Technology and Disability 17 (2005) 155–163
IOS Press

Measuring target acquisition utilizing Madentec's Tracker system in individuals with Cerebral Palsy[1]

Albert M. Cook*, Bonnie M. Dobbs, Sharon Warren and Rebecca McKeever
Faculty of Rehabilitation Medicine, University of Alberta, Edmonton, Alberta, Canada

Abstract. The purpose of this study was to determine the impact on performance of repeated trials of the Tracker system in a series of target acquisition tasks for persons with cerebral palsy (CP). Twelve persons with CP participated in the single case experimental study. Data were collected on their time to target, time to select, and distance moved to targets of increasingly smaller size across four, once weekly sessions of one hour length. Time and distance were measured using the software programs Speaking Dynamically Pro and Mouse Offroad. Nine of the 12 participants were able to achieve a smaller target at the end of the session compared to the initial target size of 2.5 inches square. Results across sessions for targets of the same size indicated that six participants reduced their times to target and seven reduced the distance moved to acquire the target. However, only two participants showed a decrease in their time to select scores. The findings are discussed in terms of the application of the Tracker One system for individuals with CP.

Keywords: Computer access, cerebral palsy, target acquisition

1. Introduction

Cerebral Palsy (CP) is a non-progressive neuromuscular disorder with an estimated prevalence of 2.57 per 1000 live births [25]. Although CP can vary in presentation and severity, individuals with CP may experience impairment in balance and voluntary motor control [11]; postural control [7]; visual-perceptual skills [21]; mobility [1]; sensation [9]; and cognition [15]. As such, CP has the potential to affect an individual's functional status across the lifespan. School age children with CP can experience a disruptive educational process, with those with more severe limitations experiencing the greatest disruption [17]. Additionally, the proportion of adults with CP who complete post-secondary education or hold gainful employment is reported to be low in comparison to the general population [1].

Computer technology is becoming increasingly prevalent in many aspects of daily life, including schooling, shopping, banking, business, and employment. Not surprisingly, level of computer skills and training have been identified as important indicators of 'successful employment outcomes' in individuals with a variety of disabilities [22]. However, many of these individuals, including those with CP, may not possess sufficient upper extremity function to effectively operate a computer keyboard or mouse utilizing traditional methods. In response to this, the assistive technology (AT) industry has developed alternative input methods and devices, with the intent to allow performance on par with non-disabled individuals [8]. Alternative hardware can range in price and sophistication from a simple mouth stick utilized to select keys on a standard keyboard to tongue or head operated devices used

---

[1] This article is based, in part, on a poster presentation made at the 2004 RESNA confrerence in Orlando, FL. http://www.resna.org/ProfResources/Publications/Proceedings/2004/Papers/Research/CAC/HeadTracking.php.

*Address for correspondence: Dr. Albert M. Cook, Dean, Faculty of Rehabilitation Medicine, Room 348 Corbett Hall, University of Alberta, Edmonton, Alberta, Canada T6G 2G4. Tel.: +1 780 492 5991; Fax: +1 780 492 1626; E-mail: al.cook@ualberta.ca.

ISSN 1055-4181/05/$17.00

to activate keys on a virtual onscreen keyboard [16]. Alternative software for virtual keyboards allows for adjustments of key size and activation times for automatic key repeat features [5], word prediction capabilities [4], and modified dwell time [2]. Concern has been expressed that some input devices are too slow to allow individuals to keep pace with their non-disabled counterparts in educational and employment settings [24].

Although there are some general studies addressing the effectiveness of alternative pointing interfaces in individuals with disabilities, there are few specific to CP, skill improvement in head-mounted devices, or a combination of the two. Phillips and Lin [23] reviewed the user operational characteristics, including satisfaction, for five currently available mouse alternatives based on head-tracking. These systems were rated on the basis of subjective evaluation by evaluators, mostly individuals with high-level spinal cord injuries. Some of the other studies involve a small number of participants [2] or participants with a variety of disabilities [3], which restricts the generalizability of results. To further complicate matters, variable performance has been noted between like participants with CP when using identical interfaces [24]. Dependent variables used in studies examining computer interfaces with disabled individuals generally involve speed, accuracy, and distance or displacement in target acquisition tasks [24], or words per minute and error rate for on-screen keyboards [3].

