



HAL
open science

Influence of the Number of Predicted Words on Text Input Speed in Participants With Cervical Spinal Cord Injury

Samuel Pouplin, Nicolas Roche, Isabelle Vaugier, Antoine Jacob, Marjorie Figere, Sandra Pottier, Jean-Yves Antoine, Djamel Bensmail

► **To cite this version:**

Samuel Pouplin, Nicolas Roche, Isabelle Vaugier, Antoine Jacob, Marjorie Figere, et al.. Influence of the Number of Predicted Words on Text Input Speed in Participants With Cervical Spinal Cord Injury: Influence of the number of predicted words in persons with SCI. Archives of Physical Medicine and Rehabilitation, 2015, 97 (259-265), 10.1016/j.apmr.2015.10.080 . hal-01246707

HAL Id: hal-01246707

<https://hal.science/hal-01246707>

Submitted on 19 Dec 2015

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

1 **TITLE: Influence of the number of predicted words on text input speed in**
2 **participants with cervical spinal cord injury.**

3

4 **SHORT TITLE: Influence of the number of predicted words in persons with**
5 **SCI**

6

7 **AUTHORS**

8 Samuel POUPLIN, OT, PhD Student¹⁻⁴

9 Nicolas ROCHE, MD, PhD³⁻⁵

10 Isabelle VAUGIER, Biostatistician⁴

11 Antoine JACOB, OT, MSc¹

12 Marjorie FIGERE, ARC⁴

13 Sandra POTTIER, Project Manager⁴

14 Jean-Yves ANTOINE⁶,

15 Djamel BENSMAIL, MD, PhD¹⁻⁴

16

17 ¹New Technologies Plate-Form, AP-HP, Raymond Poincaré Teaching Hospital,
18 Garches, France.

19 ²Physical Medicine and Rehabilitation Department, AP-HP, Raymond Poincaré
20 Teaching Hospital, Garches, France.

21 ³Inserm Unit 1179, Team 3: **Technologies and Innovative Therapies Applied to**
22 **Neuromuscular diseases**, University of Versailles St- Quentin-en-Yvelines,
23 France.

24 ⁴Clinical Innovations Center 1429, AP-HP, Raymond Poincaré Teaching Hospital,
25 Garches, France.

26 ⁵Physiology–Functional Testing Ward, AP-HP, Raymond Poincaré Teaching
27 Hospital, Garches, France

28 ⁶University François Rabelais of Tours, Tours, France, LI Lab

29

30 **ABSTRACT**

31 Objective

32 To determine if the number of words displayed in the Word Prediction Software
33 (WPS) list affects Text Input Speed (TIS) in people with cervical Spinal Cord
34 Injury (SCI) and if any influence is dependent on the level of the lesion.

35 Design

36 A cross-sectional trial.

37 Setting

38 A rehabilitation center in France.

39 Participants

40 Ninety persons with cervical SCI fulfilled the inclusion/exclusion criteria, 45 of
41 whom agreed to participate. Lesion level was high (C4 and C5 Asia A or B) for
42 15 participants (high lesion group) and was between C6 and C8 Asia A or B for
43 30 participants (low lesion group).

44 Methods

45 TIS was evaluated during 4. 10-minute copying tasks:

46 -without WPS (Without)

47 -with a display of 3 predicted words (3Words)

48 -with a display of 6 predicted words (6Words)

49 -with a display of 8 predicted (8Words)

50 Outcome Measures

51 During the 4 copying tasks, TIS was measured objectively (characters per minute,
52 number of errors) and subjectively through subject report (fatigue, perception of
53 speed, cognitive load, satisfaction)

54 Results

55 For participants with low cervical SCI, text input speed without WPS was faster
56 than with WPS, regardless of the number of words displayed ($p < 0.001$). For
57 participants with high cervical SCI, the use of WPS did not influence TIS
58 ($p = 0.99$). There was no influence of the number of words displayed in a word
59 prediction list on TIS, however perception of TIS differed according to lesion
60 level.

61 Conclusion

62 For persons with low cervical SCI, a small number of words should be displayed,
63 or WPS should not be used at all. For persons with high cervical SCI, a larger
64 number of words displayed increases the comfort of use of WPS.

