Reading Comprehension Issues and Individuals with Visual Impairments: The Effects of Using 8-dot and 6-dot Braille Code Through a Braille Display

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Abstract. The purpose of the present study was to evaluate the effects of 6-dot and 8-dot braille code on the reading comprehension ability of individuals with severe visual impairments and/or blindness when the latter receive typographic meta-data (bold and italic) by touch through a braille display. Also, patterns of hand movements were investigated and related to issues of comprehension. The most important finding related to the superiority of the 8-dot braille code in predicting reading comprehension in individuals with severe visual impairments. It was also found that reading comprehension was particularly predicted from the negative relationship between participants' fluency and comprehension. It was conjectured that all comparisons between conditions were significant suggesting that the present findings were likely robust and not reflective of idiosyncrasies in the sample. The focus of the discussion was placed on the importance of conducting additional research increasing the sample size with more extensive training for those who will constitute the extended sample.

Keywords: Typographic meta-data · 6-dot braille · 8-dot braille · Braille display · Blindness · Patterns of hand movements · Linear regression

1 Introduction

Nowadays children with visual impairments have the opportunity to use various media for accessing information. The preference of the medium usually depends on teachers' instruction and students' comprehension [1]. For example, using synthetic speech is no-time consuming procedure but does not lead to deep comprehension of a text [2]. On the other hand, it seems that when individuals with visual impairments read by touch (i.e. through print braille or through refreshable braille display) they end up with better

M. Antona and C. Stephanidis (Eds.): UAHCI 2015, Part II, LNCS 9176, pp. 71–81, 2015.
DOI: 10.1007/978-3-319-20681-3_7

comprehension rates in conjunction with lower reading rates [3]. It is also worth mentioning that blind people's hands motions when reading braille by touch have been considered as a critical parameter in braille reading and comprehension [4, 5] The main research aim of the present study focuses on issues of reading comprehension, when users with blindness receive typographic meta-data (bold and italic) by touch through a braille display. This type of information (meta-data or meta-information) is the information that sighted readers get from documents at their typographic layer (such as, type, size, etc.) or/and font style such as bold, italics, underline [6]. In addition, levels of reading comprehension were investigated towards the 6-dot and the 8-dot braille code through a braille display.

The purpose of the present study was to evaluate the effects of the medium, that is, 6-dot and 8-dot braille codes on the reading comprehension ability of individuals with severe visual impairments and/or blindness. Specifically, the present study was designed to answer the following Research Questions (R.Q.).

- R.Q.1. Are there differences in reading comprehension as a function of using 6-dot and 8-dot braille code of reading?
- R.Q.2. Is fluency of bold and italic elements differentially predictive of reading comprehension using 6-dot and 8-dot braille code of reading?
- R.Q.3. How is hand movement related to each of the two experimental conditions, the 6-dot and the 8-dot braille code of reading?

All research objectives refer to typographic meta-data and specifically to bold and italic. The reason of choosing these specific typographic signals is their frequency of use in Greek print materials [7].

2 Method

2.1 Participants

Participants were twenty individuals with severe visual impairments participated in a series of experiments using braille displays. All participants knew to read and write braille, had no other additional disabilities and their age range was from 19 to 44 years (mean = 31.35, SD = 3.57).

2.2 The Research Design

The participants were asked to read from a braille display different scripts within which meta-information was included (i.e. bold and italic). The scripts were divided into two categories. The first one consisted of texts in which bold and italic were rendered by the 8-dot braille code, and the second one consisted of an equivalent number of texts rendered by the 6-dot braille code. The rendition of meta-information "bold" and "italic" in the 8-dot and 6-dot braille codes was based on the results of the study which was conducted by Argyropoulos et al. [3]. In specific, when the meta-information in the first category of scripts was in bold then it was rendered by raised pins 7 and 8 constantly, whereas when these pins were raised intermittently (i.e. at the first, middle and last letters of a word or phrase) then the meta-information was meant to be in italic. For the rendition of “bold” and “italic” in the 6-dot braille code, the researchers used the tags which are specified by the Nemeth code with slight modifications because dots 4 and 6 constitutes the indicator for capitals in the 6-dot Greek Braille code [3]. The selected texts were aligned with all facets of the reading process (such as word length, content, level of difficulty). In turn, the participants were asked to answer comprehension questions without any time limit. The experimental procedure was video-recorded because it was the only way to describe with accuracy all participants’ hand movements on the braille display when they were reading in 6-dot and the 8-dot braille code respectively.

