Evaluation of Computer-Access Solutions for Students With Quadriplegic Athetoid Cerebral Palsy

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KEY WORDS
- assistive technology
- computer-access treatment
- human–computer interaction (HCI)
- pediatrics

People with multiple physical impairments are not capable of using proper pointer devices, thus diminishing their opportunities to communicate and learn through computers. This research design used a replicated single-case experimental approach to compare the individual performance of two students with speech impairments and quadriplegic athetoid cerebral palsy in using four different computer-access solutions (the CameraMouse, the ASL Head Array mouse emulator, the CrossScanner, and the Quick Glance Eye Tracking System). The results demonstrate statistical significance in the correlation of movement time and accuracy to the level of comfort and satisfaction, which was used to guide the selection of computer-access solutions for clinical interventions. The WinFitts and Assessment of Comfort tests used in this study can be replicated for further clinical research into computer-access systems.

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The concept of human–computer interaction (HCI) was first presented by a group of professionals at the Association for Computing Machinery's Special Interest Group on Computer–Human Interaction Conference in 1992 (Hewett et al., 1996). The concept of HCI was adopted in the present study to define the domains of computer access for people with disabilities in terms of human factors (level of comfort and satisfaction with the overall operation) and system factors (movement time and accuracy).

There are two gaps in implementing computer-access treatment for students with multiple and severe physical impairments. From the point of view of ergonomics, such students are often too physically impaired to activate mechanical input devices. Most of these students also have speech impairments, which further restrains them from accessing computers or enjoying information technology through sound-activated systems. Thus, students with multiple impairments need direct-access, nonmechanical or nonhandheld pointer interfaces (dialogue architecture) to use language-free applications (design approaches) for their learning and literacy needs. In actual practice, these nonmechanical input devices are too expensive to buy before they have been successfully tested, and no systems are available for free trial or overseas loan.

There also is a lack of comparative clinical studies to evaluate the performance of students with severe disabilities who use nonhandheld pointer interfaces. Hence, this exploratory study aims to compare the quantity output of different computer access systems in day-to-day clinical practice. Ultimately, students with special needs will benefit from an evaluation of the efficacy of computer-access solutions, because this will affect their academic, communication, and recreational needs.

Occupational therapy strives to innovatively match the residual abilities of people with severe disabilities with assistive technology that is meaningful in their daily activities. At the same time, occupational therapists must apply cutting-edge knowledge and skills throughout clinical practice and evaluation. Both therapists and clients must know the relative strengths and limitations of various available nonhand-held pointer interfaces so that the best cost-effective means can be determined (DeVries, Deitz, & Anson, 1998).

If promising results are obtained from the current study, sufficient grounds will exist to generate a large-scale clinical study of a standardized test for nonhandheld pointing interfaces for people with special needs. Thus, the goal of this pilot study was to develop a procedure for evaluating the output of computer-access systems. The results may support the expanded supply of computer-access systems for daily use by students with severe disabilities. Supplying access systems is important in terms of their potential to reduce the effects of learning difficulties and to provide access to usual computer software without adaptation.

Literature Review

Clinical Study of Computer Interface Devices

The rehabilitation literature reports efforts by researchers to develop a complete matrix by which people with disabilities can be matched with computer-access solutions. In 1994, Anson made the first attempt to develop a decision guideline to match people with disabilities and computer access technology. He suggested a group of mouse emulator solutions—such as head mouse, eye mouse, or Morse code input—for people with severe disabilities, and he concluded that therapists should make their final choice based on experience and adaptation (Anson, 1994). Hwang (2001) developed a matrix for matching people with upper-limb functional limitations with special access devices, according to the existing abilities of the users. His result also suggested a group of systems, such as an eyegaze virtual keyboard or sip-and-puff device. Hwang did not say which would be the best solution but did suggest that Fitts' Law was a valid model for evaluating computer-access solutions. Fitts' Law is a model of human movement time from one point to another that Paul Fitt developed in 1954 (Shneiderman, 1998). Soukoreff and MacKenzie (1995) then developed evaluation software to run the Fitts' Law assessment on PCs in DOS mode in 1995. In 1999, they further developed the WinFitts test (a multidirectional point-and-click test that runs on the Windows operating system) for the implementation of ISO 9241-9, which is the international standard for "Ergonomic Requirements

for Office Work With Visual Display Terminals (VDTs)—Part 9" (International Organization for Standardization [ISO], 2000).

These studies, however, may not reflect the time limit of matrices—the supply of equipment may change from time to time—and indicate that much work remains to develop a special or universal design for computer access. So far there is no valid test to compare the efficacy of the different systems within a group solution. Therefore, a valid evaluation test and procedure for evaluating special access systems for within-subject comparison among a group of suggested systems is important for clinical practice.

A comparison of related studies on keyboard interfaces is summarized in Table 1. These studies used single-case, repeated-measure designs to compare the typing speed of handheld mechanical devices. No standard test was used to measure speed, accuracy, and exertion.

