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The performance of mouse pointing and selecting for pupils with and without intellectual disabilities

Yun-Lung Lin [a], Ming-Chung Chen [b,*], Yun-Ting Chang [b], Chih-Ching Yeh [a], Ling-Fu Meng [c]

[a] Graduate Institute of Information and Computer Education, National Taiwan Normal University, Taiwan, ROC [b] Department of Special Education, National Chiayi University, 300, Syuefu Rd., Chiayi City 60004, Taiwan, ROC [c] Department of Occupational Therapy, Chang Gung University, Taiwan, ROC

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ABSTRACT

The purpose of this study was to compare the performance of mouse pointing and selecting in the tasks with different index of difficulty between 20 pupils with intellectual disabilities and 21 pupils without disabilities. A mouse proficiency assessment software was utilized to collect data. Pupils with intellectual disabilities executed tasks more correctly in bigger target even in tasks with the same index of difficulty. The group with intellectual disabilities performed worse in cursor control even when only those correctly completed tasks were used for comparison. However, a similar pattern was observed in the performance of the group without disabilities.

1. Introduction

Computers play an important role in learning for students with intellectual disabilities. Past studies have demonstrated the effectiveness of computerized instruction for such students in aspects concerning functional academics leaning, social skills, and vocational skills (Abbott & Cribb, 2001; Holzberg, 1995; Li, Chen, Lin, & Li, 2003; Ritchie & Blanck, 2003; Wehmeyer, Smith, Palmer, Davies, & Stock, 2004). With the development of inclusive education, more and more intellectually challenged students learn with their non-disabled peers in the regular education environment. They are required to use information computer technology in their learning activities, including doing

* Corresponding author. Tel.: +886 5 2263411x2315; fax: +886 5 2266554. E-mail address: mtchen@mail.ncyu.edu.tw (M.-C. Chen).

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exercises on the e-learning environments and searching information on the Internet. The educational software or e-learning environments are developed in graphical user interface (GUI) currently. However, previous studies have revealed that difficulties arise when intellectually challenged students interact with GUI, particularly for those with more severe limitations (Davies & Stock, 2001; Pushchak & Sasi, 2004; Wehmeyer, 1999; Wong, Chan, Li-Tsang, & Lam, 2009). Li-Tsang, Yeung, and Hui-Chan (2005) found that approximately one third of the 353 adults with intellectual disabilities they tested could use a mouse (double clicking: 31.7%; dragging: 38.8%) through requiring the participants to use the mouse to execute the double clicking and dragging tasks. But almost 90% of those with severe intellectual disabilities could not operate mouse. Meanwhile, researchers found that persons with ID (intellectual disability) could learn how to operate mouse after provided with the training intervention (Li-Tsang, Chan, Lam, Hui-Chan, & Yeung, 2004; Li-Tsang, Lee, Yeung, Siu, & Lam, 2007), even in young age (Shimizu & McDonough, 2006).

Although these studies demonstrated the effectiveness of the intervention and indicated the difficulties the disabled participants met, they failed to report accuracy and speed. Nor did they indicate whether disabled participants performed as well as their non-disabled peers in the maneuver of mouse. The lack of such vital information prevents educational software designers from properly developing user interface. Since these studies did not explore the performance in different settings, it remains unclear whether the participants can correctly execute the tasks in the settings where the target icons are enlarged or the distance between the icons is shortened. Besides, past studies did not provide information on efficiency, such like trajectory of the cursor movement, submovement, and movement variety. Therefore, it is necessary to investigate the related factors that affect the students' performance.

Basically, size of the icons/objects on the screen and the distance between the icons/objects are two of the fundamental factors that should be considered when designing user interface. Based on the principle of human computer interaction, Fitts' law illustrated that size of the object and the distance of the object decide the difficulty of task, named as index of difficulty (ID) (Fitts, 1954). ID is calculated from the size of the target and the distance between the start point and target. ID could be used to represent the size and distance of icons design on the user interface. Based on Fitts' law, the movement time should be the same if the ID of the task is the same deriving from movement time (MT) = a + b*ID. But do users with intellectual disabilities perform differently in the tasks with the same ID but different distances and sizes?