Angelo [2] demonstrated that, for individuals with CP, direct target acquisition is a faster method than scanning. One simple method of direct selection, the mouth stick, has been observed to yield rapid and accurate text entry in individuals with muscular dystrophy and high spinal cord injury [16]. However, study participants reported neck and jaw discomfort associated with the continual neck flexion and sustained bite on the mouth stick. Use of a mouth stick also requires good oral-motor control, which limits its applicability for persons with CP.

Another method of alternative computer access is a head controlled cursor system. Radwin et al. [24] observed that non-disabled individuals had greater movement times with such a system compared to a conventional mouse. Additionally, they observed that movement time with the former was greater for small versus large targets and for far versus near targets in both healthy individuals and those with CP. Utilizing average movement time as an indicator of relative learning, these same investigators observed that 15 sets of 48 trials (with one trial defined as mouse cursor movement from center-screen to a randomly-presented target) were sufficient to attain stable performance using both mouse and head operated systems in non-disabled individuals. It is important to note, however, the small sample size. Of the two participants with CP, one participant's learning approximated that of the non-disabled controls. The other participant's learning was more rapid but also more variable. For the CP participants, the authors reported that both speed and accuracy of head control were dramatically affected by proper trunk stability provided through a seating system.

Head-controlled cursor movement systems utilize a tracking unit that senses and measures head position relative to a fixed reference point, usually the center of the screen. As the head moves away from midline in a horizontal or vertical direction, the cursor moves on the screen. Commercial systems may use ultrasound, infrared, or image recognition methods to sense head movement by transmission of a signal to a sensor on the user's head and detection of a reflected signal. Commercial systems implement this reflective measurement differently. Several devices, including the Tracker One system, require only a reflective dot to be placed on the user's forehead. The Headmaster (Prentke-Romich) utilizes a headset to move the mouse cursor and a sip/puff tube to click [5]. Angelo et al. [3] compared the performance of this device with two similar devices in participants with high spinal cord injury, post-polio syndrome, and muscular dystrophy. They demonstrated that the Headmaster had the highest speed and accuracy, but required frequent recalibration. In addition, in some cases, the act of puffing caused the cursor to move off the target. Other individuals have reported concern that the tube prohibits simultaneous use of the computer and telephone such as might be reasonably expected in an office setting [5], resulting in dependency on another individual to set up the device. Other concerns include the comfortablity of the headset [16].

The Tracker One system (Madentec) plugs directly into a computer's USB port and mounts directly on top of the computer monitor. It moves the mouse cursor by tracking the position of a small reflective dot, which the user wears on his/her forehead or glasses. The Tracker One system can operate in joystick or mouse mode. It is compatible with USB, PS/2, Serial, and Mac ADB systems. It performs well in direct sunlight [12]. Although there is evidence to support its effectiveness in clients with spinal cord injury, little is known about its potential for individuals with CP.

There are numerous studies addressing motor- and/or task-specific performance in individuals with CP and, although not all are specific to the computer, the methodologies may have application in that context. For example, auditory and visual feedback, presented via tape deck and computer monitor respectively, were associated with improved performance in an upper extremity motor training task in young children with CP [20]. As well, the utilization of purposeful activities versus rote exercise has been associated with shorter movement time and a more direct reach path in children with CP as assessed by motion analysis [13].

The purpose of this study was to determine the impact on performance of repeated trials of the Tracker One system in a series of target acquisition tasks for persons with CP, aged nine to 49. Specifically the investigators wished to determine the impact of repeated trials on (1) time to reach and time to select a target, and on distance moved to targets of increasingly smaller size within sessions; (2) times (to reach and to select) and distance to identical size targets between sessions; and (3) perception of exertion on the part of participants both within and between sessions. It was hypothesized that time, distance, and exertion would decrease within and between sessions.

2. Methods

2.1. Participants

A convenience sample of 12 participants between the ages of nine and 49 years of age were involved in the study. All individuals had either spastic CP or athetoid CP. These types of cerebral palsy represent two of the three diagnostic categories of CP [1]. Individuals with ataxic CP were not recruited because their primary problem relates to locomotion and balance. As such, they have sufficient hand function that the Tracker One system would not be appropriate for them. The proposal was approved by the University of Alberta Health Research Ethics Board (HREB), Panel B, prior to recruiting or engaging potential participants in screening or training components. Potential volunteers were recruited through various treatment facilities and service organizations for persons with CP. The inclusion and exclusion criteria for the participants are depicted in Table 1. Potential participants were screened to ensure that they possessed physical and sensory abilities adequate to operate the Tracker One system.