65 Key words

66 Cervical spinal cord injury, text input speed, word prediction software, words
67 displayed

68

69 ABREVIATIONS:

70 SCI: Spinal Cord Injury

71 TIS: Text Input Speed

72 WPS: Word Prediction Software

73 CPM: Characters per minute

74 SD: Standard Deviation

75

76

77

78

79 **Introduction**

80 The use of technology is essential for the social and professional integration of
81 persons with cervical spinal cord injury (SCI)¹. Likewise, the emergence of new
82 interfaces such as tablets and smartphones have changed how people
83 communicate and use the Internet². However, access to Internet and social
84 websites, which is mainly based on text input, can be difficult, especially for
85 persons with high cervical SCI. A variety of devices (infrared cameras, onscreen
86 keyboards etc.) have been designed to facilitate computer use, depending on the
87 level of the lesion^{3 4.5.6.7.8.9}. Despite the use of these devices, text input remains
88 laborious with a mean text input speed (TIS) of 5 words per minute¹⁰ compared
89 with 15-20 words per minute in able-bodied people¹⁰. Several methods have
90 been developed to increase TIS^{11 9 12 13 14.15}, such as speech recognition systems¹⁶
91 or word prediction software (WPS). These methods are recommended by health-
92 related professionals¹⁷ to increase TIS. However, in a noisy home environment,
93 the use of a speech recognition system may be compromised. Also, some people
94 want to keep their privacy when they dictate a text. Thus WPS may be a solution
95 to compensate for some of the disadvantages of speech recognition software. WPS
96 display a list of predicted words that correspond to the word currently being typed
97 by the user. If one of the predictions is correct, the user selects the corresponding
98 word in the list, thereby avoiding typing each letter of the word (keystroke
99 saving¹⁸). WPS can be customized, for example by changing the number of words
100 displayed.

101

102 Data in the literature are conflicting regarding the influence of WPS on TIS, with
103 some studies showing decreases of up to 71% and others showing increases of up
104 to 45%^{19 20 21 22 23 24 25}. The main reason suggested for these differences is the
105 increase in cognitive load caused by the visual search for words in the prediction
106 list. This suggests that the number of words in the prediction list affects TIS.

107 A study in healthy people showed that keystroke savings are significantly related
108 to the number of words displayed²⁶. However, since selection time increases with
109 the number of words in the list, the benefits provided by keystroke savings may be
110 cancelled out. A simulation study showed that each additional word displayed in
111 the prediction list increases search time by 150 milliseconds²⁷. Moreover, there is
112 only a slight increase in keystroke savings between 6 and 11 words. According to
113 these studies, the best compromise between keystroke savings and cognitive load
114 appears to be 5 or 6 words²⁷.

115 A preliminary study¹⁷ carried out in our group showed that health-related
116 professionals most frequently set 6 words for their patients, similarly to data in the
117 literature. However, an unpublished study in our department showed that persons
118 with cervical SCI tended to set a display of 8 words for themselves.

119

120 These results suggest that the number of words displayed in the predicted list is
121 important, however, the optimal number has not yet been determined in a large
122 sample of persons with cervical SCI.

123 The aims of this study were therefore to determine if the number of words in the
124 predicted list influences TIS in a large population of persons with cervical SCI
125 Asia A or B and if this number was influenced by the level of cervical lesion.
126 Based on data in the current literature, we hypothesized that 6 words would be
127 optimal.

128

129 **Method**

130 Participants

131 This prospective cross-sectional study was carried out between October
132 2013 and March 2014. Persons with cervical SCI followed up in the department of
133 physical medicine and rehabilitation of a Teaching Hospital were included by a
134 physician and an occupational therapist if they were over 18 years old, had a SCI
135 between C4 and C8 Asia A or B, were computer users, could read and write
136 French and were not regular user of WPS. They were excluded if they had
137 cognitive, linguistic or visual impairments. The study was approved by the local
138 ethics committee (CPP Ile-de-France, Saint Germain en Laye) and all subjects
139 provided written informed consent before participation. Data collection was
140 performed by an occupational therapist and took place in the department of
141 physical medicine and rehabilitation in the teaching hospital in which the patient
142 was recruited.

143 Participants were included in one of two distinct groups, depending on their
144 lesion level:

145 -A high lesion group for persons with C4 or C5 Asia A or B tetraplegia
146 -A low lesion group for persons with C6, C7 or C8 Asia A or B tetraplegia.
147 The distinction between the high lesion group and the low lesion group was
148 made because persons with lesions at or below C6 have sufficient wrist extension
149 to use a standard keyboard²⁸.

150

151 Materials

152 To standardize the evaluation conditions, a Dell-XPS computer, equipped with a
153 KeyVit Onscreen Keyboard and Skippy WPS were used. Skippy was chosen as it
154 has been shown to be the WPS which is the most prescribed and used ¹⁷.

