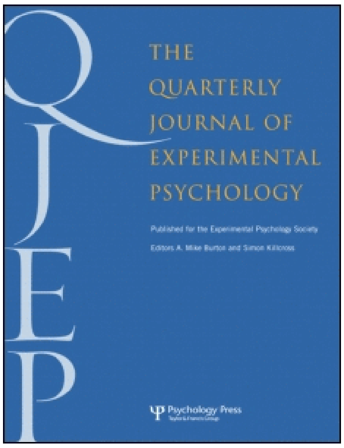

The Quarterly Journal of Experimental Psychology
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t716100704

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First Published on: 15 April 2009

To cite this Article Perea, Manuel, Acha, Joana and Carreiras, Manuel(2009)'Eye movements when reading text messaging (txt msgng)',The Quarterly Journal of Experimental Psychology,62:8,1560 — 1567

To link to this Article: DOI: 10.1080/17470210902783653

URL: http://dx.doi.org/10.1080/17470210902783653

THE QUARTERLY JOURNAL OF EXPERIMENTAL PSYCHOLOGY
2009, 62 (8), 1560–1567

Psychology Press
Taylor & Francis Group

Short article

Eye movements when reading text messaging (*txt msgng*)

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The growing popularity of mobile-phone technology has led to changes in the way people—particularly younger people—communicate. A clear example of this is the advent of Short Message Service (SMS) language, which includes orthographic abbreviations (e.g., omitting vowels, as in **wk,** week) and phonetic respelling (e.g., using **u** instead of *you*). In the present study, we examined the pattern of eye movements during reading of SMS sentences (e.g., **my hols wr gr8**), relative to normally written sentences, in a sample of skilled "texters". SMS sentences were created by using (mostly) orthographic or phonological abbreviations. Results showed that there is a reading cost—both at a local level and at a global level—for individuals who are highly expert in SMS language. Furthermore, phonological abbreviations resulted in a greater cost than orthographic abbreviations.

Keywords: Normal reading; Orthographic processing; Eye movements.

Communication among younger generations has changed dramatically in recent years with the availability of Short Message Service (SMS, for short) in mobile-phone technology and Internet. This has resulted in the advent of SMS language or text messaging. Instances of SMS language are expressions like **my hols wr gr8** (*my holidays were great*), or **c u 2moro on brdwy** (*see you tomorrow on Broadway*). The growing use of text messaging—with more than 2 billion active users—has led to the inclusion of SMS language in the new editions of mainstream dictionaries (e.g., the Concise Oxford Dictionary) and has called the attention of the mass media (British Broadcasting Corporation, BBC; Cable News Network, CNN; etc). Furthermore, the advent of SMS language is a universal phenomenon, which is not restricted to English (e.g., see http://en.wikipedia.org/wiki/Text_messaging).

SMS language is an abbreviated form of language, which has evolved from its initial use

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The research reported in this article has been partially supported by Grants PSI2008–04069/PSIC, SEJ2006–09238, and CONSOLIDER-INGENIO 2010 (CSD2008–00048) from the Spanish Ministry of Science and Innovation. We are indebted to Miguel Pérez Subías for providing us a list of word frequencies from the Short Message Service (SMS) dictionary in Spanish. We also thank Denis Drieghe, Marc Brysbaert, and an anonymous reviewer for very helpful comments on an earlier version of the paper.

http://www.psypress.com/qjep
DOI:10.1080/17470210902783653

in Internet chat rooms and instant messaging to the constrained environment of mobile phones—with a numerical keypad and a limited number of characters per message (i.e., the SMS language originated as a way of reducing the typing load on a standard mobile phone keyboard).[1] Two of the most frequent strategies are the following (see Kul, 2007): (a) *orthographic abbreviations*, in particular those implying the deletion of vowels (e.g., **wk,** week; **pls,** please), and (b) *phonetic respelling* (e.g., **c u,** see you; **sk8,** skate).

Orthographic abbreviations

Language has redundancy built in, and this is why **you cn rd ths txt wtht vwls** (Pinker, 1994). In SMS language, it is common to write only the consonantal frame of words. Indeed, individuals writing text messages seem to be implicitly aware of the much higher information value of consonants than of vowels (e.g., *frl* activates *FAROL*, lantern, whereas *aeo* does not activate *ACERO*, steel; Duñabeitia & Carreiras, 2008; see also Grainger, Granier, Farioli, Van Assche, & van Heuven, 2006). It has been claimed that (a) consonants are computed first in a process that is fast and automatic, whereas the vowels are computed in a subsequent cycle (Berent & Perfetti, 1995), and (b) consonants bear the main burden of distinguishing lexical items, whereas vowels mainly provide cues to grammatical phenomena (Mehler, Peña, Nespor, & Bonatti, 2006). Indeed, delaying the display of consonants in a word produces a greater cost than delaying vowels, as assessed by eye movement measures (Lee, Rayner, & Pollatsek, 2001) and event-related potential (ERP) waves (Carreiras, Gillon-Dowens, Vergara, & Perea, 2009). Furthermore, vowels and consonants produce a differential degree of brain activation (Carreiras & Price, 2008).