The intake screening was conducted with prospective participants utilizing the Tracker One system to ensure that they were able to use the equipment. It also served to orient participants and their parents/guardians (if in attendance) to the system. Five prospective participants were excluded due to high-level hand skills that did not make the Tracker One system the most efficient method of access for those individuals.

2.2. Procedure

A single case experimental design was used. After the initial screening and orientation session, the project coordinator collected demographic information from each of the participants. Participants and their parents/guardians were engaged in weekly testing sessions of one full hour each to a total of four sessions. For each session, the goal was for each participant to complete one set of targets. The length of time of each participant's session varied between a few minutes and 45 minutes to complete one set of targets.

Time and distance to target were assessed utilizing the software programs Speaking Dynamically Pro (Mayer-Johnson) and Mouse Offroad (AK Research Labs). The Speaking Dynamically Pro program allows one to build numerous configurations (or grids) of square or circular buttons which a mouse can activate. The buttons are illustrated with pictures, and a speaking voice or sound effect(s) is/are added as feedback when each button is selected. Different age-appropriate categories of picture are available. Participants were allowed to choose their own category type (e.g., animals, sports) each day. Adults selected pictures from five categories: forest, sunset, mountain, waterfall, or garden. The children selected pictures from the following five categories: bears, wolves, horses, moose, and owls.

In terms of measures, total time to select a target can be separated into: a) time required to move to a target, and b) time to select or 'acquire' the target. Distance to target was defined as the distance of mouse travel from the starting point to the point of target acquisition and was measured using the Mouse Offroad (a mouse odometer). Several options were considered for the measure of perceived exertion. Various analog scales that require the participant to indicate relative level of exertion (e.g., the Borg Exertion Scale [6]) were considered but participants found them too complicated. Therefore, a simple set of relative questions were constructed and used to measure perceived exertion (e.g., "Did you find it easier to use the cursor at the end of the session than the beginning?" or ". . . at the end of training?". Heart rate also was considered as a measure of exertion but some participants were unwilling to have the transducer attached to their body. Thus, this measure was excluded from the study protocol.

Table 1
Inclusion and exclusion criteria

Inclusion	Exclusion
1) Persons 9 years of age and older	1) Prior use of or exposure to Tracker One system in standard (non joystick) mode
2) Spastic or athetoid cerebral palsy	2) Inability to understand spoken English
3) Sitting tolerance for greater than/equal to 60 minutes	3) Hearing impairment which precluded ability to hear examiner instructions
4) Able to attend to a task for greater than/equal to 10 minutes	4) Efficient hand or finger function to operate a hand mouse
5) Visuomotor skills (assessed via test trial) adequate to track and locate the Tracker One system's on-screen mouse cursor	
6) Cervical range of motion (assessed via test trial) adequate to operate the Tracker One system in mouse mode (flexion/extension, rotation, diagonal movements)	

Table 2
Computer use

Variable	Frequency*
Currently Using a Computer	Yes = 83% ($N = 10$), No = 17% ($N = 2$)
Methods of Computer Use	Assisted = 42% ($N = 5$), Independent with switches = 8% ($N = 1$), Switches, Tracker/Head Mouse = 8% ($N = 1$), Keyboard, pointer = 8% ($N = 1$)
Body Part for Computer Access	Chin = 17% ($N = 2$), Hand = 25% ($N = 3$), Head = 33% ($N = 4$)
Have A Computer Available	Yes = 100% ($N = 12$)
Computer Available Where?	Home = 50% ($N = 6$), School = 8% ($N = 1$), Home and school = 17% ($N = 2$), Home and work = 8% ($N = 1$), Home and other = 8% ($N = 1$)
Computer Use for Communication	Yes = 25% ($N = 3$), No = 58% ($N = 7$)
Computer Use for Games	Yes = 66% ($N = 8$), No = 17% ($N = 2$)
Computer Use for E-mail/Internet	Yes = 42% ($N = 5$), No = 42% ($N = 5$)
Computer Use for Education	Yes = 8% ($N = 1$), No = 75% ($N = 9$)
Computer Use for Work	Yes = 0% ($N = 0$), No = 83% ($N = 10$)
Computer Use for Other	Yes = 17% ($N = 2$), No = 58% ($N = 7$)

*Where percents do not add to 100, some data may not be applicable, may be missing, or there may be rounding effects.