All participants were invited to read aloud every single script and mention all the meta-information (bold and italic) they met. In total, each of the twenty participants was invited to read through a braille display four expository texts (two texts through 6-dot braille code and two other equivalent texts in the 8-dot braille code) and then they were asked to answer five comprehension questions for each text. The answers to these questions were based on the key-words or key-phrases which were rendered in bold or in italic (in each text there were three typographic meta-information in bold and three typographic meta-information in italic). All participants were given appropriate time to familiarize themselves with the use of a braille display. Also, all experiments were conducted with the same braille display and a training period preceded the experimental procedure to assure that all participants had the same baseline regarding renderings for bold and italic by a braille display.

2.3 Measures

Reading fluency comprises three basic constituents: the first one refers to accurate reading; the second one to the reading rate, and the last one to the appropriate prosody or expression of the reading process [8]. Hence, the authors in order to fully describe the reading fluency had to take into account the previous three constituents. Because the participants of the study were individuals with severe visual impairments it was conjectured that the element of the prosody could not be taken into account due to the lack of the holistic “view” of the text [9]. In other words, automatic decoding [10] which leads to appropriate prosody seems to be very hard for individuals with severe visual impairments because it has been reported that “*Fluent readers are better at seeing a word in a single eye fixation and do not need as many refixations or regressions”* (p. 702) [8]. Hence, reading fluency in the present work was determined by (a) rate or reading overall time, and (b) accuracy. The quantification of accuracy was defined in terms of the participants’ recognition or identification of the typographic meta-data (bold and italic) within the four texts when using 6-dot braille and 8-dot braille respectively. In total, there were 12 typographic meta-information in italic and 12 typographic meta-information in bold. All correct identifications were scored with “1” while all incorrect identifications were scored with “0” (lowest score: 0 & highest score: 24). Also, it was decided to quantify reading rate in terms of the length of time that it would take for each participant to read a text (LTR – Length Time Reading).

Comprehension was measured through five comprehension questions corresponded to each text. The researchers constructed questions according to the three types of reading comprehension questions taxonomy of Pearson and Johnson [11]. All correct responses were scored with "1" while all incorrect responses were scored with "0". The scores that participants could achieve for all texts were from 0 up to 20.

2.4 Data Analysis

For the first research question, and in order to evaluate differences between 6- and 8-dot codes of reading, a paired samples t-test was employed. Power for Student's t-statistic was equal to 80 % for a two-tailed test using an alpha level of 5 % and a large effect size (equal to .8 of a standard deviation) [12]. The above configuration was associated with a pair of observations equal to n = 16. Thus, the current sample size would suffice to inferentially evaluate effects (Fig. 1).

With regard to the second research question, the critical value of the F-distribution for a linear regression model was equal to 4.279 units, for power levels equal to 80 %, an alpha level equal to 55 and a large effect size defined with a semi-partial correlation f^2 equal to 0.35. For this configuration, the required sample size equaled 25 participants, so the current analysis was slightly underpowered with the present sample size of n = 20 (see Fig. 2). Thus, the regression model was likely conservative and reflective of potential Type-II errors. For that reasons, evaluations using effect size metrics would be implemented over and above the inferential statistical findings.

For the third research question and in order to describe in detail the participants' hand movements when reading the texts by touch, a hand movement pattern was adopted [13]. According to this pattern six main characteristics of blind persons' hand movements may be determined when they read braille: (a) Scrubbing (Sc), involves the motion that the finger makes when it moves up and down over a braille character, (b) Regression (R), involves motions such when the finger(s) is/are moving back across the page to reread or check something, (c) Searching (Se), when the hands are looking for information but without reading, (d) Pausing (P), when the hand rests on the page, (e) Erratic movements (EM), when the movements include all type of motions except