155 Participants who used an onscreen keyboard used their usual pointing devices
156 (head-controlled).

157 The WPS was configured to display the list of words horizontally at the top of the
158 screen, as is most frequent. The number of words (3, 6 and 8) was chosen based
159 on results from our previous study on the use of WPS and data in the literature.

160 Two parameters were not activated: automatic learning of new words and a faster
161 presentation of the words most frequently used (frequency of use). It has been
162 shown that most persons with cervical SCI use commercial WPS without such
163 advanced settings¹⁷. Words were thus displayed alphabetically in the prediction
164 list, as is the case in the majority of WPS.

165

166 Procedures.

167 Firstly, the use of WPS was explained to each participant. Then, each participant
168 was allowed a 5 minute-training period using the WPS in a copying task. Finally,
169 each participant underwent a single evaluation session involving 4 copying task
170 conditions. The conditions were randomly assigned to avoid bias associated with
171 fatigue:

172 -without WPS (Without)

173 -with 3 predicted words (3Words)

174 -with 6 predicted words (6Words)

175 -with 8 predicted (8Words)

176 The randomization was performed using dedicated software and a system of
177 sealed envelopes was used for allocation. A maximum of 10 minutes was allowed
178 for each task and participants were given a five-minute break between each task.
179 Four 500-word texts of similar complexity were used, drawn from a speech and
180 language therapy book²⁹. The average word length was 5.1 ± 0.5 (SD).

181 The length of each text was deliberately too long for it to be copied in 10 minutes.

182 The evaluation was therefore stopped after 10 minutes. The texts were randomly
183 allocated in order to ensure that the same text was not associated with the same
184 copying task.

185 Participants were instructed to use the WPS but no instructions regarding
186 strategies of use were given. Errors could be corrected.

187 All assessments were videotaped and the videos were used for the analysis. All
188 the evaluations were performed by the same investigator to limit bias.

189

190 Outcome Measures.

191 During the 4 copying tasks, TIS was calculated as follows:

192 Objective evaluations

193 **Characters per minute (cpm):** Number of characters typed in ten minutes

194 divided by 10, including punctuation marks, spaces, backspace, selection errors,

195 and correction times.

196 **Item selection speed (item per minute):** Number of items selected in ten minutes

197 divided by 10 including punctuation marks, spaces, backspaces, arrow keys and

198 keys used to select words in the word prediction list.

199 **Number of errors and rate of word prediction use:** The number of errors and

200 number of predicted words selected from the word prediction list in ten minutes

201 were calculated from the videos.

202 Subjective evaluations (self-evaluations).

203 **Fatigue** was evaluated using a 0-10 point visual analog scale (VAS) before and

204 after every task (0: no fatigue - 10: exhaustion)

205 **Perception of speed and cognitive load** were evaluated using a 0-10 point VAS.

206 For perception of speed, 0: very slow - 10: very fast; for cognitive load, 0: low

207 cognitive load - 10: high cognitive load.

208 **Satisfaction** was evaluated using a 0-5 point VAS (0: not satisfied/5: very

209 satisfied)

210

211 Data Analysis

212 Descriptive statistics (mean±standard deviation) were used to describe continuous
213 variables and frequencies for categorical variables.

214 A Wilcoxon test was used to analyze differences in age and education level
215 between the low and high lesion groups.

216 A Chi square test was used to analyze differences in gender, frequency of use of
217 word processing and frequency of computer use between the low and high lesion
218 groups.

219 The objective and subjective data relating to TIS followed a normal distribution
220 (Shapiro–Wilk-test) and thus parametric tests were used. To compare the
221 influence of the number of words displayed in the prediction list on TIS, item
222 selection speed, number of errors, rate of word prediction use, satisfaction,
223 cognitive load and perception of speed, a repeated-measures ANOVA with two
224 factors: type of assessment (Without/3Words/6Words/8Words) and lesion level
225 (high/low) was used. A post-hoc Fisher’s least significant difference (LSD) test
226 was carried out on significant results. For the analysis of the high lesion group, we
227 used a repeated-measures ANOVA with two factors: type of assessment
228 (Without/3Words/6Words/8Words) and devices used (standard
229 keyboard/onscreen keyboard + Trackball/ onscreen keyboard + Infrared camera).

230 The level of significance was fixed at $p < 0.05$. Data were analyzed using
231 STATISTICA 10 software-StatSoft. Inc software (Tulsa, USA).