2.3. *Protocol for a single session*

Participants were seated in front of a computer with the Tracker One system mounted on top of the monitor. The Tracker One system reflective dot was attached to the participant's forehead and the system was aligned to ensure that the target was captured by the Tracker One system camera. The participant was then asked to move the cursor to the extreme corners of the screen by moving his/her head. This ensured full coverage for all possible targets. The set of targets of a given size were then presented to the participant.

As shown in Fig. 1, a central target on each computer grid presented to participants was designated as the 'home' target. Once participants selected the home target, another target would appear in one of four peripheral locations on the computer screen. Peripheral targets were arranged in the 12, 3, 6, and 9 o'clock positions. Participants were asked to move the cursor from the home target to a peripheral target and hold it there until an audible sound was elicited. Once this occurred, the participant was then requested to move the cursor back to the home target and await the next request. The order in which peripheral targets appeared was randomly varied by the program throughout the session. Target size also was reduced (2.5 inches, 2.0 inches, 1.5 inches, and 1.0 inches on a side) as a participant was able to successfully select a given size.

A successfully completed session consisted of selecting a minimum of two targets in each of the four peripheral locations (a minimum of eight selections) per each size of square target: All participants began with the largest target, 2.5 inches. If a successful set was completed at that size within the hour, the participant progressed to the next smaller size target. If a set could not be completed, the participant began with that same size target at the next session, until successful. Once a successful set had been completed, participants progressed to the next smallest target. Because participants completed more than one target at each size, mean time to target and time to select were calculated for each participant for each session, but only one distance score per session was feasible.

Table 3
Mobility Assistance

Variable	Frequency*
Power Mobility Use	Yes = 58% ($N = 7$), No = 42% ($N = 5$)
Power Mobility with Assistance	Yes = 25% ($N = 3$), No = 8% ($N = 1$)
Power Mobility Independent	Yes = 33% ($N = 4$), No = 8% ($N = 1$)
Manual Mobility User	Yes = 100% ($N = 12$)
Manual Mobility with Assistance	Yes = 75% ($N = 9$), No = 25% ($N = 3$)
Manual Mobility Independent	Leg propel = 25% ($N = 3$)
Special Seating Used	Yes = 92% ($N = 11$), No = 8% ($N = 1$)
Seating Style	Standard contoured = 17% ($N = 2$), Custom contoured = 75% ($N = 9$)

*Where percents do not add to 100, some data may not be applicable, may be missing, or there may be rounding effects.

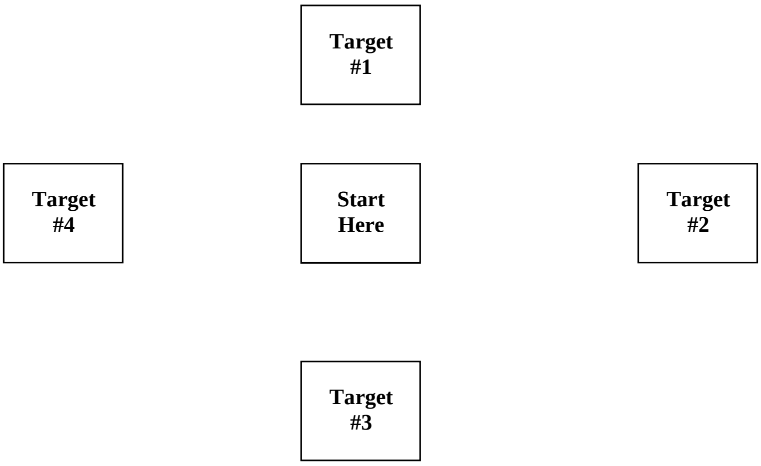

Fig. 1. Sample screen. Targets 1–4 were presented one at a time in random order. The cursor was to be moved from the center square to the target "as fast as possible". Pictures were used as targets (see text).

2.4. *Outcome measures*

Time was measured by the project coordinator, using a stopwatch to separately record the time required to move to the target in seconds (time to target); and the total time to acquire the target (also in seconds), including holding on the target for a minimum dwell time of one second as required by Speaking Dynamically Pro. Time to select was calculated as the difference between the total time and the time to move to the target. The time to target measure began when the cursor left the central home position and ended when the cursor was moved onto the peripheral target location with a one second dwell time. Time to target and time to select were recorded for each target individually in a set.