The most recent studies concerning visual tracking interfaces are summarized in Table 2; however, most of the participants in these studies were people without disabilities, and there was no standard test to compare the effectiveness of different interfaces. The typing test is a common tool for speed testing, but the content is not yet standardized. Moreover, typing English sentences might not be representative of the way in which pointer devices will be used to access computers. Hence, rehabilitation professionals do not have a common platform for within-subject or intra-group comparisons to decide which test or system is the best choice for people with special needs.

MacKenzie (2002) suggested that most evaluations of input devices are based on comparative studies and that a single-case repeated measure may be a guide to investigating the acquisition of skill over multiple sessions of practice with different systems. This method has the advantage of allowing those who work directly with people with disabilities to quickly obtain more reachable data to continue or discontinue the implementation of computer access for their clients (Kazdin, 1998). It also hints at the possibility of running a large-scale group comparative study if the initial findings from a single-case study can support further hypothesis testing.

ISO 9241-9

In 2000, the International Organization for Standardization (ISO) introduced the complete ISO 9241-9 document as the standard for "requirements for nonkeyboard input devices." ISO 9241-9 consists of tests that evaluate the performance, comfort, and effort required in the operation of common hand-operated devices for people without disability (Douglas, Kirkpatrick, & MacKenzie, 1999). The evaluation has two parts: system factors and human factors.

Table 1. Recent Studies of Comparison Among Different Mechanical Input Devices and Head Pointer

Studies	Design	Participants	Apparatus	Test	Results
"Comparing Three Head-Pointing Systems Using a Single-Subject Design" (Angelo, Deterding, & Weisman, 1991)	Single-subject design (BCD)	Total 9: • 3 with spinal cord injury (BCD) • 3 with spinal cord injury (CDB) • 1 with spinal cord injury, 1 with muscular dystrophy, and 1 without disabilities (DCB), respectively • Ages: 23–46	Head-pointing system and on-screen keyboard B = Long-Range Optical Pointer C = Head Master D = FreeWheel	Standard typing text from a typing text-book in 5 min	Head Master = Long Range Optical Pointer > FreeWheel
"Comparison of Computer Interface Devices for Persons With Several Physical Disabilities" (Lau & O'Leary, 1993)	Descriptive case-study design	4 students with severe physical disabilities • 2 with spinal cord injury • 2 with muscular dystrophy • Ages: 17–21	1. Tongue Touch Keypad 2. Head Master 3. Mouthstick	Type a sentence containing letters, numbers, and symbols keys within 15 min using on-screen keyboard	1. Speed: Mouthstick > Head Master > Tongue Touch Keypad 2. Accuracy: no significant difference 3. Exertion: Mouthstick > Head Master > Tongue Touch Keypad
"A Comparison of Two Computer Input Devices for Uppercase Letter Matching" (Durfee & Billingsley, 1998)	Single-subject design (A1, B1, A2, B2, A&B)	• 9-year-old child with spastic quadriplegia cerebral palsy with visual and cognitive deficits	A = Touch Windows B = Usual mouse	5 consecutive letter-matching tasks	Mouse > Touch Windows
"A Comparison of Two Computer Access Systems for Functional Text Entry" (DeVries, Deitz, & Anson, 1998)	Single-subject design	• Participant 1: 25-year-old person with spinal cord injury (SCI; CBCBCB) • Participant 2: 76-year-old person with SCI (BCBC)	B = Head Master C = Mouthstick Questionnaire: • Preference • Skills • Adjustment • Independence • Work endurance	Typing a narrative text for 20 min, using Thunder 7.0 and Microsoft Ghost-Writer (Macintosh version)	Participant 1: Maximum rate of text entry of 5.85 wpm with both setup Participant 2: Mouthstick (7.15) > Head Master (4.85)

Note. Long-Range Optical Pointer, Words+, 42505 10th Street West, Lancaster, CA 93534-7059; www.words-plus.com; Head Master, Prentke Romich Co., 1022 Heyl Road, Wooster, OH 44691; FreeWheel, Pointer Systems, Burlington, VT.

Evaluation of system factors. The WinFitts test is a tool for the evaluation of movement time and the accuracy of nonkeyboard pointer interface systems. It is based on Fitts' Law and was designed especially for the Windows operating system. It includes a multidirectional pointing task test (Douglas et al., 1999; ISO, 2000; MacKenzie, Kauppinen, & Silfverberg, 2001).

Evaluation of human factors. The questionnaire comprises 12 questions about the levels of comfort and effort that are involved in the operation of the system. It measures responses on a 7-point interval scale and can be used for within-group or between-group comparison (ISO, 2000).

To date, four studies have applied the WinFitts test to investigate the correlation between human factors and system factors (see Table 3). Results indicate that all of the tested handheld devices have significant differences in movement time and error rate. Furthermore, the Assessment of Comfort questionnaire (ISO, 2000) demonstrated significant correlation between the level of comfort and movement time and accuracy. Hence, the correlation table

of comfort and system factors reflects the prototype computer-access solution for people with special needs.