Besides, the Fitts' law only mentioned the relationship between movement time and ID of the task. It is interesting to reveal the relationship of ID and accuracy given that it can provide useful information for considering the size of the icons or menu bar and the distance between the icons on the interface by answering these questions.

Accuracy and movement time are outcome indicators for the mouse proficiency only, rather than for the causes of the differences. Understanding the causes of the performance differences could provide essential information for detecting the difficulties or characteristics of the cursor movement. Mackenzie, Kauppinen, and Silfverberg (2001) proposed seven new parameters as new measurement indicators, including target reentry (TRE), task axis crossing (TAC), movement direction change (MDC), orthogonal direction change (ODC), movement variability (MV), movement error (ME), movement offset (MO). Keates, Hwang, Langdon, and Clarkson (2002) added missed click (MC) and ratio of path length to task axis length (PL/TA). However, their studies focused on the participants with motor impairments only. In this study, accuracy, movement time, rate of PL/TA, MU and MV were used to represent the performance of the mouse pointing and selecting for the participants with/without intellectual disabilities.

Therefore, this study aims to explore the performance of pupils with intellectual disabilities in executing mouse pointing and selecting tasks with varied ID; and to compare performances between intellectually challenged students and non-intellectually challenged students. Accordingly, this study intends to answer the questions below: (1) Do performance differences exist between the groups (with/without intellectual disabilities) and between the tasks with different ID? (2) If the difference exists, do the pupils with cognitive disabilities perform differently from pupils without cognitive disabilities in tasks with different ID? (3) If the difference exists, do the pupils with disabilities perform differently in the tasks with various ID?

2. Methods

2.1. Participants

In total, 42 pupils with and without intellectual disabilities, fifth or sixth graders, were recruited from six schools in Taiwan. The experiment group and the compare group were then set up, each with an equal number of students for both gender and grade. The participants with intellectual disabilities should meet the criteria below: (1) identified as mental retardation (MR) by educational agencies; (2) no sensory or physical impairments; (3) able to follow oral instructions; (4) having computer experience with mouse;
(5) able to participate in the experiment for at least 20 min. 21 students met the criterion and participated in the experiment after parental approval was obtained. However, one of the 21 students with intellectual disabilities (a total of 6 boys and 14 girls with 11 of them 5th grades and 9 of them 6th grades; the mean age was 11.35 years old) failed to complete the experiment. The remaining 20 participants comprised 6 severe MR, 12 moderated MR and 2 mild MR based on their IQ score. In comparison, the compare group consisted of 21 non-intellectually disabled students (a total of 6 boys and 15 girls with 11 of them 5th graders and 10 of them 6th graders; mean age was 10.75 years old).

2.2. Research design

Two factors mixed design (2 x 4) were used to conduct the experiment. The between subjects factor was group, one group with intellectual disabilities and the other group without intellectual disabilities); the within subject was ID. There are four IDs generated from two distances (5 cm and 15 cm) and two sizes of square (0.5 cm x 0.5 cm and 1.5 cm x 1.5 cm). The types of the task were $ID_1 = 2.115$ (5 cm,
1.5 cm x 1.5 cm), $ID_2 = 3.459$ (5 cm, 0.5 cm x 0.5 cm), $ID_3 = 3.459$ (15 cm, 1.5 cm x 1.5 cm), $ID_4 = 4.954$ (15 cm, 0.5 cm x 0.5 cm). The accuracy, movement time, rate of PL/TA, N of target reentry (TRE), movement units (MU) and movement variety (MV) were used to represent the performance of mouse pointing and selecting (Hwang, Keates, Langdon, & Clarkson, 2004; Keates et al., 2002; Mackenzie et al., 2001; Mithal & Douglas, 1996). The definitions of these parameters are described below.