Distance, or amount of cursor travel, also was recorded by the project coordinator in metres via the mouse odometer. Utilizing a calibrated AK Research Mouse Odometer, the project coordinator recorded the total distance required to move to and select the target. The first odometer reading was recorded by the project coordinator. The cap over the lens of the Tracker One system was then removed to allow the participant to control the cursor. When the last target was selected, the lens cap was replaced and the odometer reading was again recorded. The difference between the start odometer reading and the end odometer reading was calculated, resulting in the travel distance for that set.

2.5. *Data analysis*

Because the participants were variable in their skill level, and because of the small sample size, time and distance results were initially graphed for each participant rather than generating group means and standard deviations to compare statistically over time. The graphs were examined to determine how they could inform the original research questions: visual inspection of the graphs was used to assess change. Change of target size was relatively straightforward, being simply whether the participants went from one fixed target size to a lower one (e.g., from 2.5 to 2.0). The adopted standard for judging change/no change for time to target, time to select, and distance moved on visual inspection

Table 4
Target size across sessions

Participant	Target size			
	Session 1	Session 2	Session 3	Session 4
1	2.5	2.5	2.5	2.5
2	2.5	2.5	2.5	2.0
3	2.5	2.5	1.5	1.0
4	2.5	2.5	2.5	2.0
5	2.5	2.5	1.5	2.0
6	2.5	2.5	2.0	1.5
7	2.5	1.5	2.5	1.5
8	2.5	2.0	2.0	2.0
9	2.5	2.5	2.0	1.5
10	2.5	2.5	2.5	2.5
11	2.5	2.5	2.5	2.5
12	2.5	2.0	1.5	2.0

was based on group patterns and approximate amount of change with outliers excluded. For time to target and time to select, the criterion was 3 seconds (e.g., a decrease in time had to be at least 3 seconds to be labeled a decrease). For distance moved, the criterion was 0.3 metres (e.g., a decrease in distance had to be at least 0.3 metres to be labeled a decrease).

3. Results

3.1. Demographic data

Twelve (12) participants completed the study: Fifty-eight per cent ($N = 7$) were male. The average age of participants was 30.5 years with a range from nine to 49. Seventeen percent ($N = 2$) had athetosis and 83% ($N = 10$) had spastic quadriplegia.[1] Tables 2 and 3 show selected participant characteristics re: computer use and mobility assistance. Table 2 shows that all of the participants had a computer available at home, work, school, or at several of these locations, and 83% of them were using a computer at the time of the study. The largest use of computers by participants was for games (68%), followed by e-mail/internet (42%) and communication (25%). The majority (33%) of the participants used head control for computer access. The remainder used hand (25%) or chin (17%) control. Independence in mobility is related to computer use in terms of experience with control interfaces and control of electronic systems. As shown in Table 3, all of the participants used manual mobility for part of the time. Seventy-five percent of those required assistance. The primary mode of independent manual wheelchair propulsion was leg/foot pushing. Fifty-eight percent also used a powered wheelchair at times in either an independent (33%) or assisted (25%) mode.

3.2. Outcome measures data

Objective 1:

The first objective was to determine the impact of repeated trials on (1) time to reach and (2) time to select a target, and (3) on distance moved to targets of increasingly smaller size within session. However, for the most part, the great majority of participants could not complete more than one target size per session. Thus, the investigators were unable to determine the impact of repeated trials on each of the outcome measures within a session.

Objective 2:

The second objective was to determine the impact of repeated trials on (1) time to reach and to select a target, (2) on distance moved to targets of increasingly smaller size between sessions, and (3) perception of exertion on the part of participants both within and between sessions. Across sessions, nine of the 12 participants were able to achieve a smaller target at the end of the sessions compared to the initial target size of 2.5 inches square. The results are shown in Table 4.

Although the initial goal of Objective 2 was to determine the impact of repeated trials on targets of increasingly smaller size across sessions, the substantial degree of intra-and inter-variability made data analyses difficult. However, data across sessions for targets of the same size were available for all of the participants. Those data are presented in Tables 5 through 7. As shown in the shaded cells in Table 5, of the 12 participants, six had decreased times to target on their last set from their first set (participants 1–5, 10), three had increased times (participants 6, 9, and 12), and three remained approximately the same, that is, within three seconds (participants 7, 8, and 11).

