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Title

Finding a city name in a traffic sign: Effects of word case and visual motion

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Running head

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- **Compliance with Ethical Standards**

All procedures performed in the study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all participants in the study. The study was approved by the University of Valencia (Spain) ethics committee for research involving humans. The data reported in this manuscript have not been used in other previous articles.

- **Conflict of Interest**

The authors have no competing interests to declare that are relevant to the content of this article.

Topic: Sensory and Perceptual Processes

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Précis

This experiment examined letter formats for city names in traffic signs under stationary and dynamic viewing. Results showed that destinations were recognized better when in titled-case (e.g., Valencia) than in all uppercase (e.g., VALENCIA), word size being equal. Word case effects also varied between stationary and dynamic viewing situations.

Abstract

Objectives

To investigate the word recognition effects of the use of all-uppercase (e.g., VALENCIA) or titled-case (e.g., Valencia) for city names in traffic signs, controlling for word size, and comparing stationary and dynamic viewing situations.

Background

Prior studies provide mixed evidence regarding the effects of word case on the recognition of city names in traffic signs. Moreover, the evidence on the potential impact of visual motion on these effects is scarce.

Method

We carried out an experimental study using simulated traffic signs. The task was to indicate, for each sign, whether it contained a given city name or not (word search task, 50% positive trials). Visual motion of signs was manipulated as a between-participants factor: stationary (the sign was still) vs. dynamic (the sign expanded as if the participant was approaching to it). Word case was manipulated as a within-participants factor: all-uppercase vs. two title-case conditions varying in font size: width-matched titled-case, and point size-matched titled-case.

Results

Both in the stationary and dynamic condition, all-uppercase resulted in more incorrect responses and slower latencies than width-matched titled-case. When compared to point size-matched titled-case, all-uppercase produced slower correct responses in the stationary condition, whereas faster in the dynamic condition.

Conclusion

Other factors being equal, all-uppercase city names will be recognized worse than their titled-case versions in traffic signs, both in stationary and dynamic situations.

Application

Results in the current experimental study would be of interest in the design of traffic signs and other circumstances in which text is presented in motion.

Keywords

Information processing, Language, Visual search, Display design principles, Highway systems

Introduction

In many countries around the world, there are regulations or conventions establishing the letter case option (i.e., lower and/or upper case) to use for the letters of a word or word category in a specific traffic sign. According to basic research, this is a factor than can influence word legibility, i.e., how easy the letters of the word are to encode (Slattery & Rayner, 2010), which, with other influencing factors, determines how easy the word is to read (i.e., its readability) and recognize. Interestingly, in some countries, some words use titled-case (e.g., 'Valencia') in some traffic signs, whereas all-uppercase (e.g., 'VALENCIA') in other traffic signs. For example, in Spain, where the present study was carried out, overhead motorway signs that indicate an exit ahead use titled-case for city names if the exit leads to another motorway, but all-uppercase if it leads to a dual carriageway road. The present study aimed to provide evidence that the choice on all-uppercase or titled-case has an impact on the search for a city name in a traffic sign showing multiple words, and also that the word case effects can be different in dynamic situations (i.e., when the sign is read from a moving vehicle) versus stationary situations (i.e., when the sign is read keeping motionless).

Very few studies have directly investigated the effects of word case on the reading or recognition of words in dynamic situations, and their conclusions are questionable because of methodological limitations. Forbes et al. (1950) asked participants to approach a sign on foot, to indicate the maximum distance at which they could correctly identify stimuli displayed on the sign (legibility distance). Controlling for word width, the legibility distance was apparently longer in titled-case than all-uppercase, whereas the opposite could be observed controlling for word height. However, the authors did not report results from analyses to test the statistical significance of these apparent patterns. Garvey et al. (1997) did such analyses for the legibility distance using 1-word traffic signs, and also for the furthest distance at which each participant could identify the location of a given word in a 3-word sign (recognition distance), using participants seated in the front passenger seat of a car that approached the sign slowly. No support for differences in the legibility distance between titled-case and all-uppercase was found, whereas the recognition distance was significantly longer with titled-case (both results referred to width-matched words). However, some words with titled-case used a different letter font than the words with all-uppercase. In addition, participants' age was 65 or older.