ISO 9241-9 not only provides guidelines for the selection of products but also develops a systematic procedure for researchers to replicate and compare results from one study to the next (MacKenzie et al., 2001). This study is the first to use the standardized test to compare the efficacy of four nonhandheld pointer interface devices for students with severe disabilities.

Methodology

Participant Selection

Two students with quadriplegic cerebral palsy with dyskinetic athetosis were recruited for the study. They were ages 13 and 15 years, had no voluntary control over all four limbs, were speech impaired, had average motor-free visual perception, had average intelligence, and were receiving mainstream educations. They could not use handheld

Table 2. Recent Studies of Comparison Among Different Visual Tracking Interfaces

Studies	Design	Participants	Apparatus	Test	Results
"Why Are EyeMice Unpopular?" (Bates & Istance, 2002)	Within-subjects design	6 people without disabilities	1. Hand mouse 2. Head mouse 3. Eye mouse (Senso-Motoric Instruments' infrared video-oculography eye tracker)	150 "real-world" tasks on Microsoft Word and Internet Explorer, using on-screen WiVik® keyboard	No overall differences. Learning time: hand mouse < head mouse < eye mouse. Experienced eye mouse users: performance should exceed a head mouse, as effectively as hand mouse.
"The CameraMouse: Visual Tracking of Body Features" (Betke, Gips, & Fleming, 2002)	Simple within group comparison	• Group 1: 20 people without disabilities • Group 2: 12 people with severe cerebral palsy or traumatic brain injury	Group 1: • CameraMouse™ • Regular mouse Group 2: • CameraMouse • EagleEyes	Test 1: Catch 10 aliens in a game Test 2: Use an on-screen keyboard to type "Boston College"	Group 1: regular mouse > CameraMouse, statistically highly significant. Group 2: able to master the CameraMouse within 2 hr, but no specific report on test result.
"Auditory and Visual Feedback During Eye Typing" (Majaranta, MacKenzie, Aula, & Räihä, 2003)	4 × 4 repeated measures	• 13 people without disabilities • With normal or corrected-to-normal vision	SensoMotoric (eye-tracking device) Feedback modes: • Visual only • Speech only • Click plus visual • Speech plus visual	4 blocks of sentences, each involving the same five short phrases of text	Mean speed of eye typing was only 6.97 words per min, which was too low for fluent text entry. Auditory feedback (click or speech) was a more effective mode for eye typing.
"Eye Gaze Interaction With Expanding Targets" (Miniotas, Špakov, & MacKenzie, 2004)	Repeated-measures factorial design	12 students with normal or corrected vision	EyeLink, an eye-tracking system requiring a head-mounting device	Grab-and-hold algorithm	Expanded target facilitated eye tracking both in terms of speed and accuracy. Limitation in accuracy of eye gaze as an input interface was amenable to techniques that increase tolerance to the inherent eye jitter.

Note. CameraMouse, CameraMouse, Inc., PO Box 3636, Abilene, TX 79604-3636; EyeLink, SensoMotoric Instruments, Inc., 97 Chapel Street, Boston, MA 02492; WiVik, Bloorview MacMillan Children's Centre, 350 Rumsey Road, Toronto, Ontario M4G 1R8 Canada.

pointer devices, so they had no previous experience with computer access. They were requested to activate the non-handheld pointer interfaces by either eye or head movement.

Setup and Apparatus

A workstation comprising a desktop computer with all of the relevant hardware and software installed was fixed on a height-adjustable arm with an 18.1-inch LCD display. The CameraMouse™ (CameraMouse, Inc., PO Box 3636, Abilene, TX 79604-3636) was named "System A" and was activated by slight body movements captured by a USB Web cam. A Head-Array Mouse Emulator (Adaptive Switches Laboratory [ASL], 125 Spur 191, Suite C, Spicewood, TX 78669)—an ASL mouse emulator that can provide solutions for power mobility, computer interfacing, and environmental control for people with severe disabilities—was designated "System B." The third system, "System C," was the CrossScanner (R. J. Cooper & Associates, 27601 Forbes Road, Suite 39, Laguna Niguel, CA 92677; www.rjcooper.com), which comprised mouse-like pointer interface software that could be easily activated by a single

click and an infrared switch that was activated by eye movement. "System D" was the Quick Glance Eye Gaze Tracker 2SH version 4.2 (EyeTech Digital Systems, 2160 E. Brown Road, Suite 2, Mesa, AZ 85213; www.eyetechds.com), a mouse replacement device that allowed the participants to place the cursor anywhere on the display by eye movement only.

Test

Under the copyright permission of the ISO, we reproduced two tests from ISO 9241-9 to compare movement time, accuracy, and level of comfort among the four systems.