Phonetic respelling

There are several ways in which phonetic respelling can be employed: from using a single letter to replace a word (e.g., **u** instead of *you*) to using a single digit to replace a word or a part of a word (e.g., **4** instead of *four*, **b4** instead of *before*). Again, individuals writing text messages seem to be implicitly aware of the key information value from phonology in the early stages of visual-word recognition (see Carreiras, Ferrand, Grainger, & Perea, 2005; Frost, 1998). For instance, in the context of normal silent reading, a parafoveal preview of a word that is a homophone of the target word speeds processing of the target word when it is later fixated (i.e., reduced fixation time on the target) more than an orthographic control (Pollatsek, Lesch, Morris, & Rayner, 1992; see also Slattery, Pollatsek, & Rayner, 2006, for evidence of phonological encoding when processing acronyms, e.g., FBI).

The main goal of the present paper is to examine the pattern of eye movements during reading SMS sentences—relative to normally written sentences—in a sample of skilled "texters". The rationale of monitoring the readers' eye movements is that the linguistic characteristics of words have an impact not only on the duration of fixations but also on which words are fixated (Rayner, 1998). For instance, when reading a sentence, low-frequency words produce longer fixations than high-frequency words (White, 2008), and words with higher frequency "neighbours" (*spice* being interfered with by *space*) produce more regressions than words with no higher frequency neighbours (see Perea & Pollatsek, 1998). Clearly, recording eye movement data during normal silent reading provides a rich set of data on the underlying cognitive processes (see Rayner, 1998; White, 2008; but see Vitu & O'Regan, 2004).

To our knowledge, this is the first study that has examined how individuals read SMS sentences. The closest parallel is the study by White, Johnson, Liversedge, and Rayner (2008; see also Rayner, White, Johnson, & Liversedge, 2006). White and colleagues examined the pattern of eye movements when participants read sentences with transposed-letter words (e.g., *"the boy coudl not slove the probelm so he aksed for help"*). They found that,

[1] We should note here that in the past years, a number of mobile phone models come with a full keyboard for SMS messaging.

although individuals could understand the sentences with transposed-letter words without difficulty, reading times both at a global level and at a local level showed a cost. Unlike the study of White and colleagues, in the present study, individuals were asked to read sentences with words written in a *familiar* code: SMS language (i.e., all the words in a sentence like **my hols wr gr8,** *my holidays were great*, are familiar for texters).

Given the central role of orthography and phonology in normal reading, and given that SMS abbreviations tend to be orthographic or phonological, we constructed two types of SMS sentences: (a) sentences in which the abbreviations were mostly orthographic, and (b) sentences in which the abbreviations were mostly phonological (see Table 1, for examples). (As indicated below, to increase the readability of the sentences, we always selected the most frequent abbreviation in a Spanish SMS dictionary, and this was the reason why there could be some orthographic abbreviations in the phonological sentences and some phonological abbreviations in the orthographic sentences.) In all these sentences, the critical target word was an orthographic abbreviation or a phonological abbreviation. Note that this local manipulation will allow us to examine to what extent these abbreviations form part of the mental lexicon. In this respect, there is empirical evidence that shows that other abbreviations (e.g., acronyms such as BBC, WC, etc.) have their own representation in the brain (e.g., the masked prime *WC* facilitates the processing of *TOILET* relative to the unrelated control prime *NY*; see Brysbaert, Speybroek, & Vanderelst, in press, for review). In this light, it may be worth indicating that ongoing work in our laboratory has shown that a masked SMS prime such as "**lght**" (i.e., an orthographic abbreviation of *light*) activates the lexical representation of its associate *DARK* relative to an unrelated prime (e.g., **clth**), thus extending the findings of Brysbaert et al. (in press) to the context of SMS abbreviations. Thus, SMS abbreviations may also have their own representations in the brain.