232

233 **Results**

234 **Demographic results**

235 Ninety persons with cervical SCI fulfilled the inclusion/exclusion criteria, of
236 whom 45 agreed to participate in this study (35 males and 10 females; mean age
237 39.6 (SD10) years). Mean time since lesion of the overall group was 10.6 (SD8)
238 years.

239 Fifteen participants were included in the high lesion group (14 males and 1
240 female, mean age 40.9 (SD9) years). Ten participants had used a computer for
241 over 10 years, 2 between 5 and 10 years, 2 between 1 and 5 years and 1 for less
242 than 1 year. Six subjects used infrared tracking technology and 9 used a trackball
243 controlled by the chin. All used onscreen keyboards. Thirteen subjects used word
244 processing programs regularly (>3 times/week) and 2 did not (≤3 times/month).

245 Thirty participants were included in the low lesion group (21 males and 9
246 females, mean age 39.5 (SD11) years). Twenty-six participants had used a
247 computer for over 10 years, 3 participants between 5 and 10 years and 1 between
248 1 and 5 years. All participants used a standard keyboard without splints and used
249 word processing programs regularly (>3 times/week).

250

251 There were no significant differences between groups for age, gender, years of
252 education and frequency of use of word processing programs. However,
253 participants in the low lesion group used the computer more frequently than
254 participants in the high lesion group ($p<0.001$).

255

256 **Results of objective evaluations**

257 TIS (Characters per minute)

258 -----Insert table 1 -----

259 There was a significant effect of condition on TIS

260 (Without/3Words/6Words/8Words)($F(3,129)=8.64;p<0.001$); there was also a

261 significant effect of lesion level ($F(1,43)=27.6;p<0.001$) and a significant

262 interaction between the 2 factors ($F(3,129)=8.89,p<0.001$).

263 The post-Hoc analysis indicated that participants with low lesions inputted text

264 faster than participants with high lesions. For participants with low lesions, text

265 input was faster without WPS than with WPS (3Words/6Words/8Words)

266 regardless of the number of words displayed ($p<0.001$). For participants with high

267 lesions, there was no influence of WPS (3Words/6Words/8Words) on TIS

268 ($p=0.99$).

269 In the high lesion group, there was no significant effect of condition on TIS

270 ($F(3,39)=0.2 ; p=0.89$); however, there was a significant effect of the device used

271 ($F(1,13)=11,2 ; p=0.005$ with no interaction between the 2 factors ($F(3,39)=0.75 ;$

272 $p=0.52$)

273

274 Number of Errors

275 -----Insert table 2 -----

276 There was a significant effect of lesion level on the number of errors
277 ($F(1,43)=35.3;p<0.001$). However, there was no influence of condition
278 ($F(3;129)=0.9;p=0.43$) and no interaction between the 2 factors
279 ($F(3,129)=0.18,p=0.90$).

280 The Post-Hoc analysis indicated that the high lesion group made fewer errors than
281 the low lesion group ($p<0.001$). There was no influence of condition ($p=0.44$) on
282 the number of errors in either group.

283 In the high lesion group, there was no significant effect of condition on the
284 number of errors ($F(3,39)=1.5 ; p=0.22$), no significant effect of the device used
285 ($F(1,13)=0.002 ; p=0.96$) and no interaction between the 2 factors ($F(3,39)=1.6 ;$
286 $p=0.20$)

287
288

289 Item selection speed.

290 -----Insert table 3 -----

291 There was a significant effect of condition on item selection speed
292 (Without/3Words/6Words/8Words)($F(3,129)=7.84;p<0.001$). There was also a
293 significant effect of lesion level ($F(1,43)=28.76;p<0.001$) and a significant
294 interaction between the 2 factors ($F(3,129)=11.11;p<0.001$).

295 The Post-Hoc analysis indicated that participants with high lesions had a higher
296 key selection speed than participants with low lesions. Key selection speed was

297 higher without WPS for participants with low lesions ($p < 0.001$) whereas there
298 were no differences between conditions for the high lesion group ($p = 0.99$).
299 In the high lesion group, there was no significant effect of condition on item
300 selection speed ($F(3,39) = 0.9$; $p = 0.44$). However, there was a significant effect of
301 the device used ($F(1,13) = 9.8$; $p = 0.007$) with no interaction between the 2 factors
302 ($F(3,39) = 0.8$; $p = 0.49$)

303

304 Rate of word prediction use.

305 -----Insert table 4 -----

306 There was a significant effect of lesion level on rate of use of word prediction.
307 ($F(1,43) = 5.6$; $p = 0.02$). There was no influence of condition ($F(2,86) = 1.6$; $p = 0.18$)
308 and no interaction between condition and lesion level ($F(2,86) = 2.6$, $p = 0.07$).