2.2.1. Accuracy

Accuracy refers to the percentage of correct responses. The correct response was observed when the mouse was clicked with the cursor in the target area. The bellow parameters were calculated from the correct task only.

2.2.2. Movement time

Movement time (MT) is defined as the time from the beginning of cursor movement to the end point while a clicking action is executed.

2.2.3. Rate of PL/TA

Rate of PL/TA is defined as the actual length of the trajectory of the cursor movement divides the distance of the task. The ideal rate of PL/TA is 1 when the trajectory of cursor movement followed the virtual line of the distance. The higher rate indicates worse efficiency of the cursor movement.

2.2.4. Micromovements

Micromovements indicate N of target reentry (TRE), movement units (MU), movement variety (MV). TRE represents the numbers of cursor reentry the target before clicking. Movement variability (MV) represents the extent to which the sample cursor points lie in a straight line along an axis parallel to the task axis. MU occurs at the phase the cursor accelerates and decelerates (Meng et al., 2007). The more of TRE, MU, and MV represent worse mouse control.

2.3. Apparatus and experimental tasks

A computerized assessment tool (CAT) for mouse proficiency developed and used by the previous studies (Chen, Chu, Wu, & Yeh, 2006; Chen, Meng, Hsieh, Chu, & Li, 2004)wereusedto measure the performance of mouse pointing. CAT was executed on an Acer laptop with Pentium M 730 processor 1.6 GHz equipped with 15 in. LCD monitor. Participants used the same optical mouse to perform the tests. The subtest of "targeting and clicking" was used. CAT system displays each single task once. The target disappears once the left button was activated either correctly or not. CAT system recorded the responses (time spent and coordinates of cursor per deci-second) automatically without feedback. The responses were used to calculate the parameters mentioned above.

The tasks required the participants to move the mouse cursor to the target and click the left button when the cursor is in the target. Four kinds of task (ID_1,ID_2,ID_3, and ID_4) displayed randomly. Each kind of task consisted of the same task in 8 directions (08,458,908, 1358, 1808, 2258, 2708, and 3158). Therefore, each participant performed 32 tasks for the experiment. CAT system ended automatically when the 32 tasks were completed.

2.4. Experimental procedure

The experiment was conducted individually in participants' school computer lab. Each participant was introduced the purpose of the evaluation and practiced to be familiar with both the procedure and mouse operating. Then in formal testing process, the participants were required to navigate the mouse cursor to the target and click as correctly and quickly as they could once the cursor was in the target.

2.5. Data analysis

The mean of the dependent variable, except accuracy, calculated from the correct response represented the individual's performance. Two factors ANOVA with mixed design was used to analyze the data. The simple main effect of the groups and ID would be examined if the two factors interaction was significant. Otherwise, the main effect of groups and ID would be examined separately. The current study used SPSS 13.0 to analyze the data. The multiple post hoc LSD tests were conducted to compare the difference between two IDs if the simple main effect or main effect examinations reach a statistical significance ($p = .05$).

3. Results

The means and standard deviation of the dependent variables for each group and IDs are shown in Table 1. The results of simple main effect testing were indicated in Table 2. The results would be described based on the dependent variables.

3.1. Accuracy

As the means indicated in Table 1, the accuracy students without intellectual disabilities performed was over 96% across the four IDs. On the other hand, the performance of the students with intellectual disabilities varied across the four IDs. The interaction between group and task was significant ($F = 4.067$, $p = .009$). The results of simple main effect testing show that there was no significant difference for students without intellectual disabilities ($F =.905$, $p =.444$), but significant difference existed for students with intellectual disabilities ($F = 5.764$, $p = .002$). The result of post hoc LSD tests shows that four conditions (ID_1–ID_2,ID_1–ID_4,ID_2–ID_3 and ID_3–ID_4) were different. The results under specific ID indicated that except ID_1 ($F =2.604$, $p = .115$) the students without intellectual disabilities performed were higher (ID_2: $F = 8.977$, $p =.005$; ID_3: $F = 6.840$, $p = .013$; ID_4: $F = 12.554$, $p =.001$).