Outside the traffic domain, the studies on the effects of word case on word recognition have only addressed stationary reading situations, and the effects of all-uppercase or titled-case on the recognition of city names have been rarely covered in this literature. A closely related study was conducted by Peressotti et al (2003), in which no support was found for significant differences in the recognition of all-uppercase and titled-case proper nouns which included person and geographical site names. Broadening the focus even more, we can also consider the studies comparing all-uppercase and all-lowercase. Most of them found worse results for all-uppercase (Baron & Strawson, 1976; Breland & Breland, 1944; Mayall & Humphreys, 1996; Paap et al., 1984; Paterson & Tinker, 1946; Perea et al., 2015; Perea et al., 2017; Poulton, 1967; Smith et al., 1969; Vergara et al., 2020). Still, note that there have also been some studies pointing to specific word properties that could cancel the disadvantage of all-uppercase over all-lowercase (Garner, 1981; Rho, 2001; Perea & Rosa, 2002; Perea et al., 2018), and even more, a few studies found that all-uppercase can be best in acronyms, brand names, and abbreviations that are typically printed with all-uppercase (Gontijo et al., 2002; Henderson & Chard, 1976; Perea et al., 2015; Seymour & Jack, 1978), and also in common words presented in special conditions, for example, using rapid serial visual presentation (Arditi & Cho, 2007), or in the person's visual periphery (Pušnik et al., 2016).

In short, so far, there is no conclusive response to the question on the effects of using all-uppercase or titled-case for city names on word recognition, neither in stationary situations, nor in dynamic situations. Moreover, no research has been reported examining the differences in the effects of word case on word recognition between these two kinds of situations directly. Note that both stationary and dynamic situations are relevant in the traffic context. For example, a stationary presentation is appropriate to represent when drivers can only glimpse at a sign, e. g. while driving in heavy traffic or through a sharp bend. On the other hand, there are common driving situations in which the driver is afforded a progressive and dynamic view of a sign, for example while approaching it on a straight road with low traffic. Therefore, our study examined and compared the effects of titled-case versus all-uppercase on the recognition of city names in traffic signs in stationary and dynamic situations. In particular, a word search task was used, in which the participants' performance in searching for the name of a particular city in traffic signs showing multiple words was assessed. Searching for a city name on multiple word-traffic signs is a common task for road users, for example, when they want to reach a destination while travelling along a non-familiar route. Word search tasks have been already used to investigate the effects of word case on the recognition of words in traffic signs, for example, in a study by Garvey et al. (1997), already mentioned. However, the present study has important differences with respect to that study, and also with respect to other previous studies on the subject. Crucially, the current work compared the effects of word case on the search for the target in two visual motion conditions: one in which the sign appeared abruptly and remained steady on the screen, with clear words on it (the stationary condition), and another one in which an extremely small sign appeared on the screen and expanded progressively, as if the participant were approaching it, in such a manner that the words could not be identified until sometime after the trial onset (the dynamic condition). Moreover, this study was designed accordingly to the Signal Detection Theory (SDT; Green & Swets, 1966; Hautus et al., 2022), so participants were presented with both positive trials (in which one of the words in the sign was the target) and negative trials (none of the words in the sign were the target), to indicate whether or not the target was in the sign. The SDT is a framework for studying human performance of sensory or cognitive tasks in which the quality of the input can be low (e.g., the stimulus is weak, incomplete, uncertain, or ambiguous), and we thought that the rapid search for a city name in a multiple word-traffic sign could entail visual inputs of low quality in a large proportion of trials, especially in dynamic situations. According to SDT, in such circumstances, there might be some individuals, or conditions, in which there is a tendency to respond 'Yes, the target is in the sign' (liberal response criterion), and also other individuals or conditions in which the tendency is to respond 'No, the target is not there' (conservative response criterion). These tendencies would impact the proportion of correct responses in positive trials, hence the need for negative trials and the proposal of measures of task accuracy computed both from correct responses in positive trials (hits) and incorrect responses in negative trials (false alarms), such as d'. In addition, the theory also provides response criterion measures, such as β. In consideration of the possibility that the experiment results were affected by any of these tendencies, we computed hits, correct rejections (i.e., correct responses in negative trials), and also d' and β, besides the usual measure of correct response latency.