309 The Post Hoc analysis showed no interaction between low and high lesions
310 ($p = 0.33$) or between lesion level and condition ($p = 0.99$).

311 In the high lesion group, there was no significant effect of condition on rate of use
312 of word prediction ($F(2,26) = 1.49$; $p = 0.24$); However, there was a significant
313 effect of the device used ($F(1,13) = 5.6$; $p = 0.003$ with no interaction between the 2
314 factors ($F(2,26) = 2.65$; $p = 0.09$)

315

316 **Results of the subjective evaluations**

317 Fatigue

318 There was no significant effect of condition ($F(3,129)=1.86;p=0.97$) or lesion
319 level ($F(1,43)=0.2;p=0.65$) and no interaction between the 2 factors
320 ($F(3,129)=1.86;p=0.13$).

321 Perception of TIS

322 There was a significant effect of condition ($F(2,86)= 4.91; p<0.001$) and lesion
323 level ($F(1,43)= 6.82; p=0.01$) with no interaction between the 2 factors
324 ($F(2,86)=2.34; p=0.10$).

325 The Post-Hoc analysis indicated that, for the low lesion group, participants
326 perceived text input as faster with a display of 3 words compared to 8 words
327 ($p=0.003$). Participants with high lesions perceived text input as faster with a
328 display of 6 and 8 words than participants with low lesions (respectively
329 $p=0.03;p<0.001$).

330 Cognitive load

331 There was no influence of condition ($F(2,86)=1.42;p=0.24$) or lesion level
332 ($F(1,43)=0.91;p=0.35$) and no interaction between the 2 factors
333 ($F(2,86)=1.33;p=0.26$).

334 Satisfaction

335 There was no influence of condition ($F(2,86)=0.31;p=0.73$). There was a
336 significant effect of lesion level ($F(1,43)=5.97;p=0.02$) and a significant effect
337 between the 2 factors ($F(2,86)=3.25;p=0.04$). The Post-Hoc analysis indicated that
338 for the high lesion group, satisfaction with 8 Words was higher than for the low
339 lesion group ($p=0.01$)

340

341 **Discussion**

342 We found in this study that the influence of WPS on text input speed depended on
343 the lesion level of the user. TIS was faster without WPS for participants with low
344 lesions, whatever the number of words displayed, while there was no influence of
345 WPS in participants with high lesions. These results refute our hypothesis and
346 contrast with previous results in the literature.

347

348 Influence of WPS on TIS.

349 The influence of WPS on TIS differed depending on the level of cervical SCI.
350 This result was further confirmed by the rate of word prediction use in each
351 group.

352 **In each group.**

353 For the low lesion group, the decrease in TIS with WPS was associated with a
354 decrease in key selection speed, even if the cognitive load was not higher with
355 WPS in this group. However, this is in accordance with previous studies^{19,22} and
356 could relate to the necessity to search for predicted words on the computer screen
357 while using a physical keyboard.

358 For the high lesion group, TIS, item selection speed and cognitive load were not
359 affected by WPS, whatever the device used. These results therefore suggest that
360 not only is the use of WPS not effective to increase TIS in people with cervical
361 SCI, it may actually have a negative influence on TIS. However, the adjustment of

362 other settings could change the influence of WPS on TIS. In another study
363 conducted by our team (in press), we showed that the activation of “frequency of
364 use” increased TIS in persons with high cervical SCI. The difference in results
365 between the two groups may relate to the fact that the cognitive load induced by
366 the visual search for words in the prediction list is lower with the use of an
367 onscreen keyboard since a smaller degree of visuospatial exploration is required
368 than for a standard keyboard (used by the low SCI level group). Tam et al (2009)
369 confirmed this hypothesis since they found that people with cervical SCI who
370 used an external device to display the word prediction list near the standard
371 keyboard had to look at their fingers when they typed³⁰.

372 **Between group comparison**

373 There were fewer text input errors in the high lesion group than the low lesion
374 group. This could be the result of the lower TIS of the high lesion group along
375 with the fact that use of an onscreen keyboard requires a smaller degree of
376 visuospatial exploration.