For students with intellectual disabilities, the accuracy is higher when the target icon was presented in the same distance and bigger size (ID_1–ID_2,ID_3–ID_4) and shorter distance and bigger size (ID_1–ID_4) of course. However, when the tasks were the same ID (3.459), the target icon presented in longer distance but bigger size had higher accuracy rate. Furthermore, when the tasks presented in same size but different distance, the accuracies were not different (ID_1–ID_3,ID_2–ID_4). The results

Table 1

Variable	Group	ID_1		ID_2		ID_3		ID_4		Total
		Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean
Accuracy		0.938	0.118	0.794	0.251	0.900	0.144	0.788	0.230	0.855
	1 2 Total	0.982	0.045	0.964	0.070	0.988	0.055	0.970	0.055	0.976
		0.960	0.090	0.881	0.200	0.945	0.115	0.881	0.187	0.915
MT		1.956	0.915	3.146	1.493	3.290	1.475	4.418	1.781	3.203
	1 2 Total	0.740	0.205	1.148	0.256	1.194	0.316	1.649	0.360	1.183
		1.333	0.893	2.122	1.454	2.217	1.486	3.000	1.880	2.193
R_PL/TA		1.813	0.809	1.941	0.859	1.522	0.302	1.547	0.361	1.706
	1 2 Total	1.493	0.288	1.659	0.394	1.292	0.117	1.361	0.158	1.451
		1.649	0.616	1.797	0.670	1.404	0.252	1.452	0.289	1.578
TRE		0.090	0.158	0.446	0.517	0.216	0.230	0.581	0.602	0.333
	1 2 Total	0.030	0.055	0.110	0.155	0.054	0.085	0.162	0.165	0.089
		0.059	0.120	0.274	0.410	0.133	0.189	0.367	0.480	0.211
MU		5.525	2.043	8.566	3.027	9.409	3.728	11.951	4.593	8.863
	1 2 Total	2.406	0.788	3.765	0.688	3.718	0.774	5.168	1.149	3.764
		3.928	2.187	6.107	3.239	6.494	3.898	8.477	4.740	6.314
MV		18.803	9.597	16.181	9.248	30.285	11.224	28.647	10.778	23.479
		19.040	7.656	16.417	8.363	27.306	4.440	26.518	9.735	22.320
	1 2 Total	18.924	8.548	16.302	8.695	28.759	8.483	27.557	10.185	22.900

Group	Variable	ID_1–ID_2	ID_1–ID_3	ID_1–ID_4	ID_2–ID_3	ID_2–ID_4	ID_3–ID_4
Group 1	Accuracy MT	0.018 0.000	0.186 0.000	0.010 0.000	0.015 0.646	0.891 0.001	0.014
	TRE MU	0.003 0.000	0.007 0.000	0.001 0.000	0.032 0.290	0.300 0.001	0.000
							0.002
							0.000
Group 2	MT TRE MU	0.000 0.034	0.000 0.329	0.000 0.002	0.345 0.159	0.000 0.142	0.000
		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	0.015

The mean and standard deviation of the performance in six parameters for two groups.

meant it was not distance but the size of target that affected the accuracy for students with intellectual disabilities.

3.2. Movement time

The interaction effect was significant ($F = 10.164$, $p = .000$). The results of simple main effect testing indicated that students with intellectual disabilities and students without intellectual disabilities performed differently in all four types of task (ID_1: $F = 35.350$, $p = .00$; ID_2: $F = 36.525$, $p = .000$; ID_3: $F = 40.535$, $p = .000$; ID_4: $F = 48.777$, $p = .000$). Both students with intellectual disabilities (group 1) and student without intellectual disabilities (group 2) performed differently among the four types of task individually (group 1: $F = 25.115$, $p = .000$; group 2: $F = 104.757$, $p = .00$). For both groups, the result of post hoc LSD tests shows that except one condition (ID_2–ID_3) all five conditions were significant differently. The results supported Fitts' law again. The participants, with intellectual disabilities or not, spent more time in completing the task when the target was presented in the situation where the distance was the same but target was in smaller size. The pupils with intellectual disabilities, however, executed at a much slower pace.