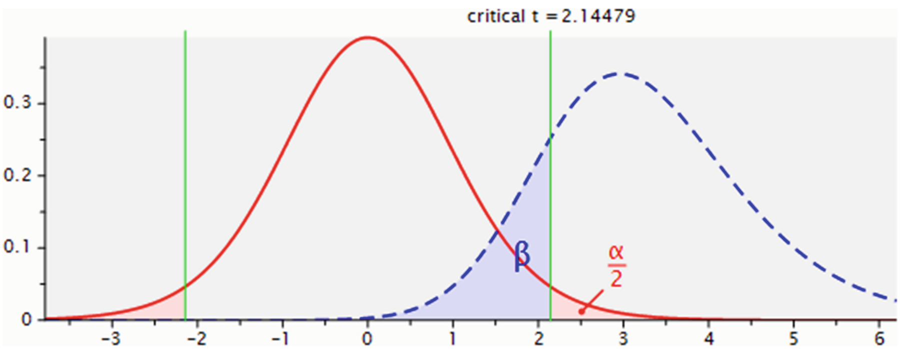


Fig. 1. Power estimates for a paired samples t-test as a function of an alpha level of 5 %

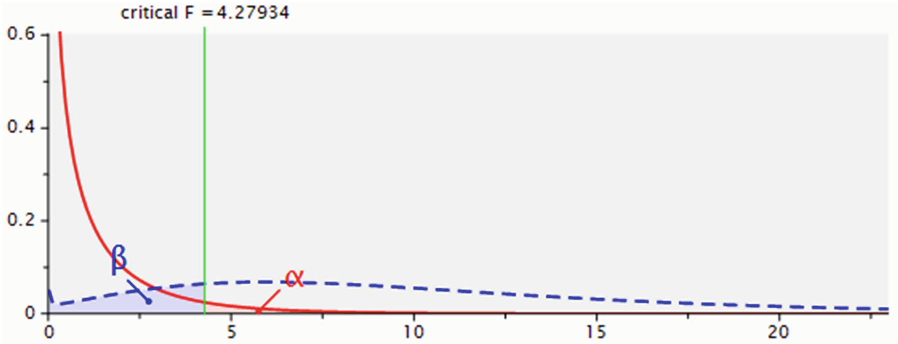


Fig. 2. Power curve for the linear regression model with one predictor

reading, and (f) Normal Braille Reading (NBR), when fluid movements take place on the paper by the user's hands.

2.5 Results

The results are presented as answers per research question and are shown below:

R.Q.1. Are there differences in reading comprehension as a function of using 6-dot and 8-dot braille code of reading?

Results using a paired samples t-test indicated that there were significant differences between the two conditions [t(19) = 3.222, p = .0045], with reading comprehension being favored in the 8-dot braille code (see Fig. 3). The mean in reading comprehension was equal to 6.0 units in the 6-dot braille code ($C.I._{95\ \%}$ = 5.182-6.818) compared to 7.45 in the 8-dot braille code ($C.I._{95\ \%}$ = 6.730-8.170). Inspection of the confidence intervals suggests that it is very unlikely that this difference is due to chance.

R.Q.2. Is fluency of bold and italic elements differentially predictive of reading comprehension using 6-dot and 8-dot braille code of reading?

A linear regression analysis model was fit to the data to predict reading comprehension from the ratio of time and accuracy (i.e., fluency). Results are shown graphically in Figs. 4 and 5. With regard to the bold elements the coefficient of determination was equal to 14.6 % for the overall sample, suggesting a medium effect size [12]. The respective regression equation was equal to y = 8.1099 + -4.3748 x. The omnibus findings, when split to the two experimental conditions were associated with predictions equal to 5.9 % for the 6-dot condition and 4.9 % for the 8-dot condition, none of which reflecting an effect size that would approach meaningful estimates. Figure 4 shows the scatterplot and predicted regression lines for each experimental condition. The parallel lines are suggestive of approximately equal predictions and the sign of the fact that fluency was a negative predictor of reading comprehension.