377 The lack of influence of WPS on fatigue in both groups contradicts data in the
378 literature. WPS has previously been shown to reduce fatigue in persons with
379 cerebral palsy³¹. This difference might be related to the fact that persons with
380 cervical SCI have lower levels of fatigue than persons with brain injury. This
381 should, however be evaluated in further comparative studies. The results of the
382 present study may also have been affected by the fact that the “frequency of use”
383 and “learning new words” parameters were disabled. This could affect TIS,

384 fatigue and the number of errors. It would therefore be interesting to study the
385 influence of these parameters more specifically in future studies.

386

387 Influence of the number of words displayed on TIS.

388 We initially hypothesized that the number of words displayed in the prediction list
389 would influence TIS. However, there was no influence of the number of words
390 displayed on TIS or on key selection speed in either group, whatever the device
391 used. Similarly, there was no influence on rate of word prediction use. These
392 results contrast with previous results in the literature. Koester found that a display
393 of 5 or 6 words is the best compromise between increasing TIS and cognitive
394 load²⁷. This difference may be related to differences in methodology and the fact
395 that the sample of participants with cervical SCI was larger in the present study.
396 Participants with low lesions perceived text input to be faster with a display of 3
397 words rather than 8 words. This may be related to the fact that a shorter list
398 requires a shorter visual search time. In contrast, satisfaction was higher with a
399 display of 8 words for participants with high lesions. The higher TIS of
400 participants with low cervical SCI may make reducing visual search time a
401 priority while the use of a virtual keyboard by participants with high lesions and
402 the low associated TIS may induce a preference for a greater choice of words and
403 greater key stroke savings. However, it must be noted that altering the number of
404 words displayed only affected the perception of TIS but had no objective
405 influence.

406

407 **Study limitations**

408

409 The difference in the number of subjects and the difference in the frequency of
410 computer use in the high and low cervical SCI groups could constitute a bias in
411 the interpretation of the results. However, any such bias appears to have had a
412 minimal impact since the variability of the two groups was almost similar. No
413 studies found in the literature have evaluated the influence of lesion level on TIS.
414 This study on word prediction software involved the largest sample of persons
415 with cervical SCI currently available in the literature and thus the results are
416 worthy of note.

417 Moreover, the use of different computer access devices in the high lesion group
418 influenced text input speed and item selection speed. Nevertheless, the results
419 suggest that the impact of these different devices on the influence of word
420 prediction software and the number of words displayed was small. We found no
421 influence of the number of words displayed on TIS in the high lesion group, and
422 no influence of the WPS on TIS as a function of the type of device used. In
423 addition, the lack of validation of the visual analogue scales used may constitute a
424 limitation for the analysis and the interpretation of results.

425 The alteration of other parameters such as the frequency of words displayed may
426 influence TIS by increasing the relevance of the displayed words. Moreover, lack

427 of training in the use of WPS could also influence TIS. The influence of training
428 should be considered in future studies.

429

430 **Conclusions**

431 The influence of the number of words displayed in a word prediction list on TIS
432 differed depending on the level of cervical SCI. The use of WPS decreased TIS in
433 participants with low lesions, whatever the number of words displayed. In
434 participants with high lesions, there was no influence of WPS on TIS and no
435 influence of the number of words displayed. The results of this study suggest that
436 changing the number of words displayed may alter the perception of ease of text
437 input in persons with SCI but does not have an objective influence on TIS. Further
438 studies should be carried out to evaluate the influence of other WPS parameters
439 on TIS. These results are important for health-related professionals whose role is
440 to advise persons with SCI in the choice of word prediction software. It seems
441 important to reduce the number of words displayed for persons with low cervical
442 SCI, or not to use WPS at all, and to increase the number of words displayed for
443 persons with high cervical SCI in order to increase the comfort of use of WPS.
444 However, it must be kept in mind that these results are based on a single data
445 collection session. It would be useful to evaluate the impact of specific training on
446 the influence of WPS. The impact of other parameters of word prediction software
447 should also be considered in further studies, such as the location of the prediction

448 list and the feature of only suggesting words of 5 characters or more, to decrease

449 visual search time.

