3$, respectively. The index of difficulty for selection, pointing, or dragging tasks is as (3)

$$I_D = \log_2 \frac{d + w}{w} \qquad (3)$$

where d is the distance of movement to the target and w is the target width (see Fig. 2).

B. Method

1) Participants: We decided to recruit five graduate students as participants who were an average of 34.2 years old, all regular standard mouse users, had an average of 3.5 years

TABLE I
INDEX OF DIFFICULTY DESIGN

d (pixel)	w (pixel)	I_D (bits)	Index of difficulty level
960	15	6.02 (ID_1)	High
800	30	4.79 (ID_2)	Medium
500	50	3.46 (ID_3)	Low
250	70	2.19(ID_4)	Very low

of LP use for presentation, and all of the participants are right-handed.

2) Design: We conducted a within-subject design and reduce the learning effects by randomizing the order of the level of difficulty (I_D level) for each participant and we conduct a sufficient practice session to ensure that learning effects are stabilized. The experiment used two devices: a standard mouse and a laser pointer. However the LP was treated as two devices, since it was tested in two modes: using ON-OFF technique and using ON-OFF-ON technique; there are four I_D levels, four blocks per I_D level, and 50 trial (tapping) per block for two rectangles. Therefore for five participants, the design is 5 x 3 x 4 x 4 x 50; the total number of trials in the experiment was 12,000.

In order to test whether or not a laser spot clicking technique would be better than others and measure its performance, we developed a one-direction tapping test application to test between ON-OFF, ON-OFF-ON technique and a standard mouse as a baseline condition. This test application will record two dependent variables, time to complete each block and tapping coordinates. The independent variables in this test application are level of I_D and device.

Table I describes the design of four I_D levels, using 1024 x 768 pixels display resolution based on (3) and ISO suggestion. Figure 3(a) illustrates the test application display for ID_1 which is the difficult task; up to Fig. 3(d) illustrates ID_4 which is the easiest task for participants.

In order to assess the comfort of devices, we conduct questionnaires using comfort-rating scale for each device. This rating scale consists of assessment of comfort and fatigue questions. Furthermore, we give open questions and ask for suggestions or comments at the end of the experiment.

3) Apparatus/materials: The experiment was conducted on a notebook Toshiba R631 running Windows 7. Output was presented on a whiteboard with an 83 x 63 cm display screen using a NEC projector. We use a Logicool c525 webcam USB camera for capturing image frames. For pointing device we use a standard mouse produced by Sanwa and an off-the-shelf green laser pointer.

For this experiment we develop a test application based on Annex B of ISO/TS 9241-411 procedure for a one-direction tapping test in Qt 4.7, *an EHPE ver. 3ML software*, to record the data from input devices. The recorded data will be used to measure the performance of devices. For assessment of comfort we use the comfort rating scale as described in the Annex C of ISO/TS 9241-411.

4) Procedure: All participants were tested individually. The participant position is at 2.5 m distances from a whiteboard as a display surface. An 83 x 63 cm display screen from a projector was projected on the whiteboard for all experiments. With these setting we found that the maximum movement

TABLE II
EXPERIMENT RESULT (IN DETAILS)