For the italic elements, the findings were significantly more pronounced with the overall prediction being associated with an R-square equal to 16.8 %, exceeding a medium effect size per Cohen [12]. The prediction in the 6-dot condition was equal to

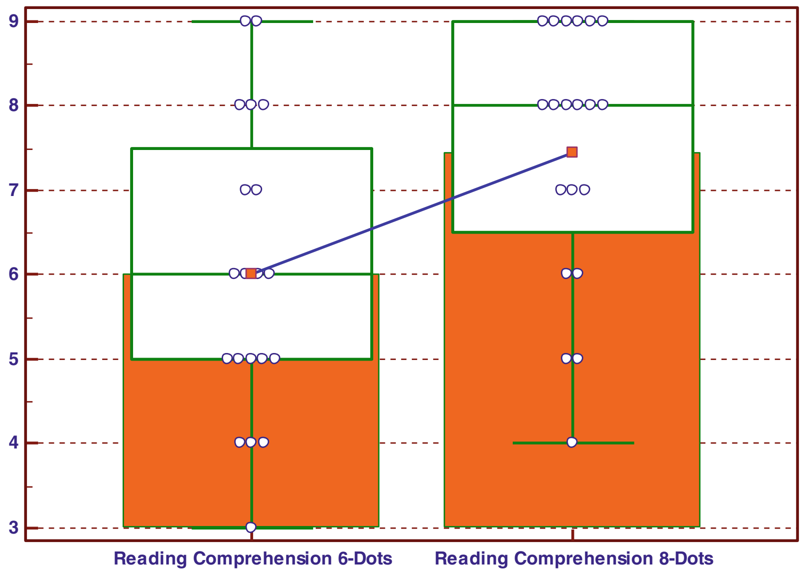


Fig. 3. Differences in reading comprehension between 6-dot and 8-dot conditions. The solid line indicates differences at the mean level and the boxed lines interquartile ranges.

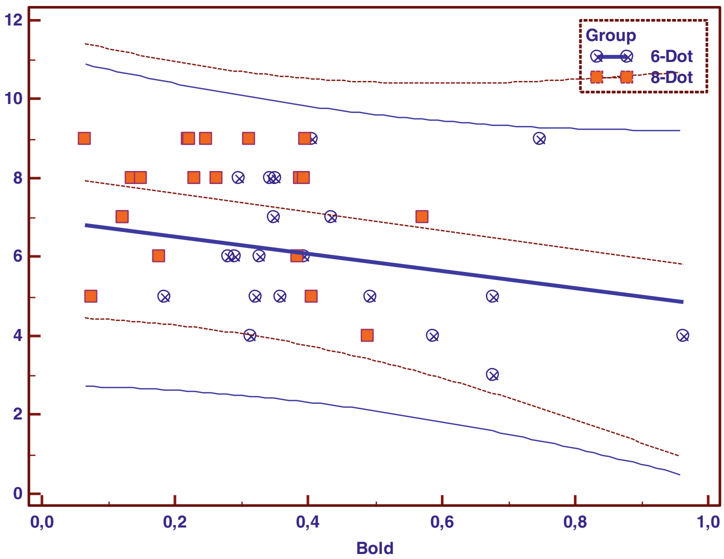


Fig. 4. Fitted regression lines for the prediction of reading comprehension from fluency of the bold elements in the 6-dot and 8-dot braille code.

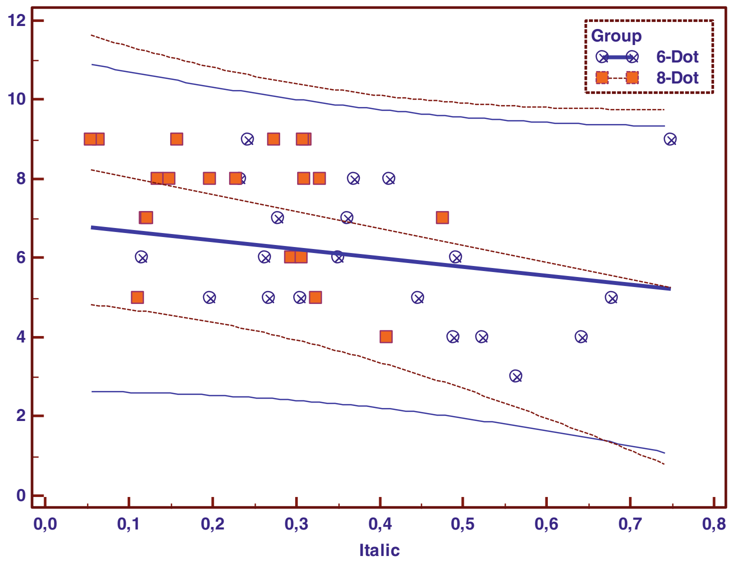


Fig. 5. Fitted regression lines for the prediction of reading comprehension from fluency of the italic elements in the 6-dot and 8-dot braille code.