Because of the communicative characteristics of SMS language, all the sentences were relatively short in length and were written in an informal language (e.g., the sentence **irmos l cnciert n m mto,** *iremos al concierto en mi moto*, which is the Spanish for *we'll go to the concert on my motorbike*). To minimize the impact of the distinct dialects (e.g., some texters may prefer **2moro** for *tomorrow*, and others may prefer **2mrw**), for each word of the sentence, we always selected the most frequent abbreviation in a Spanish SMS dictionary. Furthermore, before conducting the experiment, all the SMS sentences were tested with a sample of 12 individuals with the same characteristics as those in the experiment. None of them had any difficulty understanding the sentences—these individuals had to rate the readability of the SMS sentences in a 1–5 Likert scale, and the average ratings were always above 4.4.

Table 1. *Examples of stimuli presentation in the four conditions*

Condition	*Example sentence*
Orthographic	irmos l cnciert n m mto
Control	iremos al concierto en mi moto
	[we'll go to the concert on my bike]
Phonological	akab l kldo d 1 vz
Control	acaba el caldo de una vez
	[finish the soup at once]

Method

Participants

A total of 26 students from the University of Valencia ($M = 19$ years) participated in the experiment. All were native speakers of Spanish with normal or corrected-to-normal vision and reported being highly skilled in SMS language.

Materials and design

We created 72 experimental sentences across four experimental conditions. These conditions derived from a 2 (type of code: SMS language, control—i.e., normally written sentence) × 2 (type of set/abbreviation: orthographic, phonological) design (see Table 1). The SMS script was obtained from the Spanish SMS frequency list of the *Asociación de Usuarios de Internet* (available at http://www.diccionariosms.com; retrieved September 30, 2008). For each SMS sentence, we always selected the most frequent SMS abbreviation in the above-cited dictionary. The sentences contained 6.2 words on average ($SD = 1.4$). Sentences in the orthographic and phonological sets were matched, on a pairwise basis, in overall word frequency ($M = 1{,}439$ vs. 1,492, respectively, Davis & Perea, 2005). The SMS sentences, on the one hand, and their corresponding control sentences, on the other, were equated in length ($M = 22$ and 23 characters in the orthographic and phonological SMS sentences, respectively; $M = 32$ and $M = 34$ characters for their corresponding control conditions). For the local measure analysis, one critical word of each sentence was selected whose average location was around the centre ($M = 3.3$ words) of the sentence.[2] Critical target words in the orthographic and phonological sets were paired in word frequency in the Spanish database ($p > .40$, $M = 105$ and $M = 190$, range 1−705 and 1−4,800, respectively) and in the SMS dictionary ($p > .13$, $M = 6$ and $M = 18$, respectively). Critical target words were also paired in length in the orthographic and phonological sets (normally written words: $M = 6.5$ and $M = 6.4$ letters, respectively; SMS words: $M = 4.4$ and $M = 4.4$ letters, respectively). Two lists of 72 sentences were created—the four conditions were counterbalanced according to a Latin square design, so that no participant saw any critical word/sentence more than once. The sentences are available at http://www.valencia.edu/mperea/SMSmaterials.pdf; retrieved September 30, 2008. As indicated in the introduction, all these SMS sentences were previously tested with a different sample of texters of the same characteristics as those in the experiment, and none of them had any difficulty understanding the sentences.

Apparatus

The eye movements of the participants were recorded with an EyeLink II eye tracker manufactured by SR Research Ltd. (Canada). The sampling rate for the pupil size and location is 500 Hz. The spatial accuracy is better than 0.5°, and the spatial resolution of the system is 15 min of arc. Possible head motion was detected as movements of the four light-emitting diodes (LEDs) attached to the corners of the computer screen and was compensated for online from the eye position records.

Procedure

Each participant was tested individually in a quiet room. Participants were instructed to read the sentences so that they understood them, regardless of how they were presented in the monitor—SMS or standard text. They were told to press a button box to terminate the display. Each trial started with the presentation of a fixation point that was left-aligned (coinciding with the location of the first letter of each sentence). After proper eye calibration, participants had to gaze at that point, and the sentence appeared on the screen. Calibration was checked after each trial, and participants were recalibrated whenever necessary. To ensure that participants attended to and understood the meaning of the sentences, they were asked to answer comprehension questions about the sentence they had just read after 20% of the sentences. The order of the trials was randomized (in a mixed block) per each participant. Participants had little difficulty answering the questions correctly (over 92% of correct responses, with no differences across conditions). After the experiment, participants were asked for any unknown SMS abbreviations in the presented sentences. A total of 2 participants reported a couple of SMS words that were unusual for them—these trials were discarded from the analyses.

Results

Fixations under 80 ms that were within one letter of the next or previous fixation were merged into that fixation. Any remaining fixations under

[2] In four cases, we chose the last word as the critical word, because it was the only one to fit the orthographic or phonological criterion.

