TEXT ENTRY RATE OF ACCESS INTERFACES USED BY PEOPLE WITH PHYSICAL IMPAIRMENTS

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ABSTRACT

This study systematically reviewed the research on assistive technology (AT) access interfaces used for text entry, and conducted a quantitative synthesis of text entry rates associated with common interfaces. We searched 10 databases and included studies in which: typing speed was reported in words per minute or equivalent; the access interface was available for public use; and individuals with physical impairments were in the study population. We used only the text entry rates reported for individuals with physical impairments; studies also had to report the sample size, and the average and standard deviation for the text entry rate data. Thirty-nine studies met the criteria and involved 7 interface types. Automatic speech recognition (ASR), physical keyboard, on-screen keyboard (OSK) with cursor selection, and OSK with scanning selection had at least 4 studies and 30 subjects each, with text entry rates averaging 15.4, 12.5, 4.2, and 1.7 wpm, respectively.

PURPOSE

The purpose of this study is to perform a systematic literature review, in order to develop a better understanding of the typing speed provided by text entry methods for people with physical impairments. This is a companion study to Koester and Arthanat (2016) in which we presented results for physical keyboard typing. Here, we focus primarily on the remaining access methods.

METHODS

Search Strategy

To search the literature, we used the approach outlined by Schlosser et al. (2005). The guiding search question was: “What are the reported speeds of text entry methods relevant to people with physical limitations?” We generated keywords based on the Person, Intervention, and Outcomes components:

1. Person: categories related to disability such as “Disabled Persons” and “Motor Skills Disorders” and specific diagnoses that typically produce physical impairments.
2. Intervention: categories related to computer access methods, such as “Assistive Technology,” “Communication Aids for Disabled” and keywords specific to particular types of access (e.g., “mouthstick”).
3. Outcome: keywords related to text entry rate, speed, and accuracy, as well as a general “Outcome” category.

The full search string was formed by combining keywords as Person AND Intervention AND Outcome. For the complete search string, see the supplementary material for this paper (Koester and Arthanat, 2017).

We searched 10 databases: PubMed, PEDro, OTseeker, ERIC, DARE, Cochrane, google scholar, ACM, CINAHL, and PsychInfo, yielding 3687 records. Another 30 articles were identified by reviewing citations in major assistive technology textbooks. We manually screened all 3717 records based on the title and abstract, keeping those that focused on at least one assistive technology to enhance computer use or communication, yielding 635 articles.

Study Selection

We performed a second round of abstract screening to exclude abstracts where the dependent variables mentioned did not include some measure of text entry performance. (Abstracts that didn’t include specific dependent variables were retained at this point.) We also excluded abstracts that focused exclusively on pointing performance rather than typing. This stage retained 380 articles.

We reviewed the full text of those 380 articles, excluding articles for the following reasons:

1. Text entry rate (TER) was not reported, either in words per minute (WPM) or equivalent.
2. None of the access interfaces was available for consumer use, either via commercial sale or as a free download.
3. The study included only able-bodied subjects.
4. The method of measuring TER did not follow conventional techniques.
5. The results reported were anecdotal, duplicated in another article, or unclear.

This process left 43 articles for further analysis.

Organization of Evidence

We extracted data from the 43 studies into a spreadsheet based on the critical review form of the McMaster University Evidence-Based Practice Group (Law et al., 1998), extracting the study purpose and design, participant characteristics and sample size, access method(s), text entry measurement procedures, and quantitative typing speed data. We organized the data by the interface types used in the study. Interface types were physical keyboard, automatic speech recognition (ASR), Morse code, OSK with cursor selection, OSK with scanning selection, brain-computer interface, and other.

Quantitative Analysis

The purpose of the quantitative synthesis was to combine the text entry rates across studies for each access interface, in order to get an overall estimate of the TER for that access interface. For each interface, we created a spreadsheet tabulating the data from all studies that involved that interface. Four studies were removed because they didn't report standard deviation, which is required for mathematically combining results across studies. This process yielded 56 entries (i.e., data rows in the spreadsheets) from 39 articles across the seven interface types.

The final step in the quantitative synthesis was to combine the extracted data across all studies for each interface type. Using the sample size and the average and standard deviation of text entry rate for each study, we computed the combined average and standard deviation of TER for each interface type, using the calculator at statstodo.com (Chang, 2016).