WinFitts. This multidirectional point-and-click test, based on the principle of Fitts' Law [*.wfs], is a self-computing program that records the system performance, then aggregates summary data that is suitable for input into a regression program (Kirkpatrick, 1999).

Assessment of Comfort. ISO introduced this questionnaire to "provide information on potential methods of testing input devices and to encourage institutions or individuals to conduct research on these methods such that further

Table 3. Clinical Studies of the ISO 9241-9

Studies	Design	Participants	Apparatus	Test	Results
"Testing Pointing Devices Performance and User Assessment with the ISO 9241 Part 9 Standard" (Douglas, Kirkpatrick, & MacKenzie, 1999)	Between-subjects factorial design	A total of 24 people without disabilities • 12 for touchpad • 12 for joystick	1. Finger-controlled isometric joystick 2. Touchpad	1. One-direction task (Fitts test, 270 trials) 2. Multidirectional task (WinFitts, 720 trials) 3. Questionnaire (ISO standard)	Significant difference in multi-directional task (WinFitts), joystick > touchpad. No significant difference in one-direction task. Significant statistical difference in "force required to operate" only.
"Accuracy Measures for Evaluating Computer Pointing Devices" (MacKenzie, Kauppinen, & Silfverberg, 2001)	Within-subjects factorial design	12 university students without disabilities	1. Mouse 2. Trackball 3. Joystick 4. Touchpad	ISO 9241-9 (WinFitts), Total 36,000 trials	No significant difference between trackball and touchpad. Statistically significant in TRE (Target Re-Entry): touchpad > trackball. No significant difference in error rate.
"An Isometric Joystick as a Pointing Device for Handheld Information Terminals" (Silfverberg, MacKenzie, & Kauppinen, 2001)	Within-subjects factorial design	12 employees with prior experience in using isometric joystick	1. One-handed IBM TrackPoint™ 2. Two-handed IBM TrackPoint 3. Notebook TrackPoint	1. Separate selection 2. Press-to-select (total 864 × 12 trials) 3. ISO 9241-9 questionnaire	Suggested that an isometric joystick was suitable as a pointing device for handheld terminals. Separate selection button is needed to ensure accurate selection.
"An Evaluation of Two Input Devices for Remote Pointing" (MacKenzie & Jusoh, 2001)	Repeated measures factorial design	12 paid volunteers, none with prior experience of remote pointing devices	1. GyroPoint—air 2. GyroPoint—desk 3. RemotePoint 4. Usual mouse	1. ISO 9241-9 (one-direction task) 2. ISO 9241-9 questionnaire	Mouse > remote pointing. RemotePoint had the lowest error rate but was slowest in speed. Comfort: mouse > GyroPoint > RemotePoint.

Note. ISO = International Organization for Standardization; IBM TrackPoint, IBM Research Center, 630 Harry Road, San Jose, CA 95120-6099; GyroPoint, GyroPoint, Inc., 12930 Saratoga Avenue, Saratoga, CA 95070; GyroPoint, Gyration, Inc., Saratoga, CA; RemotePoint, Interlink Electronics, Camarillo, CA.

validation can be supplied" (ISO, 2000, p. 37). The Assessment of Comfort includes 12 questions: Q1—force required for actuation, Q2—smoothness during operation, Q3—effort required for operation, Q4—accuracy, Q5—operation speed, Q6—general comfort, Q7—overall operation of input device, Q8—finger fatigue, Q9—wrist fatigue, Q10—arm fatigue, Q11—shoulder fatigue, and Q12—neck fatigue. This assessment is measured on an interval scale (ISO, 2000) from 7 (highest score) to 1 (lowest score).

Design

This study was a repeated-measure, multiple-treatment design (ABCD) that applied the same procedures across two participants according to balanced Latin squares (MacKenzie, 2002). Each participant served as his or her own "control" (Law, 2002). These included

- Angles (0°, 45°, 90°, 135°, 180°, 225°, 270°, 315°), at random
- Sequence (1, 2, 3, 4, 5, 6, 7, 8), once for each angle
- Blocks (1, 2, 3, 4, 5, 6, 7, 8).

With two participants, the total number of trials was $2 \times 4 \times 8 \times 8 = 512$. Thus, the sensitivity and significance (Todman & Dugard, 2001) of this test was $1/512 \times 100 = 0.195\%$. The participants completed each phase of eight consecutive sessions (2 sessions per week), using one interface device, before moving to the next device and replicating the process for all four devices.

Internal reliability consistency for repeated measures. The validity of this study can be supported by the replication of the same subject within the same and replicated settings (Portney & Watkins, 2000). The reliability of single-case research is often reported in the form of internal reliability, which is the measure of the percentage of agreement between observers (Kazdin, 1982; Portney & Watkins, 2000). In this study, we did not have observers for the WinFitts test because it was programmed to auto-run over sessions and to computerize the results of movement time and error rates. This method provided absolutely consistent internal reliability.