450

451

- 453 1. Folan A, Barclay L, Cooper C, Robinson M. Exploring the experience of
454 clients with tetraplegia utilizing assistive technology for computer access.
455 *Disabil. Rehabil. Assist. Technol.* [Internet]. 2015 [cited 2014 Jul 9];10:46–
456 52. Available from: <http://www.ncbi.nlm.nih.gov/pubmed/24050283>
- 457 2. Bigot P, Crouette E. La diffusion des technologies de l'information et de la
458 communication dans la société. Rapp. réalisé à la demande du Cons.
459 Général des Technol. l'Information (Ministère l'Economie, des Financ.
460 l'Emploi) l'Autorité Régulation des Commun. Electron. des Postes.
461 [Internet]. Paris : Centre de Recherche pour l'Etude et l'Observation des
462 Conditions de Vie, 2014, 220 p. Available from :
463 <http://www.credoc.fr/pdf/Rapp/R317.pdf>
- 464 3. Laffont I, Biard N, Bouteille J, Pouplin S, Guillon B, Bernuz B, et al.
465 Tétraplégie: solutions technologiques de compensation des incapacités
466 découlant de l'atteinte des membres supérieurs. *La Lett. médecine Phys.*
467 *réadaptation* [Internet]. 2008 [cited 2012 Dec 6];24:113–21. Available
468 from: <http://www.springerlink.com/index/10.1007/s11659-008-0106-y>
- 469 4. Betke M, Gips J, Fleming P. The camera mouse: visual tracking of body
470 features to provide computer access for people with severe disabilities.
471 *IEEE Trans. Neural Syst. Rehabil. Eng.* [Internet]. 2002;10:1–10. Available
472 from: <http://www.ncbi.nlm.nih.gov/pubmed/12173734>
- 473 5. Huo X, Park H, Kim J, Ghovanloo M. A dual-mode human computer
474 interface combining speech and tongue motion for people with severe
475 disabilities. *IEEE Trans. Neural Syst. Rehabil. Eng.* [Internet]. 2013 [cited
476 2015 May 11];21:979–91. Available from:
477 <http://www.ncbi.nlm.nih.gov/pubmed/23475380>
- 478 6. Kim DG, Lee BS, Lim SE, Kim DA, Hwang S Il, Yim YL, et al. The
479 selection of the appropriate computer interface device for patients with high
480 cervical cord injury. *Ann. Rehabil. Med.* 2013;37:443–8.
- 481 7. Kim J, Park H, Bruce J, Rowles D, Holbrook J, Nardone B, et al.
482 Qualitative assessment of tongue drive system by people with high-level
483 spinal cord injury. *J. Rehabil. Res. Dev.* [Internet]. 2014 [cited 2015 May
484 11];51:451–65. Available from:
485 <http://www.ncbi.nlm.nih.gov/pubmed/25019667>

- 486 8. Choi C, Na Y, Rim B, Kim Y, Kang S, Kim J. An SEMG computer
487 interface using three myoelectric sites for proportional two-dimensional
488 cursor motion control and clicking for individuals with spinal cord injuries.
489 Med. Eng. Phys. [Internet]. 2013 [cited 2015 May 11];35:777–83.
490 Available from: <http://www.ncbi.nlm.nih.gov/pubmed/22939517>
- 491 9. Turpin G, Armstrong J, Frost P, Fine B, Ward C, Pinnington L. Evaluation
492 of alternative computer input devices used by people with disabilities. J.
493 Med. Eng. Technol. [Internet]. 2005;29:119–29. Available from:
494 <http://www.ncbi.nlm.nih.gov/pubmed/16019881>
- 495 10. Le Pévédic B. Prédiction Morphosyntaxique Évolutive HandiAS, Doctoral
496 Thesis, Ecole Doctorale Sciences pour l'Ingénieur, 1997, Nantes, 142p.
- 497 11. Pouplin S, Robertson J, Antoine J, Blanchet A, Kahloun JL, Engineer D, et
498 al. Effect of dynamic keyboard and word-prediction systems on text input
499 speed in persons with functional tetraplegia. J. Rehabil. Res. Dev.
500 2014;51:467–80.
- 501 12. Raynal M, Vigouroux N. Genetic algorithm to generate optimized soft
502 keyboard. CHI '05 Ext. Abstr. Hum. factors Comput. Syst. - CHI '05
503 [Internet]. 2005;1729. Available from:
504 <http://portal.acm.org/citation.cfm?doid=1056808.1057008>
- 505 13. Kushler C. AAC using a reduced keyboard. Proc. CSUN Conf. Technol.
506 Pers. with Disabil. CSUN'98. Calif. State Univ. Nortridge CA. 2001;
- 507 14. Isokoski P. Performance of menu-augmented soft keyboards. Proc. 2004
508 Conf. Hum. factors Comput. Syst. - CHI '04 [Internet]. 2004;423–30.
509 Available from: <http://portal.acm.org/citation.cfm?doid=985692.985746>
- 510 15. Harbusch. An evaluation an evaluation study of two button scanning with
511 ambiguous keyboards. In: 7th Conference for the Advancement of
512 Assistive Technology in Europe, AATE'2003. Dublin, Ireland. 2003.
- 513 16. Rieger JM. The effect of automatic speech recognition systems on speaking
514 workload and task efficiency. Disabil. Rehabil. [Internet]. 2003 [cited 2013
515 Jul 2];25:224–35. Available from:
516 <http://informahealthcare.com/doi/abs/10.1080/0963828021000030855>
- 517 17. Pouplin S, Roche N, Hugeron C, Isabelle V, Bensmail D.
518 Recommendations and settings of word prediction software by health-
519 related professionals for people with spinal cord injury□: a prospective
520 observational study. Eur. J. Phys. Rehabil. Med. 2015;article in press.