Times to select scores also were available from all of the 12 participants (see Table 6). Only two participants showed a decrease (participants 2 and 10), seven showed an increase (participants 1, 5, 6, 8, 9, 11, and 12), and three remained approximately the same, that is, within three seconds (participants 3, 4, and 7).

---

[1] Thirty-three per cent ($N = 4$) of the participants were living with family, 33% ($N = 4$) in a group home, 17% ($N = 2$) alone, 8% ($N = 1$) in assisted living, and 8% ($N = 1$) in other arrangements. Seventeen per cent ($N = 2$) lived with parents and siblings, 17% ($N = 2$) with parents alone, and another 17% ($N = 2$) with support staff; 25% ($N = 3$) lived with staff and roommates, 8% ($N = 1$) with siblings, and 17% ($N = 2$) other. Forty-two per cent ($N = 5$) were currently attending school and another 42% ($N = 5$) were attending some other type program, such as a work program.

Table 5
Time to target in seconds (shaded numbers were those compared both graphically and statistically)

Subject	T to T Session 1	T to T Session 2	T to T Session 3	T to T Session 4
1	.	71.77	34.57	49.04
2	93.39	89.96	85.79	73.70
3	10.00	5.27	7.17	18.15
4	25.54	46.96	21.83	40.72
5	13.59	8.14	42.03	7.24
6	19.58	34.80	73.14	98.66
7	4.42	6.32	4.15	6.35
8	21.30	24.12	37.46	23.58
9	14.46	31.43	47.78	29.18
10	.	41.08	70.98	29.14
11	44.45	60.56	103.12	43.03
12	22.63	28.96	47.11	35.50

T to T = Time to target

Table 6
Time to select in seconds (shaded numbers were those compared both graphically and statistically)

Subject	T to S Session 1	T to S Session 2	T to S Session 3	T to S Session 4
1	.	3.89	27.66	8.33
2	42.86	1.00	1.00	55.73
3	1.00	1.00	4.92	1.00
4	1.00	1.58	3.69	1.00
5	1.00	5.06	64.27	34.55
6	24.26	51.16	1.00	108.41
7	2.61	4.11	1.00	1.00
8	21.46	13.29	30.14	50.67
9	32.83	38.39	17.54	11.61
10	.	31.93	8.06	1.00
11	38.84	1.30	60.05	49.41
12	93.17	35.82	261.17	79.27

T to S = Time to select

The distance measures are shown in Table 7. Seven participants showed a decrease in distance (participants 1, 4–7, 10, and 12) across sessions, two an increase (participants 2 and 8), and three stayed about the same, that is, within 0.3 metres (participants 3, 9, and 11).

As described earlier, it was not possible to obtain a consistent measure of exertion for this population.

4. Discussion

Based on descriptive statistics, the results show a modest improvement in the participants' skill in using the Tracker One system over time, in that the majority could gradually hit increasingly smaller targets and decrease their distance moved to select the target. The typical pattern for clients was to gradually decrease scores on one target size, then increase when they initially moved to a smaller target size but then decrease again at that target size. Specifically, 50% of participants were able to decrease their time to target across sessions and more than half (58%) were able to decrease the distance moved. Participants had more difficulty in time to select a target, in that fewer (20%) participants were able to decrease their time to select. There are a number of reasons for this. Time to select increased in some cases, which may be due to the inclusion of a fixed acceptance time of one second in all results. Some participants were able to move to the target area quickly, but they were unable to hold the cursor on the target for the required acceptance time. This resulted in acquisition of the target multiple times, but all for less than the minimum one second acceptance time. This tended to increase the time for selection artificially. The necessity for holding the cursor on the target for a pre-determined select or acceptance time is a characteristic of the head controlled cursor. This is in contrast to a hand operated track ball or mouse which can be positioned and the hand removed while acceptance time (or a mouse button) is activated. A complicating factor for our participants was that the target locations had no border or outline to delineate the edges of the targets. This reduced feedback to the participants regarding the point at which the target was acquired and made it more difficult to know when to hold the cursor steady for target selection. This may have increased select times especially for smaller targets. One approach to overcome this limitation is to use

Table 7
Distance moved in metres (shaded numbers were those compared both graphically and statistically)

Subject	DM Session 1	DM Session 2	DM Session 3	DM Session 4
1	.	7.59	4.76	3.54
2	6.35	2.18	9.19	5.62
3	.58	.35	.65	1.01
4	.76	.61	.22	.67
5	3.11	2.35	8.98	5.13
6	5.27	1.96	1.57	9.45
7	.67	.57	.27	.75
8	2.22	3.53	5.67	4.66
9	8.31	8.11	4.37	2.75
10	.	3.41	3.52	1.07
11	3.86	2.94	5.50	3.80
12	8.43	6.99	92.58	6.57

DM = Distance moved

a 'joystick-mode' with a head controlled cursor system [10] in which there is a relatively large dead zone of head movement before cursor movement is activated. The Tracker One system has a mode similar to this but it was not used in this study. One of the participants in the study had previously used this mode with some success (self report).