The data used in this review are publicly available at kpronline.com/ter-review.php.

RESULTS

Summary across Interfaces

Table 1 summarizes the results for each main interface, in order of average text entry rate. Three interfaces provided text entry rates above 10 wpm (speech recognition, physical keyboard, and two-switch Morse code), while the remaining four interfaces yielded text entry rates below 5 wpm.

Cursor Selection On-screen Keyboard.

These interfaces present a virtual keyboard on the screen. To enter text, the user moves the mouse cursor to the desired target and either clicks or dwells there. This category does not include the tap-to-type on-screen keyboard that is used on a tablet or smartphone. Table 2 groups the TER data for these 11 studies across four motor sites. The average TER across all 52 subjects in these studies was 4.24 wpm.

Scanning Selection On-screen Keyboard.

Scanning selection interfaces also present a virtual keyboard on the screen, but selections are made using one or two switches. Table 3 groups the TER data for these 14 studies across main categories of typing method (letter-by-letter or letters + word prediction) and number of switches. The average text entry rate across all 34 subjects in these studies was 1.67 wpm.

Automatic Speech Recognition.

Automatic speech recognition (ASR) allows the user to enter text by speaking. Table 4 groups the text entry data for the four qualifying studies involving ASR. The average text entry rate across all 50 subjects in these studies was 15.42 wpm.

DISCUSSION

This systematic literature review is a unique and novel effort in organizing and understanding what is known about text entry performance for individuals with physical impairments. Given the intricacies of control interface selection and the absence of established benchmarks, the findings of this review can serve as external evidence for AT control interface selection. The evidence lends a baseline expectation of the TER that may be achieved by a given individual with a physical impairment, when using a specific interface. At the same time, client experience, clinician reasoning, interface placement, configuration, and rate enhancement also need to be factored in to optimize TER specific to the client.

Future Work

One need is to work toward more well-defined and replicable methods in computer access research. While many of the basic elements were mentioned in most articles, important details were almost always omitted. A common structure for performing text entry studies would provide a stronger platform for cumulating results across studies over time.

This database of studies is a good foundation to address a variety of questions about computer access methods and to identify gaps in the literature base to guide future research. We hope to find effective ways of maintaining and leveraging this database over time, possibly by allowing others to add studies and use the database to explore their own questions.

REFERENCES

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Interface	N	Mean	SD	95% CI	Min	Max
Speech recognition	50	15.42	9.99	[12.65, 18.19]	3.5	32.2
Standard keyboard	164	12.47	8.9	[11.11, 13.83]	1.2	48
2-switch Morse	1	12.39	-	-	-	-
1-switch Morse	1	4.88	-	-	-	-
Cursor selection OSK	52	4.24	2.82	[3.47, 5.01]	0.6	11.82
Scanning selection OSK	34	1.67	1.22	[1.26, 2.08]	0.51	6.51
Brain-computer interface	4	0.66	0.08	[0.58, 0.74]	0.56	0.72

Table 1. Data summarizing overall statistics for each interface. 95% CI is the 95% confidence interval for the mean.

Upper Extremity Control of Cursor OSK						
Study	**Diagnosis & Setup**	**N**	**Mean**	**SD**	**Min**	**Max**
Lancioni 2011	CP, hand joystick	1	0.6	0		
Smith 2009*	CP & C5-6	4	7.47	2.75	3.48	9.72
Wobbrock 2008	Hi SCI, trackball	1	4.86	0		
Wobbrock 2006	Hi SCI, trackball, WP	1	11.82	0		
Wobbrock 2004	6 CP, 1 MS, w/c joystick	7	0.84	0.36		
Total for Upper Extremity Control:		14	3.79	4.06	0.6	11.82
Head Control of Cursor OSK						
Study	**Diagnosis & Setup**	**N**	**Mean**	**SD**	**Min**	**Max**
Pouplin 2016*	C4-5	6	6.74	1.20		
Pouplin 2015	C4-5	6	3.78	0.93	2.52	8.82
Pires 2012	C3-4, CP	2	1.68	0.34	1.44	1.92
Devries 1998	C5, GBS	2	4.55	0.92	3.9	5.2
Lau 1993	2 SCI, 2 DMD	4	4	1.43	1.8	5.02
Total for Head Control:		20	4.58	1.9	1.44	8.82
Chin Control of Cursor OSK						
Study	**Diagnosis & Setup**	**N**	**Mean**	**SD**	**Min**	**Max**
Pouplin 2016	C4-5, chin + trackball	9	3.3	2.8		
Mixed Control of Cursor OSK						
Study	**Diagnosis & Setup**	**N**	**Mean**	**SD**	**Min**	**Max**
Pouplin 2014*	4 UE, 4 head, 1 eye	9	5.13	2.26	1.4	**7.6**
OVERALL TOTAL:		52	4.24	2.82	0.6	11.82