The original WinFitts calibration was 8 cm × 8 cm (186 × 186 pixels), but the target size was too small for the

eye to track and was adjusted to 16 cm × 16 cm (372 × 372 pixels) onto a 32-bit high-color display with images that were 800 × 600 pixels. The distance between the home and the target was 40 pixels (17.2 mm) and the diameter of the target was 20 pixels (8.6 mm), where 1 pixel = 0.43 mm (MacKenzie et al., 2001). Hence, the display of the target size was similar to a font size of 20, the same size as the standard Windows "caption buttons." If the participants could point and click the target of the WinFitts test with any computer-access system, then they could gain access to any standard Windows applications with the interface device used. Eight targets (see Figure 1) were arranged in a circular layout.

Results

The original raw data for the WinFitts test were collected directly by the software and then transformed into two measurements: the mean movement time and the mean accuracy rate. The within-subject comparisons of the output are summarized in Table 4. No adjustments to the data were made, and no data were excluded from the trials. The ASL mouse emulator reported the best output in movement time in both cases (mean movement time of Participant 1 = 12.5 s, SD = 5.63; Participant 2 = 11.85 s, SD = 1.39). The CrossScanner with the infrared switch reported the highest rate of accuracy in both cases (mean accuracy of Participant 1 = 95.88%, SD = 11.67%; Participant 2 = 98.63%, SD = 3.76).
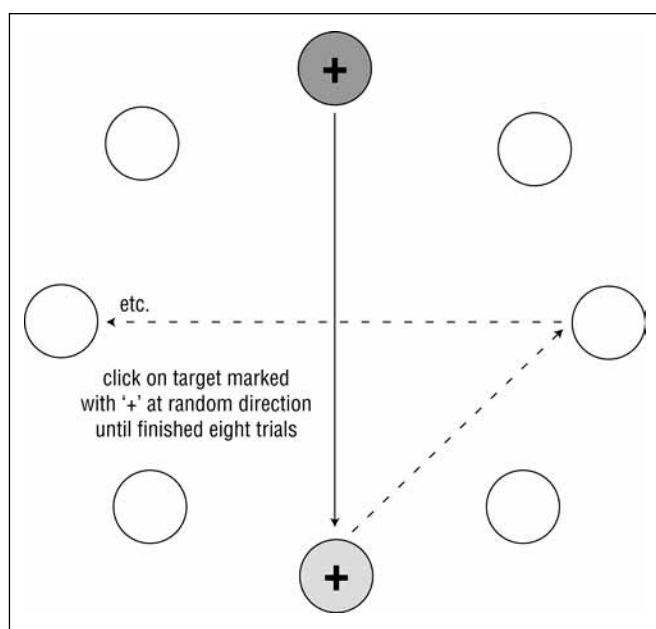
Figure 1. Overall layout in the WinFitts task of the present study (Wong & Man, 2005).

Results for Participant 1

The graphical output for visual analysis is presented in Figure 2. A dramatic drop or increase in trend and level between each phase suggested that there was no learning effect between systems. Participant 1 was unable to use Quick Glance independently in terms of precise point-and-click interactions under the experimental conditions.

The performance of Participant 1 in accessing the CrossScanner showed a statistically significant correlation, $r = -0.79$ ($p < 0.05$) between movement time (mean = 53.16 s, SD = 8.08) and rate of accuracy (mean = 95.88%, SD = 11.67). Participant 1 gave both the CrossScanner and the CameraMouse the highest rating for level of comfort (75 out of 84).

There were statistically significant correlations among the system factors and human factors of Participant 1's performance, as shown in Table 5. The results in the correlation table reflect a unique prototype of computer-access solution for Participant 1; that is, "force required for actuation" is significantly correlated with movement time ($r = 0.96$) and "effort required for operation" ($r = 0.98$), and "operation speed" is significantly correlated with "general comfort" ($r = 0.97$) and "overall operation of input device" ($r = 0.95$). Conclusively, there was no significant difference in correlation between accuracy and comfort among these three nonhandheld interfaces, which implies that Participant 1 was more concerned about movement time and comfort of use than accuracy because he had not used a computer before. According to these statistical findings, the occupational therapist should prescribe the CrossScanner to Participant 1 as an effective access solution.

Results for Participant 2

The computation result of Participant 2 in "movement time and accuracy" showed a significant correlation in the CrossScanner ($r = -0.71$, $p < 0.01$) and the ASL Head-Array Mouse Emulator ($r = -0.81$, $p < 0.05$). The negative correlation index means that faster movement time is associated with a higher rate of accuracy. The rate of accuracy of the CrossScanner was higher than the ASL Head-Array and CameraMouse. Participant 2 could not activate the Quick Glance Eye Tracking System to finish the WinFitts test. Of the four systems, Participant 2 gave CrossScanner the highest score (78 of 84) in the Assessment of Comfort.