d (pixels)	w (pixels)	ID (bits)	Mouse				LP ON-OFF				LP ON-OFF-ON			
			w_e (pixel)	ID_e (bits)	t_m (ms)	TP (bits/s)	w_e (pixel)	ID_e (bits)	t_m (ms)	TP (bits/s)	w_e (pixel)	ID_e (bits)	t_m (ms)	TP (bits/s)
960	15	6.02	13.79	6.14	1259	4.88	15.96	5.93	4674	1.27	16.08	5.92	4624	1.28
800	30	4.79	23.08	5.16	1210	4.26	30.59	4.76	2701	1.76	27.08	4.93	3126	1.58
500	50	3.46	37.76	3.83	963	3.98	43.53	3.64	2186	1.67	45.99	3.57	2787	1.28
250	70	2.19	45.47	2.7	759	3.56	49.81	2.59	1671	1.55	45.16	2.71	2064	1.31
960	15	6.02	13.56	6.17	1054	5.85	16.39	5.90	4336	1.36	16.95	5.85	4907	1.19
800	30	4.79	25.19	5.03	876	5.74	29.06	4.83	2640	1.83	26.83	4.95	3176	1.56
500	50	3.46	35.01	3.93	988	3.98	41.61	3.70	2107	1.76	38.34	3.81	2598	1.47
250	70	2.19	45.2	2.71	741	3.65	47.28	2.65	1696	1.56	50.30	2.58	1893	1.36
960	15	6.02	13.31	6.19	1090	5.68	16.18	5.91	4115	1.44	16.06	5.93	4756	1.25
800	30	4.79	25.64	5.01	870	5.76	26.22	4.98	2630	1.89	26.76	4.95	3216	1.54
500	50	3.46	37.53	3.84	996	3.86	41.48	3.71	2183	1.70	35.84	3.90	2647	1.47
250	70	2.19	44.17	2.74	775	3.53	51.88	2.54	1719	1.48	53.13	2.51	1989	1.26
960	15	6.02	26.68	5.21	1092	4.77	30.07	5.04	4620	1.09	29.31	5.08	4493	1.13
800	30	4.79	23.41	5.14	863	5.95	27.67	4.90	2708	1.81	28.22	4.88	3041	1.60
500	50	3.46	35.39	3.92	968	4.05	48.28	3.51	2094	1.67	39.69	3.77	2713	1.39
250	70	2.19	46.24	2.68	781	3.43	54.65	2.48	1672	1.48	55.09	2.47	1902	1.30
		Mean	30.71	4.40	955	4.56	35.67	4.19	2734	1.58	34.43	4.24	3121	1.37

TABLE III
EXPERIMENT RESULT

Measurement	Device		
	Mouse[a]	LP ON-OFF[a]	LP ON-OFF-ON[a]
TP (bps)	4.56 (0.95)	1.58(0.22)	1.37(0.15)
t_m (ms)	955.33(158.3)	2734.47(1083)	3120.97(1038.9)
Err.rate (%)	1.78(1.58)	9.8(11.02)	11.08(7.58)

[a]mean (sd)

TABLE IV
QUALITATIVE RESULT

Assessment	Device		
	Mouse	LP ON-OFF	LP ON-OFF-ON
Comfort	5.48	3.66	3.61
Fatigue	3.91	2.71	2.71

angle of participant's wrist to do the click test is 2 deg. For mouse testing the participant was seated at a desk but for the LP test the participant was in the standing position. The aim of the experiment was explained and participant filled out a pre-experiment questionnaire, and then each participant was allowed to learn the use of the mouse and LP on the test application program until speed and accuracy did not show any improvement.

A one-direction tapping test was used to test the tapping speed and accuracy of a mouse and two kinds of LP clicking techniques. The program displayed two rectangles, in which the width and its distance depend on four I_D levels. There are four blocks per I_D level and the program will record time elapsed of every block. The task is to point and click, along one axis, within each rectangle 25 times per block. Each task session starts when the user first moves the cursor into a rectangle and actuates a button (in case using a mouse) and a laser spot clicking technique (in case using an LP). For "ON-OFF" technique, a participant turns on the LP and points its spot into the rectangle and then turns off the LP on

the desired position. In case of "ON-OFF-ON" technique, participant turns on the LP while pointing its spot into the rectangle and after that turns off the LP and turns it on again as long as the spot is still inside the rectangle while the program records its coordinate. An error occurred if the user tapped outside the rectangle or a rectangle was tapped twice. For the first one, we will count it as an error by providing a beeping sound when the error occurred. We informed participants to work as quickly and accurately as possible.

C. *Experiment Results and Discussion*

1) Analysis of fit: We did regression analysis of movement time for all trial for mouse and two LP clicking techniques. By using ID_e as a predictor variable shows R^2=0.59, R^2=0.79, and R^2=0.86 for mouse, LP ON-OFF, and LP ON-OFF-ON respectively. Figure 4 shows regression for data in Table II. An initial observation is that clicking techniques with both LP ON-OFF and LP ON-OFF-ON seem conform to Fitts' law, as is evident by the high values of R^2.