Table 2. Data for cursor selection OSK interface, showing all studies divided into four body-site categories. Statistics are for words per minute text entry rate. Text entry is letter-by-letter without word prediction, except for Wobbrock 2006, in which prediction enhanced TER by 3 wpm for this subject. *Study also reported word prediction data; TER was very similar to letters-only text entry. SCI = spinal cord injury, CP = cerebral palsy, DMD = Duchenne's Muscular Dystrophy, GBS = Guillain-Barre Syndrome, UE = Upper Extremity.

Letters-Only 1-switch Scanning									
Study	**Dx**	**Site**	**Layout**	**Speed**	**N**	**Mean**	**SD**	**Min**	**Max**
Roark 2015	LIS	Chin	Freq	1.0	1	1.2	0		
Pouplin 2014	LIS	-	Freq dyn	-	1	1.1	0	3.48	9.72
Mankowski 2013	CP	-	Mx	Mx	5	1.07	0.1	0.98	1.22
Chiapparino 2011	CP	Hand	-	2.0	1	1.33	0		
Lancioni 2011	CP	Mx	-	Mx	3	0.94	0.13	0.86	1.09
Lancioni 2010	CP	Hand	-	Mx	2	1.05	0.06	1.0	1.09
Chan 2010	CP	Throat	Dvorak	1.5	1	0.51	0		
Simpson 2007	CP	Mx	Freq	Mx	4	1.59	0.43	1.08	2.05
Pires 2012	CP	Head	-	-	1	1.36	0		
Lancioni 2009	CP	Mx	-	-	2	0.99	0.08	0.94	1.05
Koester 1990	GBS	Hand	Freq	0.6	1	3.92	0		
Total for Letters-Only 1-switch:					22	1.27	0.67	0.51	3.92
Letters + WP 1-switch Scanning									
Study	**Dx**	**Site**	**Layout**	**Speed**	**N**	**Mean**	**SD**	**Min**	**Max**
Koester 2014*	Mixed	Mx	Mx	Mx	9	2.72	1.8	1.12	6.51
Lancioni 2013**	ALS	Mouth	-	-	1	1.85	0		
Blain 2010	C1-4	Tongue	-	1.5	1	1.1	0		
Total for Letters+WP 1-switch:					11	2.49	1.7	1.1	6.51
Letters-Only 2-switch Scanning:									
Study	**Dx**	**Site**	**Layout**	**Speed**	**N**	**Mean**	**SD**	**Min**	**Max**
Lancioni 2010	CP	Voice+hand	-	-	1	1.33	0		
OVERALL TOTAL:					34	1.67	1.22	0.51	6.51

Table 3. Data for scanning selection OSK interface. Statistics are for words per minute text entry rate. Diagnosis, switch site, letter layout (e.g., Frequency, Alphabetical), and scan speed (in seconds) are also shown, where available. Mx = varied values, but reported individually for each subject; dash = unknown. *Data are for revised configuration, where WP outperformed LO, 2.72 to 1.51 wpm; in original configuration, WP and LO were no different. **WP better than LO (1.48 wpm) for this individual. LIS = locked-in syndrome, CP = cerebral palsy, GBS = Guillain-Barre Syndrome, ALS = Amyotrophic Later Sclerosis.

Automatic Speech Recognition						
Study	**Diagnosis**	**N**	**Mean**	**SD**	**Min**	**Max**
Pouplin 2015	C4-5 SCI	5	18.8	3.83		
Alcantud 2006	-	15	13.81	14.5		
Koester 2004	10 SCI + 3 RSI + 10 other	23	16.90	7.88	3.5	32.2
Sears 2001	C6 SCI and above	7	11.61	6.78		
OVERALL TOTAL:		50	15.42	9.99	3.5	32.2

Table 4. Data for automatic speech recognition interface. Statistics are for words per minute text entry rate. SCI = spinal cord injury, RSI = repetitive stress injury.