Results of the study suggest that four, one-hour sessions do not appear to be sufficient for participants to achieve optimum performance, but repeated trials (practice) did improve performance for our participants (decreased movement times and distances) for any single target size. However, this study does not provide any insight into how much training time might be necessary, although it appears that two to three sessions at any one target size were needed before most participants could progress to a smaller target size. For non-disabled participants, Radwin et al. [24] observed that 15 sets of 48 trials were necessary to attain stable performance using both mouse and head operated systems when average movement time was used as an indicator of relative learning. This also is consistent with head pointing use by non-disabled participants who took up to 21 days to achieve optimum performance (less than 3% change in performance) [14].

A cursor enlargement program was used to accommodate for limited vision of some participants. Some participants used a sequential method of target acquisition in which they moved the cursor along the top margin of the screen to line up with the target vertically and then dropped their head down to acquire the target horizontally.

Mouse speed was set on the Windows control panel screen and was reduced about 20% from typical non-disabled use. The lack of smoothness of cursor movement (termed "stickiness" by one participant) also played a role in performance. A few participants found this 'annoying' but were not able to control the cursor when it was set on a faster motion speed that appeared to be smoother. This result is consistent with published reports of gain effects for head controlled cursor systems. Lin et al. [18] studied the gain defined as the relationship between head movement and cursor displacement. They found that the gain (amount of cursor movement related to amount of head movement) had significant effects on movement time to targets for 10 non-disabled participants. Gain effects were largest for long displacement distances and small target widths, with higher gains resulting in longer movement times for either of these conditions. LoPresti et al. [19] investigated several types of head displacement to cursor movement gain relationships in a sample of 22 non-disabled participants and three participants with multiple sclerosis. They found that participants had faster performance when the sensitivity of the cursor movement was reduced (i.e., reduced gain). These results are consistent with the data shown in Table 5. With a few participants, this 'stickiness' also allowed them to be able to 'pause' long enough on a target to have it select the target.

One participant had an asymmetrical tonic neck reflex on the right side that resulted in her having difficulties turning her head to acquire the target on the left (position 4). Another participant had very slumped posture that she was able to correct on verbal cue resulting in better success with the task. This postural correction was temporary, being held for only a few seconds to minutes and produced fatigue. One other participant had very asymmetrical posture with a trunk side flexion (non-fixed) to the right side and a right side tilt of head posture. This positioning necessitated use of the Tracker dot on his nose and wheelchair positioning at an angle to the screen in order to allow him to have full range of cursor movement on the screen. Each of these postural constraints affected the use of the Tracker One system. In a study of 10 non-disabled participants, Schaab et al. [26] reported that viewing distance and head angle both affect performance (movement time for a given target width and distance of movement) of head pointing systems. It is likely that these postural abnormalities had a major effect on movement times for these participants.

5. Conclusion

The results obtained in this study indicate that individuals with CP may be able to utilize the Tracker One head controlled cursor system if they are given sufficient practice time. It also is important that target sizes be gradually reduced as skill increases. Positioning of the individual relative to the screen also affects performance. It also is important that the on-screen selection software have an adjustable acceptance time to avoid the problems in holding a target that were encountered in this study.

Acknowledgments

The work was done under the 'Medical Device Development Program' which was funded through the

Canada/Alberta Western Economic Partnership Agreement (WEPA). Johanna Darrah provided significant assistance through many fruitful discussions. Madentec, Ltd. loaned the Tracker One system used in the study.

References

[1] C. Anderson and E. Mattson, Adults with cerebral palsy; A survey describing problems, needs, and resources, with special emphasis on locomotion, *Development and Medical Child Neurology* **43**(2) (2001), 75.

[2] J. Angelo, Comparison of three computer-scanning modes as an interface method for persons with cerebral palsy, *American Journal of Occupational Therapy* **46**(3) (1992), 217–222.