2) Throughput: Throughput (TP), in bps, provides a valid measurement of the speed and accuracy of participants in each task as suggested by the ISO/TS 9241-411. Table II describes the experiment result for TP, movement time (t_m) and error rate in details. Table III is the summary of Table II for our further discussion.

In these experiments the standard mouse is used as a baseline condition, having an average TP 4.56 bps, while the TP of ON-OFF technique is 1.58 bps. This is 65% under the TP of the mouse. Throughput ON-OFF-ON technique is 1.37 bps, which is 70% under the TP of the mouse. It found that the TP of ON-OFF is 13% above the ON-OFF-ON technique. The TP difference between mouse and ON-OFF technique is statistically significant (t_{30}=12.20, p<0.01) as well as the difference between mouse and ON-OFF-ON technique (t_{30}=13.26, p<0.01). An interesting point is that the TP difference between ON-OFF technique and ON-OFF-ON technique is also significant (t_{30}=3.16, p<0.01).

The average movement time (t_m) for mouse was 955ms (sd. 158). For ON-OFF and ON-OFF-ON technique, the average

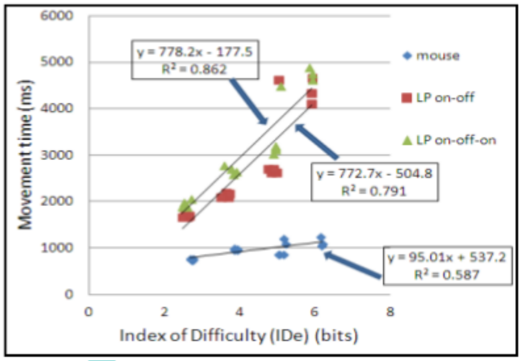

Fig. 4.Scatter plot and regression lines for data in Table II.

t_m was 2734ms (sd. 1083) and 3121ms (sd. 1039) respectively. The t_m difference between mouse and ON-OFF technique is significant (t_{30}=6.50, p<0.01) and also mouse and ON-OFF-ON technique (t_{30}=8.24, p<0.01). The t_m difference between ON-OFF and ON-OFF-ON technique is not significant.

Finally, we compare these results with other publications in performance for mouse device. Our mouse TP is 4.56 bps. This result confirms the findings presented in the literature [21] where the range of mouse TP is 3.7-4.9 bps and also reported in [22] where the range of mouse TP is 3.0-5.0 bps. From this result we ensure that our experimental apparatus, procedures, data collection, analysis, etc. likely uses the same technique as the other publication. For t_m, we found that there is a significant difference between the mouse and LP, and we confirm this result as presented in [12].

3) Error rate: Error rate (miss ratio) is the percentage of selections with the pointer outside the target. In this experiment we measured the error rate in order to be able to analyze the input devices more completely, even though error rate analyses are not mentioned in the ISO/TS 9241-411. We analyze error rate using I_D as a repetition as illustrated in Fig.5 and Table III.

Error rate is closely related to I_D. ID_1 is the difficult task while ID_4 is the simplest, as expected error rate for ID_4, which is the lowest for each device. We found the unique difference between devices; only the error rate of mouse and ON-OFF-ON technique was significantly different (t_6 = 2.46, p< 0.05). There is no significant difference between error rate of ON-OFF and ON-OFF-ON technique. From this it is notified that the error rate for the ON-OFF-ON technique is 84% greater than the error rate of a mouse.