80 ms and over 1,200 ms were discarded. A total of 3.8% of the trials were excluded due to tracker loss or blinks during sentence reading. As in the White et al. (2008) experiments, the results were analysed in terms of global and local measures. Global measures were based on all of the fixations within the sentence. Local measures were based only on the selected critical word. Repeated measures analyses of variance based on participant and item variability were undertaken.

Global measures

Global measures include total sentence reading time, total number of fixations across the sentence, total number of forward and backward fixations (fixations preceded by progressive and regressive moving saccades, respectively), words per second, average fixation duration, and average saccade length. The global measures provide an index of the overall difficulty that readers experienced throughout the entire sentence in the different conditions.

All of the global measures showed a significant effect of type of code (all Fs > 4.94, ps $< .003$): Normally written sentences were read substantially faster than SMS sentences (see Table 2 for reading times). Furthermore, there was a significant effect of type of abbreviation (Fs > 6.27, ps $< .001$) in the total sentence reading time, the total number of fixations across the sentence, and the total number of backward fixations. Finally, the interaction between type of code and type of abbreviation was significant in total reading time, total number of fixations, number of fixations backward, and saccade length. That is, the reading cost for SMS sentences was larger in the phonological condition than in the orthographic condition (all the F and t values are available at http://www.valencia.edu/mperea/SMStables.pdf).

Local measures

We calculated the duration of the first fixation in the critical word, the gaze duration (the sum of all fixations on the critical word before leaving it), the percentage of regressions back to the critical word (probability of refixating the word after leaving it), the probability of skipping the critical word, and the duration of the total time spent reading the critical word (the sum of all fixation durations within the word). The first-fixation duration and the gaze duration reflect immediate influences of lexical variables on eye movements. In contrast, the percentage of regressions back to the target word and the total reading time on a word are generally taken to reflect later stages of linguistic processing. As in the global analyses, words in SMS language required longer reading times and more fixations than normally written words (see Table 3).

Words in SMS language were more difficult to read and also less skipped than were normally

Table 2. *Global measures for each condition*

	Global measures													
	Total reading time		*Words per second*		*Total no. fixations*		*Fixations forward*		*Fixations backward*		*Average fixation duration*		*Average saccade length*	
Condition	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Orthographic	2,172	592	3.3	0.9	6.7	1.6	4.8	0.9	2.3	0.8	262	24	4.6	0.6
Control	1,278	455	5.5	1.5	4.8	1.5	3.8	0.9	1.6	0.7	220	18	6.2	0.7
Effect	−893**		2.2**		−1.9*		−1.0**		−0.7**		−42**		1.6**	
Phonological	2,534	608	3.0	0.8	7.8	1.9	5.3	1.0	2.6	0.9	266	18	4.5	0.6
Control	1,400	539	5.6	1.8	5.3	1.8	4.2	0.9	1.7	0.8	218	21	6.5	0.8
Effect	−1,134**		2.6**		−2.5**		−1.2**		−0.9**		−48**		2.1**	

*$p < .05$. **$p < .01$.

Table 3. *Local measures for each conditions*

	Local measures									
	Total time		*First-fixation duration*		*Gaze duration*		*% regressions*		*% skipping*	
Condition	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Orthographic	556	139	255	34	363	67	23.4	13.3	5.3	5.1
Control	297	109	212	19	240	30	15.8	14.7	22.2	11.0
Effect	−259**		−43**		−123**		−7.6*		16.9**	
Phonological	714	195	264	32	405	81	31.3	17.1	7.5	8.3
Control	322	140	204	20	240	36	15.8	14.1	16.1	10.7
Effect	−392**		−60**		−165**		−15.5**		8.6*	

$^{*}p < .05$. $^{**}p < .01$.

written words (all *F*s > 22.35, *p*s < .01) for all of the measures: There was also a significant effect of type of abbreviation (*F*s > 4.08, *p*s < .04) in total time and gaze duration. More important, there was a significant interaction between type of code and type of abbreviation for all measures in the participant analysis (*F*s > 4.3, *p*s < .03; see all the *F* and *t* values at http://www.valencia.edu/mperea/SMStables.pdf)—note that this interaction was significant for total time, gaze duration, and percentage of skipping measures for the item analysis (*F*s > 3.74, *p*s < .05). That is, the reading cost for words in SMS language is greater in the phonological than in the orthographic script.