[3] J. Angelo, C. Deterding and J. Weisman, Comparing three head-pointing systems using a single subject design, *Assistive Technology* **3**(2) (1991), 43–49.

[4] D. Anson, The effect of word prediction on typing speed, *American Journal of Occupational Therapy* **47**(11) (1993), 1039–1042.

[5] D. Anson, Using the Headmaster with Macintosh Apple II, and MS-DOS computers, *American Journal of Occupational Therapy* **45**(10) (1991), 889–897.

[6] G. Borg, Psychophysical bases of perceived exertion, *Medicine and Science in Sports and Exercise* **14** (1982), 377–381.

[7] E. Brogen, M. Hadders-Algra and H. Forssberg, Postural control in sitting children with cerebral palsy, *Neuroscience Biobehavioural Review* **22**(4) (1998), 591–596.

[8] A.M. Cook and S.M. Hussey, *Assistive Technologies: Principles and Practice,* 2nd edition, Mosby Yearbook, St. Louis, 2002.

[9] J. Cooper, A. Majnemer, A. Rosenblatt and R. Birbaum, The determinants of sensory deficits in children with hemiplegic cerebral palsy, *Journal of Child Neurology* **10**(4) (1995), 300–309.

[10] D.G. Evans, R. Drew and P. Blenkhorn, Controlling mouse pointer position using an infrared head-operated joystick, *IEEE Transactions on Rehabilitation Engineering* **8**(1) (2000), 107–117.

[11] M.E. Gormley, Jr., Treatment of neuromusculare and musculoskeletal problems in cerebral palsy, *Red Rehabilitation* **4**(1) (2001), 5–16.

[12] http://www.madentec.com.

[13] J.S. Horgan, Reaction time and movement time of children with cerebral palsy: Under motivational reinforcement conditions, *American Journal of Physical Medicine* **59**(1), 22–29.

[14] R.J. Jagacinski and D.L. Monk, Fitt's law in two dimensions with hand and head movement, *Journal of Motor Behavior* **17** (1985), 77–89.

[15] M.A. Khan, Intellectual and developmental assessment of cerebral palsy in cases in a Libyan city, *Indian Journal of Medical Science* **46**(8) (1992), 235–238.

[16] C. Lau and S. O'Leary, Comparison of computer interface devices for persons with severe physical disabilities, *American Journal of Occupational Therapy* **47**(11) (1993), 1022–1030.

[17] C. Lepage, L. Noreau, P.M. Bernard and P. Fougeyrollas, Profile of handicap situations in children with cerebral palsy, *Scandinavian Journal of Rehabilitation Medicine* **30**(40), 263–277.

[18] M.L. Lin, R.G. Radwin and G.C. Vanderheiden, Gain effects using a head-controlled computer input device, *Ergonomics* **35**(2) (1992), 159–175.

[19] E.F. LoPresti, D.M. Brienza and J. Angelo, Head-controlled computer controls: Effect of control method on performance for participants with and without disabilities, *Interacting with Computers* **14** (2002), 359–377.

[20] S. Mackey, The use of computer-assisted feedback in a motor control task for cerebral palsied children, *Physiotherapy* **75**(3) (1989), 143–148.

[21] C. Menken, S.A. Cermak and A. Fisher, Evaluating the visual-perceptual skills of children with cerebral palsy, *American Journal of Occupational Therapy* **41**(10) (1987), 646–651.

[22] S.D. Pell, R.M. Gills and M. Carss, Relationship between use of technology and employment rates for people with physical disabilities in Australia: Implications for education and training programs, *Disability Rehabilitation* **29**(8) (1997), 332–338.

[23] R.R. Radwin, G.C. Vanderheiden and M.L. Lin, A method for evaluating head-controlled computer input devices using Fitts' Law, *Human Factors* **32**(4) (1990), 423–438.

[24] B. Phillips and A. Lin, *Head-tracking technology for mouse control: A comparison project,* in Proceedings 2003 RESNA Conference, 2003.

[25] Robertson C.M. Robertson, L.W. Svenson and M.R. Joffres, Prevalence of cerebral palsy in Alberta, *Canadian Journal of Neurological Sciences* **25**(2) (1998), 117–122.

[26] J.A. Schaab, R.G. Radwin, G.C. Vanderheiden and P.K. Hansen, A comparison of two control-display gain measures for head-controlled computer input devices, *Human Factors* **38**(3) (1996), 390–403.