Table 1. Braille Code and Hand Movements

	R	R-Sc	Sc	NBR
6-dot				
	142	37	10	50
8-dot				
	138	58	5	35

Note: R = Regression, R-Sc = Combined Regression & Scrubbing, S = Scrubbing, NBR = Normal Braille Reading

4.9 % but for the 8-dot condition equal to 10.6 %, suggesting a significant differentiation between the two conditions. This significantly more salient relationship in the 8-dot condition, paired with the significance differences in level between the levels of fluency in the two conditions (see Appendix A) is partly responsible for the higher achievement of reading comprehension in the 8-dot condition.

R.Q.3. How is hand movement related to each of the two experimental conditions, the 6-dot and the 8-dot braille code of reading?

For the type of the participants' hand movement, the findings indicated that more fluid movements took place when they used the 6-dot braille code (50NBR) compared to the 8-dot braille code (35NBR). Also it is worth noting that the pattern of regression was found to be more frequent under the 8-dot condition (138R & 58R-Sc) compared to the 6-dot condition (142R & 37R-Sc). Table 1 describes the type of the participants' hand movement according to Write, Wormsley and Kamei-Hannan study [13].

2.6 Discussion

The purpose of the present study was to evaluate the effects of the medium, 6-dot and 8-dot braille code on the reading ability of individuals with severe visual impairments. Several important findings emerged.

The most important finding related to the superiority of the 8-dot braille code in predicting reading comprehension in individuals with severe visual impairments. Albeit having a relative small sample size, the effect size was large suggesting the presence of robust findings. Potential explanations for the superiority of the 8-dot braille code may be related to issues of sensitivity and exposure to haptic stimuli since tactile movements on the 8-dot cell was more dominating compared to the 6-dot braille (more regression patterns in the 8-dot braille code compared to the 6-dot braille code, see Table 1) and as a result participants' attention was more intense in the first case (R.Q.1 & R.Q.3). It may be argued that this condition led the participants to a more elaborating tactile process enhancing their cognitive operations using more effectively their working memory. Working memory is the cognitive system that is responsible for holding and processing of new and already stored information [14].

The second most important finding related to the fact that reading comprehension was particularly predicted from the negative relationship between fluency and comprehension (R.Q.2). In the literature, the relationship between reading fluency and reading comprehension has been largely positive with some exceptions in which negative effects have also been documented. As Paris and Paris [15] noted, the relationship between fluency and comprehension for low achievers is expected to be positive as the prerequisite skill of decoding reading units is important to comprehend text. In other words, there can be no comprehension if words cannot be meaningfully read. In fact Paris and Paris [15] went one step further to posit that at low levels of reading accuracy (floor levels) this relationship is spuriously high there is a high degree of non-independence between decoding and other reading-related variables (e.g., vocabulary, prior knowledge, passage genre and test format-see Paris & Paris, 2001).

However, for higher ability individuals this relationship has been challenged as fluency is not even considered a necessary and prerequisite condition of reading comprehension as both fast rates and slower rates are associated with high reading ability. The fact that the relationship between fluency and reading comprehension was negative for the present high achieving group agrees with the findings from previous studies with again high achievers [16, 17]. In the present study point estimates of decoding were high, suggesting that the present sample was comprised of high decoders (e.g., point estimates of 5.0 with maximum values of 6.0). The fact that the relationship between high decoding ability and reading comprehension is negative largely explains the superiority of the 8-dot braille code as the levels of fluency were lower within this condition compared to the 6-dot braille code under evaluation.