In analyzing the repeated measure of three systems, a clinical prototype of computer-access solution for Participant 2 was drawn from her correlation table. "Neck fatigue" was statistically correlated with "operation speed" and "general comfort" at $r = 0.98$ and $r = 0.97$, respectively. This result indicated that the absence of neck fatigue would lead

Table 4. Summary of Participants' Performance in WinFitts Test Across Different Systems

	Participant 1						Participant 2					
	Movement time (s)		Accuracy (%)		Speed and accuracy		Movement time (s)		Accuracy (%)		Speed and accuracy	
System	M	(SD)	M	(SD)	(r)		M	(SD)	M	(SD)	(r)	
CameraMouse	150.70	(147.40)	28.63	(15.80)	0.54		78.63	(62.19)	51.25	(19.23)	−0.34	
ASL Head-Array	12.50#	(5.63)	66.75	(21.82)	−0.41		11.85#	(1.39)	78.63	(10.13)	−0.81*	
CrossScanner	53.16	(8.08)	95.88##	(11.67)	−0.79*		47.70	(2.34)	98.63##	(3.76)	−0.71**	
Quick Glance	—		—		—		—		—		—	

Note. # = best performance in movement time; ## = best performance in accuracy; *correlation is significant at the 0.05 level (2-tailed); **correlation is significant at the 0.01 level (2-tailed); ASL = Adaptive Switches Laboratory; — = no data for analysis.

to a faster speed; that is, the degree of neck fatigue would predict the efficiency of movement time. Regarding neck comfort, the CrossScanner was found to be most comfortable (6 of a possible 7), whereas the ASL Head Array was the least comfortable.

No significant difference existed between "movement time and accuracy" and "comfort of use," which means that the standard score of movement time and accuracy reflected the actual effectiveness of the systems. Levene's test of movement time and the accuracy of the CrossScanner and ASL Mouse Emulator were (a = 0.05) $t(14)$ = 54.98 and (a = 0.05) $t(14)$ = 8.86, respectively, which means that the null hypothesis is rejected. There was significant difference

between the effectiveness of the CrossScanner and ASL Head-Array. The ASL Head-Array had a faster movement time than the CrossScanner, whereas the CrossScanner had a higher rate of accuracy than ASL Head-Array. Hence, the ASL Head-Array and the CrossScanner were prescribed to Participant 2 for further training.

After 2 months of training with the ASL Head-Array and another 2 months of training with the CrossScanner, Participant 2 decided to use the CrossScanner because the ASL Head-Array caused intense neck pain that diminished her work endurance, movement time, and accuracy. This result is identical with the previous Assessment of Comfort: Neck fatigue will predict the system's performance.
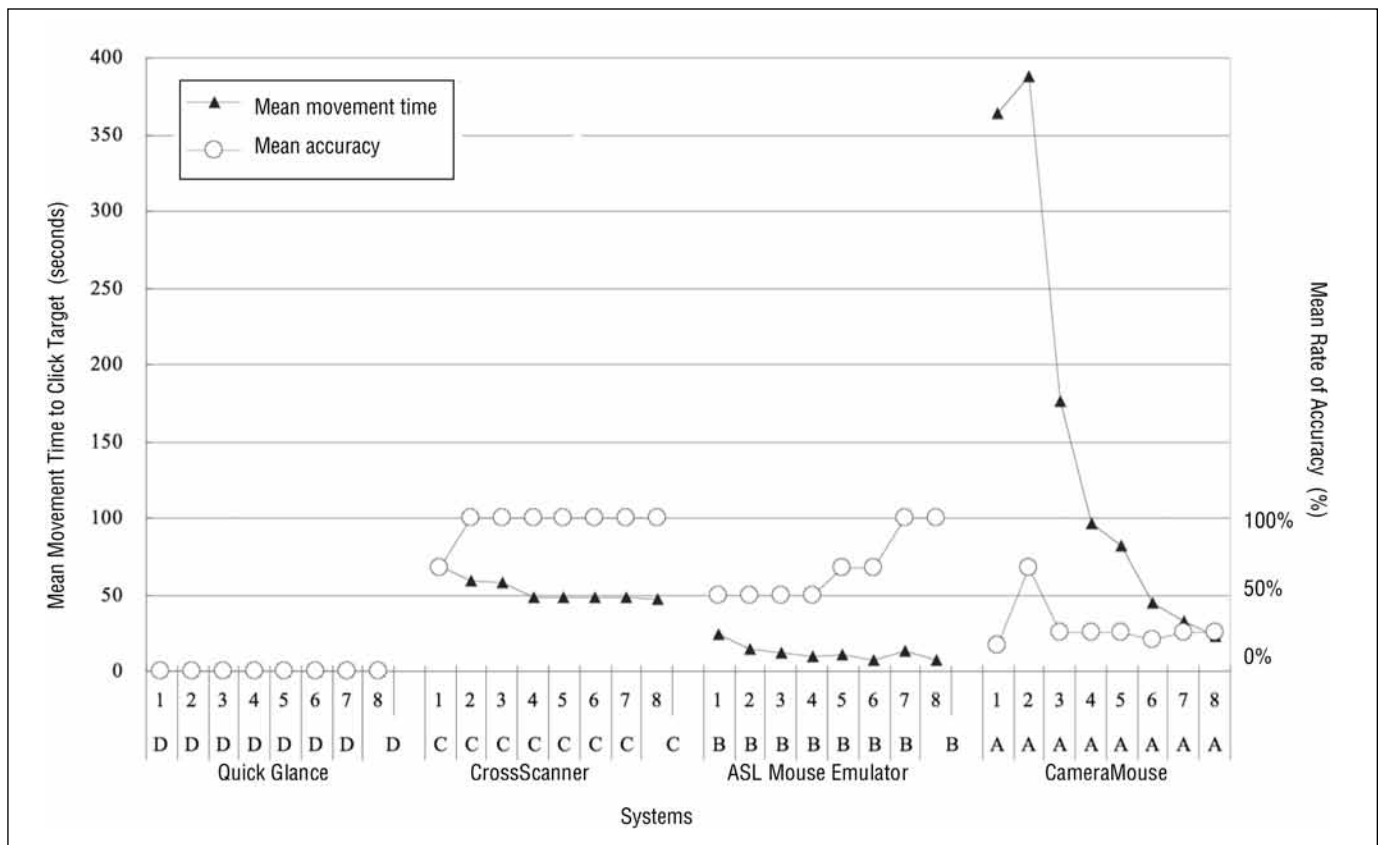
Figure 2. Graphical output of WinFitts test for Participant 1.