Variable	Group	ID_1		ID_2		ID_3		ID_4		Total
		Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean
Accuracy		0.938	0.118	0.794	0.251	0.900	0.144	0.788	0.230	0.855
	1 2 Total	0.982	0.045	0.964	0.070	0.988	0.055	0.970	0.055	0.976
		0.960	0.090	0.881	0.200	0.945	0.115	0.881	0.187	0.915
MT		1.956	0.915	3.146	1.493	3.290	1.475	4.418	1.781	3.203
	1 2 Total	0.740	0.205	1.148	0.256	1.194	0.316	1.649	0.360	1.183
		1.333	0.893	2.122	1.454	2.217	1.486	3.000	1.880	2.193
R_PL/TA		1.813	0.809	1.941	0.859	1.522	0.302	1.547	0.361	1.706
	1 2 Total	1.493	0.288	1.659	0.394	1.292	0.117	1.361	0.158	1.451
		1.649	0.616	1.797	0.670	1.404	0.252	1.452	0.289	1.578

3.3. Rate of PL/TA

The interaction effect was not significant ($F = .274$, $p = .863$). The main effect of group was significant ($F = 5.416$, $p = .025$). The students with intellectual disabilities performed worse based on the mean (group 1 = 1.706; group 2 = 1.451), however, the difference is not huge. The main effect of ID was also significant ($F = 9.463$, $p = .00$). The result of post hoc LSD tests shows that fours conditions are significantly different (ID_1–ID_3,ID_1–ID_4,ID_2–ID_3,ID_2–ID_4). The results of the tests revealed that both groups moved cursor more efficiently in the tasks with longer distance; such observation was made even in tasks of the same ID.

3.4. N of TRE

The interaction effect is significant ($F = 4.596$, $p = .004$). The results of simple effect testing of group shows that both groups performed differently among the tasks with various ID (group 1: $F = 9.112$, $p = .000$; group 2: $F = 5.678$, $p = .002$). For students with intellectual disabilities, the results of post hoc LSD tests indicated the significant differences were ID_1–ID_2,ID_1–ID_3,ID_1–ID_4,ID_2–ID_3, and ID_3–ID_4. However, only ID_1–ID_2,ID_1–ID_4, and ID_3–ID_4 have significant difference for students without intellectual disabilities. Based on the mean of the TRE, both groups performed more overshoots in the tasks with same distance but smaller target (ID_1–ID_2,ID_3–ID_4). When the tasks were the same ID, the students with intellectual disabilities had more overshoots in short distance but smaller target (ID_2– ID_3). Furthermore, when the target were big, they had more TRE in longer distance (ID_1–ID_3), however, the performance indicated no significant difference when the target were small (ID_2–ID_4). In a word, the smaller targets resulted in worse performance.

The results of simple main effect tests of task showed that except ID_1 ($F = 2.666$, $p = .111$), the other three types of task had significant difference (ID = 2, $F = 8.146$, $p = .007$; ID = 3, $F = 9.230$, $p = .004$; ID = 4, $F = 9.441$, $p = .004$).

3.5. MU

MU represents the degree of smooth cursor movement. The interaction effect was significant ($F = 56.381$, $p = .00$). The results of simple main effect tests showed that both groups performed differently among the four types of task (group 1: $F = 28.662$, $p = .000$; group 2: $F = 71.850$, $p = .000$). The results of post hoc LSD tests showed that except one condition (ID_2–ID_3) all the five conditions are significant for both groups. The results showed that both groups produced more MU in higher ID tasks. However, the students with intellectual disabilities generated more MU in all four types of task (ID_1: $F = 42.352$, $p = .000$; ID_2: $F = 50.180$, $p = .000$; ID_3: $F = 46.873$, $p = .000$; ID_4: $F = 43.042$, $p = .000$) based on the means in Table 1.