We thought that when viewed dynamically, the quality of traffic sign visual inputs would be lower, compared to when the signs are viewed in a stationary manner. Therefore, we expected that the search for the targeted city would be generally worse in the dynamic condition, i.e., fewer hits and correct rejections, lower d', and/or slower correct responses when the target was viewed in motion.

We also expected fewer hits and correct rejections, a lower d', and/or slower correct responses in signs using all-uppercase than in signs using titled-case, other factors being equal. Two different reasons, frequently argued to account for the advantage of all-lowercase over all-uppercase in the recognition of common words, were behind these expectations (Paterson & Tinker, 1946; Perea et al., 2018). First, in the Latin alphabet, most letters with uppercase seem less visually distinct from each other than most letters in lowercase. Therefore, the legibility of a city name would be worse if it uses the uppercase format than the titled-case format. Second, it may also be that city names are generally less familiar in the all-uppercase format than in the titled-case format. As far as we know, estimations about the relative frequency of city names in titled-case and all-uppercase have not been reported in literature so far, neither in general nor in traffic signs. Nevertheless, in English, estimations of the frequency of letters with uppercase in printed text or on the Internet are much lower than those for letters with lowercase (Jones & Mewhort, 2004), and it seems that the same occurs in other languages that use similar orthographic rules for proper nouns, such as Spanish.

As for the response criterion in the task, we did not expect that the visual input quality, nor the letter distinctiveness or letter/word familiarity, would affect this aspect of the task performance, so we did not expect any differences in β between the stationary and dynamic situations, nor between signs using all-uppercase and titled-case, nor any interaction effects.

Finally, considering that the effects of word case on the recognition of common words have been located at perceptual stages (Vergara et al., 2020), and also some evidence that the effects of a stationary or dynamic word presentation influences word perception (Tejero et al, 2019), we expected an interaction between the two factors (Sternberg, 2013). Indeed, some related evidence suggests that the visual degradation of a word affects more the recognition of all-uppercase than all-lowercase words (Garner, 1981). Therefore, our hypothesis was that the advantage of titled-case over all-uppercase in response latency would be larger in the dynamic presentation, other factors being constant.

Method

The study was carried out conforming to the ethical standards and laws in research involving humans and had been approved by the university at which it was done.

Participants

Forty-eight participants were recruited from a database of volunteers to university research. Participants were randomly assigned to the stationary or dynamic condition, until completing two groups matching in gender (15 women and 9 men in each condition), and age (stationary condition: $M \pm SD$ = 21.25 ± 2.05 years old; dynamic condition: $M \pm SD$ = 21.83 ± 2.51 years old; $t_{(46)}$=.892, p = .377). All participants completed three blocks of trials which differed in word case: traffic signs using all-uppercase words, width-matched titled-case words, or point size-matched titled-case words (see *Task and stimuli*).

Power analyses with G*Power v3.1.9.6, considering a mixed ANOVA with α = .05, 1–β = .80, and a correlation among repeated measures ranging from .70 to .90, supported that a sample of 48 participants would be adequate to reliably find between-participants main effects of, at least, d = 0.74 to 0.80 (η^2 = .12 to .14), within-participants main effects of d = 0.17 to 0.29 (η^2 = .007 to .02), and two-way interactions effects of d = 0.17 to 0.29 (η^2 = .007 to .02).