- 521 18. Wandmacher T, Antoine J, Poirier F, Départe J-P. Sibylle, An Assistive
522 Communication System Adapting to the Context and Its User. *ACM Trans.*
523 *Access. Comput.* 2008;
- 524 19. Koester HH, Levine SP. Effect of a Word Prediction Feature on User
525 Performance. *Augment. Altern. Commun.* [Internet]. 1996;12:155–68.
526 Available from:
527 <http://informahealthcare.com/doi/abs/10.1080/07434619612331277608>
- 528 20. Laffont I, Dumas C, Pozzi D, Ruquet M, Tissier AC, Lofaso F, et al. Home
529 trials of a speech synthesizer in severe dysarthria: patterns of use,
530 satisfaction and utility of word prediction. *J. Rehabil. Med.* [Internet]. 2007
531 [cited 2012 Nov 16];39:399–404. Available from:
532 <http://www.ncbi.nlm.nih.gov/pubmed/17549332>
- 533 21. Vigouroux N, Vella F, Truillet P, Raynal M. Evaluation of AAC for text
534 input by two groups of subjects □: able-bodied subjects and disabled Motor
535 Subjects. In: 8th ERCIM UI4All, Vienne (Autriche). 2004.
- 536 22. Anson D, Moist P, Przywara M, Wells H, Saylor H, Maxime H. The effects
537 of word completion and word prediction on typing rates using on-screen
538 keyboards. *Assist. Technol.* [Internet]. 2006;18:146–54. Available from:
539 <http://www.ncbi.nlm.nih.gov/pubmed/17236473>
- 540 23. Anson D. The effect of word prediction on typing speed. *Am. J. Occup.*
541 *Ther.* 1993;47:1039–42.
- 542 24. Koester HH. Learning and performance in scanning systems with and
543 without word prediction - report on a pilot study. In: *Proceedings of*
544 *RESNA 1992* -. 1992.
- 545 25. Koester HH. The effect of a user's search strategy on performance with
546 word prediction. In: *Conference proceeding of RESNA*. 1997.
- 547 26. Venkatagiri HS. Effect of Window Size on Rate of Communication in a
548 Lexical Prediction AAC System. *AAC Augment. Altern. Commun.*
549 1994;10:105–12.
- 550 27. Koester HH, Levine S. Keystroke-level models for user performance with
551 word prediction. *Augment. Altern. Commun.* [Internet]. 1997;13:239–57.
552 Available from:
553 <http://informahealthcare.com/doi/abs/10.1080/07434619712331278068>

- 554 28. Guttmann L. Spinal Cord Injuries, Comprehensive Management and
555 Research. 1ere édit. Blackwell Science Ltd; 1973.
- 556 29. Fraval Lye M, Boutard C. Textzados. Ortho Edit. Isbergues: 2004.
- 557 30. Tam C, Wells D. Evaluating the benefits of displaying word prediction lists
558 on a personal digital assistant at the keyboard level. Assist. Technol.
559 [Internet]. 2009 [cited 2012 Dec 6];21:105–14. Available from:
560 <http://www.ncbi.nlm.nih.gov/pubmed/19908678>
- 561 31. Wandmacher T, Antoine J, Poirier F, Départe J-P. Sibylle, An Assistive
562 Communication System Adapting to the Context and Its User. ACM Trans.
563 Access. Comput. 2008;1:1–30.

564

565

566

567

568

569

570

571

572

573 **TABLES**

574

575 Table 1. Characters per minute – Mean (sd)

576 Table 2. Number of errors – Mean (sd)

577 Table 3. Key selection speed (key presses per minute) – Mean (sd)

578 Table 4. Rate of word prediction use– Mean (sd)

579

580