Table 5. Correlations Matrix of Human Factors and System Factors of Participant 1

	sdmt	sdacc	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q11
sdmt	—		Force for actuation	Smooth-ness	Effort	Accu-racy	Operation speed	Comfort	Overall operation	Finger fatigue	Wrist fatigue	Arm fatigue	Shoulder fatigue	Neck fatigue
sdacc	.284	—												
Q1	.958(*)	.020	—											
Q2	.417	.484	.391	—										
Q3	.884	−.150	.980(*)	.383	—									
Q4	−.212	.575	−.298	.757	−.313	—								
Q5	.366	.120	.449	.927	.512	.602	—							
Q6	.389	−.089	.527	.823	.620	.424	.974(*)	—						
Q7	.604	.299	.631	.951(*)	.644	.524	.954(*)	.912	—					
Q8	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	—				
Q9	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	—			
Q10	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	—		
Q11	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	(a)	—	
Q12	.636	−.265	.800	.597	.886	.000	.798	.897	.807	(a)	(a)	(a)	(a)	—

Note. sdmt = standard score of movement time; sdacc = standard score of accuracy.

*Correlation is significant at the 0.05 level (2-tailed).

[a]Cannot be computed because at least one of the variables is constant.

Summary

Although both participants were students with dyskinetic athetosis and quadriplegia who had not had previous experience in computer access, the clinical prototypes of access solutions that best suited them were different. This pilot study used the standardized WinFitts Test to evaluate the system factors and introduced a correlation matrix of the Assessment of Comfort and the system output to guide the occupational therapist to select and justify the prescription of access solution for individuals.

Discussion

Limited by the small-scale design of our study, this article focuses on the advantages and drawbacks of existing computer-access interfaces but nevertheless serves as initial evidence of the benefits of the ASL Head-Array and the CrossScanner. The CrossScanner showed the highest rate of accuracy among the four systems and across the two partic-ipants. In both cases, the CrossScanner was a reliable inter-face because it required a single action that could be trans-formed into a left click, right click, double click, or drag, according to the user's choice.

After passing the WinFitts test, the two students indi-cated that the CrossScanner could replace a mouse under the Windows operating system. The ASL Head-Array seemed to be too demanding—and in particular, too uncomfortable—for the students.

The participants could easily use the CameraMouse with head or face motions. The primary advantage of using the CameraMouse was the interface, and the secondary gain—given that both students had athetosis—was the dis-tinctive visual feedback on their postural control. Hence, the CameraMouse is an attractive consideration for postu-ral training as well as computer access for students with athetosis.