4) Qualitative evaluation: We use an independent rating scale that contains twelve questions listed in the ISO standard: questions 1 to 7 for assessment of comfort and questions 8 to 12 for assessment of fatigue. This evaluation is

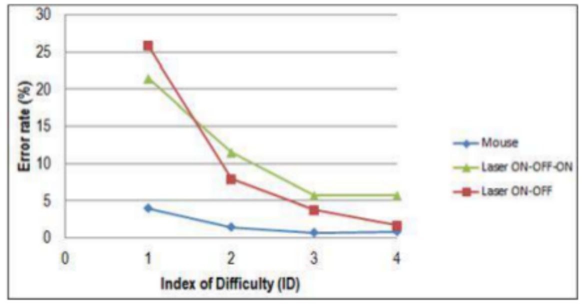

Fig. 5.Error rate by index of difficulty.

done after the participants completed a series of tasks with an input device. For each question, participants select an option 1 to 7 that best describes their impression of each input device. Option 7 is the best impression. Table IV shows the result of this questionnaire. The minimum value is 1 and maximum is 7. The average of comfort of ON-OFF technique is slightly higher than ON-OFF-ON technique.

Furthermore, we asked participants to give some suggestion. The important comment was to include the fatigue of eyes in the questionnaires due to the laser spot brightness, not only the fatigue of the finger, wrist, arm, shoulder, and neck. We will use this comment for questionnaire modification in the future. The other comment is about ID_1 task, which is very hard and may be impossible using an LP for this task. The interesting comment is that participants like to use the laser as an input device because of its flexibility of movement while accessing the PC at a distance and some participants feel interest in using a new pointing device.

D. Discussion

The result of our throughput and error rate comparison between the mouse and two clicking techniques from LP is that the two techniques are significantly below the mouse. Similarly there is a significant difference in throughput between ON-OFF and ON-OFF-ON technique. Since throughput related to movement time and precision, we found that the throughput of ON-OFF technique was 13% above ON-OFF-ON technique. Although the error rate difference between ON-OFF and ON-OFF-ON technique was not significant. However ON-OFF-ON technique have error rate 84% greater than mouse. It seems that this technique was prone to error.

Since the ON-OFF technique has positive advantages over ON-OFF-ON technique such as the throughput and comfort, we consider use of this laser spot ON-OFF gesture to emulate a left-click action in the real application.

One of the comments of participants is that ID_1 is the hardest and impossible for an LP device to fulfill the task. Since the width of the rectangle in ID_1 is 15 pixels, we thought that it was not an appropriate task for an LP because the laser spot size is around 10 x 10 pixels. We also compare this result with other publications [13], and it was stated that participants could not turn the spot on where they wanted, could not hold it still where they wanted, and could not turn it off where they wanted. There are at least 3 to 4 pixels of

TABLE V

THE COMPARISON TABLE OF ID_1 EFFECT

	Mouse			LP ON-OFF			LP ON-OFF-ON		
	w[b]	wo[c]	Im[d]	w[b]	wo[c]	Im[d]	w[b]	wo[c]	Im[d]
TP (bps)	4.56	4.31	-5.48	1.58	1.68	6.33	1.37	1.43	4.38
t_m (ms)	955	899	5.86	2734	2167	20.74	3121	2596	16.82
ER[a] (%)	1.78	1.03	42.13	9.80	4.47	54.39	11.08	7.63	31.14

[a]Error rate, in %

[b]w: analyze using ID_1 to ID_4, represents in mean

[c]wo: analyze without ID_1, represents in mean

[d]Im: the percentage of improvement, in %

wiggle room, which implies that widgets designed for laser interaction must be fairly big. Next, we explore the t_m data more deeply and analyze it using block repetition and found that all t_m in ID_1 is significant different to t_m on other IDs for LP but not for the mouse. We try to analyze data by omitting ID_1 in order to compare the results with the previous one. Table V describes the difference between the original experiment and after omitting ID_1 data. As we can see in the percentage improvement column for LP, there is a positive improvement after omitting the ID_1, especially on the error rate. Through this experiment we found that it is better that the widget's minimum width for LP pointing interaction system is approximately 30 pixels as in ID_2 if the participant is in 2.5 m distance from the display surface.

III. CONCLUSION

In this paper we have discussed the need of clicking technique for interacting with large display using laser pointer spot; developed and evaluated two kinds of clicking techniques using ISO procedure. Finally, we found that the throughput and user comfort of ON-OFF clicking technique is superior to ON-OFF-ON clicking technique in selecting object task. It seems that two techniques are likely different. Improvement in such variation of interaction techniques using laser pointer will be the direction of the future work.

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