3.6. Movement variety

The interaction effect was not significant ($F = .549$, $p = .650$). The main effect of group was also not significant. The main effect of ID ($F = 31.466$, $p = .000$) was significant. The results of post hoc LSD tests showed that except for one condition (ID_3–ID_4) all the five conditions were significant. Participant performed better when distance was shorter.

4. Discussion

The results of this study indicated that the pupils with intellectual disabilities who had mouse using experience performed worse than their peers without disabilities, although they could use the mouse to interact with the computer. The pupils with intellectual disabilities executed the tasks less accurately especially when the targets displayed in smaller size. Furthermore, for pupils with intellectual disabilities, the results also revealed that the rate of accuracy was different when ID was the same. They performed more accurately in tasks with longer distance but larger target size. CAI applications that take advantage of multi-media and GUI designs could have large potential benefits, but will likely be ineffective if not developed according to appropriate interaction design. Complex media combinations of the software may constrain person with intellectual disabilities to interact with computer. The finding suggests that application developers need to prioritize the size of icons and appropriate icon spacing when designing the interface of CAI software and e-learning programs for them.

Since the Fitts' law is based on the assumption that the error rate is less than 4% (Soukoreff & MacKenzie, 2004), the performance of the participants without disabilities fitted the assumption. However, the participants with intellectual disabilities did not. Taking this fact into consideration, and to ensure that the results of testing of movement time were in accordance with the principle of Fitts' law and the movement time was related to the task's index of difficulty, the authors decided to use only the data generated from tasks which disabled participants performed correctly.

The ratio of cursor trajectory and the distance of the task represent the efficiency of the cursor moving. The results of the ratio tests demonstrated that pupils with intellectual disabilities performed less efficiently. However, the performance of the two groups was not of huge difference.

The performance of micromovements showed the similar pattern between the two groups among TRE, MU and MV. Although ID affected the performance of micromovements, the participants with intellectual disabilities controlled the mouse better in tasks with larger size. For example, the number of target reentry (TRE) was smaller in ID_2 tasks than in ID_3 tasks even their ID was same.

Base on the results described above, the authors found that size of the target plays a more important role in affecting the performance of mouse pointing and selecting for the participants with intellectual disabilities. The evidence would be clearer if we focus on comparing the results of the tasks with the same index of difficulty. Furthermore, comparing the results of the ID_3 tasks in group 1 were closer to the results of the ID_2 tasks in group 2 among the accuracy, R_PL/TA, and TRE.

Although this paper demonstrated the impact of the size of the target and the difference between the pupils with intellectual disabilities and those without disabilities, the results still should be explained with caution. Because the authors only recruited the participants with intellectual disabilities who had mouse using experience. The results of this paper could not be extended to describe those who use the alternative pointing devices, e.g. trackballs, joystick. Besides, the parameters used to represent the performance, except accuracy, adopted the data calculated from only tasks which participants correctly completed. The results might not entirely reflect what the performance for the participants with intellectual disabilities is.

Future research should examine the issues mentioned above. First, the future study could recruit those without mouse proficiency to participate in the training program for mouse operating. The data of the performance should be collected during the experiment so as to investigate the situation of improvement or the effect of learning. Second, the research should recruit the intellectually disabled participants of different ages to participate in the experiment where only performance measurement is investigated or the experiment where participants are given the mouse operating training in advance. Although past studies indicated younger adults performed better, the relationship among user experience, user learning experience and their performance remains unclear. Finally, the study could explore the performance of the alternative pointers by recruiting participants who use specific devices already. It would provide more confident evidence for interface design if the results generated from the different devices are consistent.

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