As suggested by one reviewer,[3] one important question to ask is whether the number of letters that disappear in the transition from normal language to SMS language has an effect. For instance, as indicated in the introduction, the SMS word **wk** (*week*) deletes two letters, whereas the SMS word **hols** (*holidays*) deletes four letters. To examine this issue, we conducted a post hoc regression analysis on the gaze durations of the target words. The number of disappearing letters in the SMS correlated significantly with the gaze durations on the target word, $r = .24$, $p = .041$). Interestingly, although one has to be cautious about post hoc analysis, what we should note here is that this correlation occurred to a larger degree for phonological abbreviations ($r = .33$, $p = .050$) than for the orthographic abbreviations ($r = .12$, $p > .14$). (In any case, note that, in the present experiment, the length of the SMS words across orthographic/phonological conditions was well controlled.)

Discussion

The boom in SMS messages has led to changes in the way we communicate—in particular for younger generations (see Perea, Duñabeitia, & Carreiras, 2008; Tagliamonte & Denis, 2008). Clearly, this is a phenomenon that needs to be studied from different perspectives. Here we have examined how readers read sentences created in SMS language—in comparison with normally written sentences. The results are clear-cut: Individuals who are highly expert in SMS language find it easy to understand sentences in text messaging (as deduced from the comprehension scores), but there is an important reading cost.

Despite the fact that SMS sentences are much shorter than normally written sentences, reading times were substantially longer for SMS sentences than for normally written sentences, and individuals made more forward/backward fixations during reading. Thus, our data show that it is

[3] We thank Denis Drieghe for suggesting this analysis.

easier to read normal print than SMS language. This may simply reflect that the participants, although very skilled in the use of text messaging, are still more familiar with normal print—note that all individuals showed a reading cost. That is, even though orthographic/phonological abbreviations are likely to have a representation in the mental lexicon—as in the case of acronyms (see Brysbaert et al., in press), normally written words are more frequent than their SMS counterparts. (Clearly, it may be of interest to examine the role of factors such as word frequency and repetition in additional research using SMS language.) Another possibility is that the ease of encoding SMS abbreviations may be modulated by top-down processes. For instance, the reading cost may be reduced when the text appears in a more constraining context—by using several sentences from an SMS conversation (e.g., the SMS abbreviation **hols** may be easier to process if the context, from a previous sentence, is related to past trips in the summer). Furthermore, the present testing environment (i.e., one line of text) may have favoured the reading of normal text over SMS text. Perhaps SMS sentences could provide an advantage under more "natural" conditions (i.e., when the window of visible text is relatively small and restricted)—note that lines in a mobile phone tend to be rather short, and the reading of SMS words may minimize the reading of warp around text and scrolling. In addition, the SMS sentences in the present experiment used a large set of abbreviations—note that texters may use an amalgamation of actual words and abbreviations when writing SMS language—and this may have increase the reading cost of SMS sentences.

It is important to note that the reading cost associated with SMS sentences was smaller for orthographic than for phonological abbreviations. It seems that it is easier to access the whole word form by deleting some vowels (**wk** in week; as in relative position priming experiments, see Grainger et al., 2006) than by preserving the sounds of words (e.g., replacing *you* with **u**). One reason why phonological coding conveys a greater reading cost could be that the phonological codes need to be computed to access the word form, and this takes more time than accessing directly from the orthography to the word form. Another possibility is that the automatic decoding of the orthographic code interferes with the phonological abbreviations. That is, the phonological SMS effect could be due to the inherent difficulty of phonological sentences, which was augmented by the deletion/replacement of characters, irrespective of SMS type. This would be consistent with the presence of a greater cost of the number of disappearing letters for the phonological SMS words than for the orthographic SMS words. Furthermore, we must keep in mind that phonological abbreviations—at least in Spanish—tend to create SMS words that employ infrequent-frequency letters (e.g., **x**, **k**, **w**, or **y**: as in **kye**, *calle*, the Spanish for *street;* **xico**, *chico*, *boy;*, **wela**, *abuela*, *grandma*). Further research is necessary to evaluate whether this pattern also occurs in a "deeper" orthography (e.g., English).

In sum, SMS language is a new form of communication that takes advantage of the redundancy of written language—via abbreviations. The present experiment has shown that, for highly skilled texters, SMS sentences are reasonably intelligible but harder to process than normal print. More empirical evidence is needed to understand the similarities/differences between SMS and normal print across a number of variables (e.g., number of disappearing letters, the role of word frequency, the role of phonology, landing position, etc) and to examine the educational implications for new generations (e.g., in terms of spelling and grammar) of this new medium.

Original manuscript received 6 November 2008
Accepted revision received 25 December 2008
First published online 15 April 2009

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