Because the capture field of the Quick Glance Eye Tracking System is limited by the transmission angle of the infrared light (see Figure 3) and both students had athetosis,
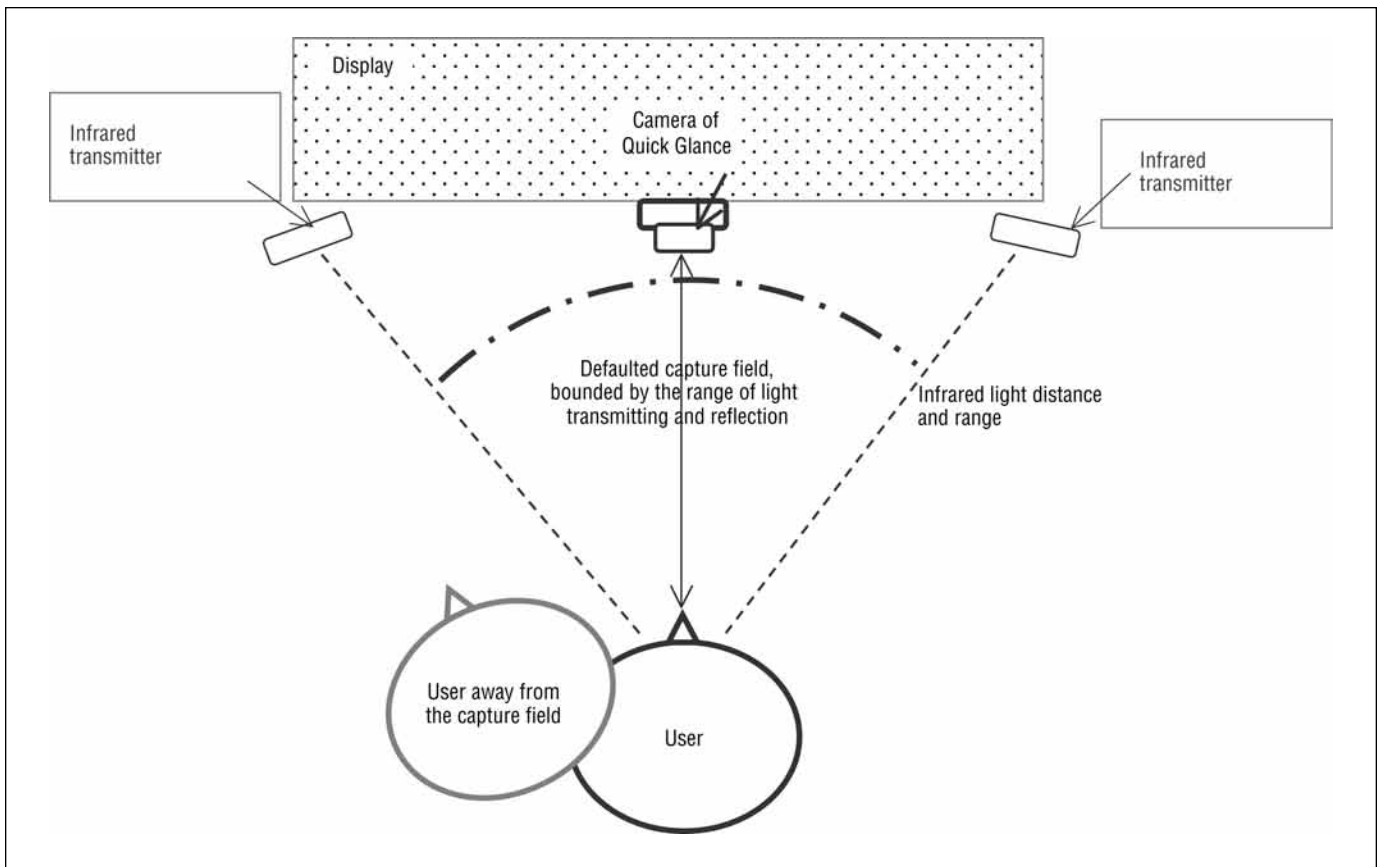
Figure 3. Mechanism of Quick Glance Eye Tracking System.

the students continually moved out of the capture field; therefore, neither participant could activate this system to finish the WinFitts test.

The participants suggested two items that in the future could evaluate the level of comfort with a computer-access system: duration of work and eye strain. The domains of "comfort" and "satisfaction" with computer access, as a matter of psychometric study, require more attention. The findings and analysis that are presented in this study should be carefully reviewed and require further study with a large sample, if possible.

Future Work

In view of the very small number of students with congenital disabilities who lack experience in using computers, our study had many limitations. However, the need to match students with severe disabilities with special nonhandheld devices is routine for occupational therapists in special education, and a standardized and validated evaluation procedure for access solutions should be adopted as soon as possible. Improving the research design that we used may lead to more scientific and specific predictive results for matching equipment and people with severe disabilities. Further studies could focus on analyzing six areas of pointer perfor-

mance in terms of academic needs and communication needs: one-direction tapping, multidirectional tapping, dragging, freehand tracing/drawing, freehand input/handwritten characters or pictures, and grasp-and-park/homing or device switching (Douglas et al., 1999). Further evaluations of the efficacy of nonhandheld pointer interfaces for people with severe disabilities could be replicated in different clinical settings. MacKenzie and Jusoh (2001) suggested that ISO 9241-9 provides a consistent and valid procedure for within-group or between-group comparisons that allows companies that are engaged in developing, manufacturing, and marketing pointer devices to either improve their existing technology or design completely new devices. Hence, in the future, nonhandheld pointer devices could potentially offer more solutions or alternatives for people with special needs. The ultimate scenario of digital inclusion will empower students with severe disabilities to participate in communication, recreation, and continuous learning with equal opportunity. ▲

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