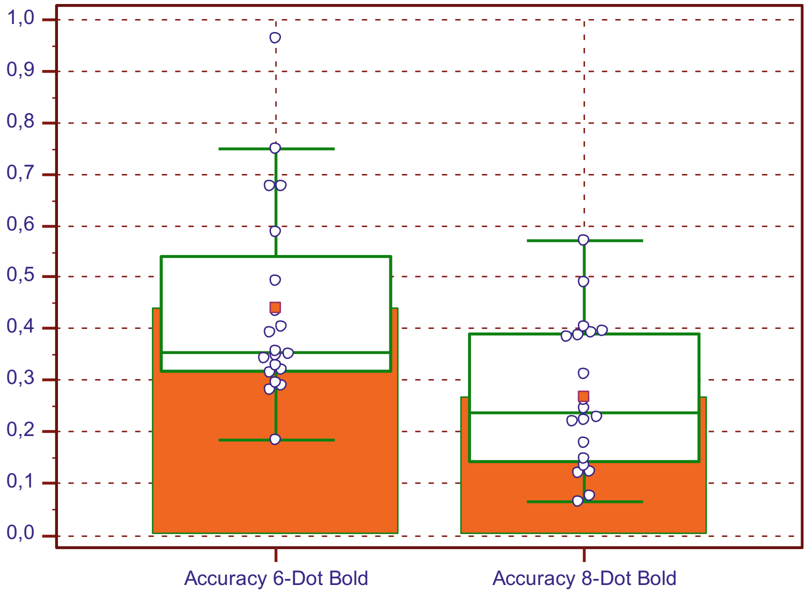
The present study is limited for several reasons. First, sample size was relatively small and potentially some of the findings could be reflective of Type-II errors as large error variances could potentially mask true effects. However, in the present study, all comparisons between conditions were significant suggesting that the present findings were likely robust and not reflective of idiosyncrasies in the sample.

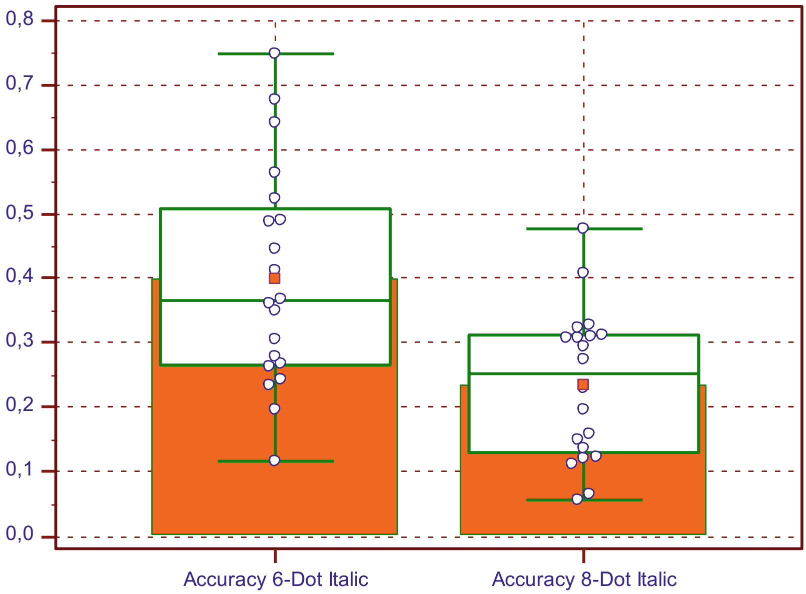
In the future it will be important to take the present methodology large scale. That is, implement the newly developed 8-dot braille code to a larger sample and with more extensive training so that issues of familiarity and automaticity would be more prevalent. That will allow for a more full evaluation of the pros and cons of the 8-dot braille code and its effects on reading and comprehension.

Acknowledgements. This research has been co-financed by the European Union (European Social Fund – ESF) and Greek national funds through the Operational Program “Education and Lifelong Learning” of the National Strategic Reference Framework (NSRF) under the Research Funding Project: “THALIS-University of Macedonia- KAIKOS: Audio and Tactile Access to Knowledge for Individuals with Visual Impairments”, MIS 380442.

Appendix A

Box-plots with mean values showing differences in level between rates of accuracy (i.e., fluency) using the bold elements (upper panel) and italic elements (lower panel). All differences exceeded conventional levels of significance at $p < .05$.





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