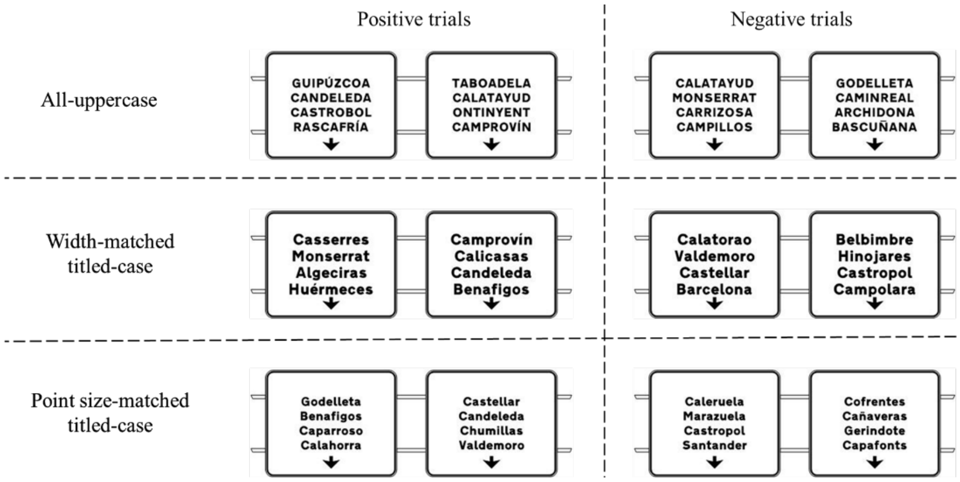
Task and stimuli

The task ran in a Windows 10 computer, with a 15.4-inch monitor (1680 x 1050 pixels), using DMDX software (Forster & Forster, 2003). The task was individually performed in a quiet university lab, with medium light intensity. An adjustable chinrest was used to keep a viewing distance of 51 cm.

Each trial of the task began with a fixation cross at the center of the screen (500 ms). Then, the participant was presented with a pair of motorway direction signs, placed side by side, displaying four 9-letter words on each, i.e., eight words in total (see Figure 1). All words were actual names of Spanish cities, towns, or villages. The participant had to indicate whether or not the target ('Candeleda') was one of the words in the sign pair, by pressing the correct key ('yes', or 'no'). The target was present in half of the trials (positive trials). One hundred and seventy-four different word sets were used (30 for practice, 144 for test trials; see supplemental materials for a description of word selection; the traffic signs are at https://osf.io/p3bqg/?view_only=a3c6fc484aa4460f8cea8c4522943d94). On each positive trial, besides the target, the sign pair included three additional words beginning with 'Ca', whereas on each negative trial, the sign pair included four words beginning with 'Ca' and none of them was the target.

Figure 1

Some examples of the traffic signs used in positive and negative trials in the all-uppercase, width-matched titled-case, and point size-matched titled-case conditions.



Signs were designed according to official regulations, using CarDim software (I.P.S. Vial, S. L.), with black lettering in “CC Rige” font. This font, used in Spanish motorways, is based on the internationally-used Transport font. Letter size was initially set at a H height of 300 mm. In most “CC Rige” letters, the area occupied with uppercase for a given point size is larger than with lowercase. Therefore, the manipulation of word case consisted of three conditions: All-uppercase (approximate

point-size 13 pt), width-matched titled-case (i.e., a titled-case condition in which the horizontal space occupied by the target was equal to that of the uppercase condition, approximate point-size 16 pt), and point size-matched titled-case (i.e., another titled-case condition that matched in point-size with the all-uppercase condition). In the stationary condition, the signs were presented using JPG files, whereas AVI files were used in the dynamic condition. On a trial of the stationary condition, the signs remained with no changes at the center of the screen until the participant’s response or the maximum time to respond expired (five seconds). In the dynamic condition, the signs were initially presented as a tiny image at the center of the screen, with words still not legible, increasing gradually for a maximum time of six seconds, until (a) it reached a size in which the sign pair nearly covered the full screen width, or (b) a participant’s response was registered. We used Blender software to create the visual expansion effect, considering the reported initial and final sizes and a six-second animation at a uniform speed. Besides the visual motion mode, the stationary and dynamic conditions did not differ in any other aspects (see the supplemental materials for more details regarding sign size).

Procedure

First, the participants read and signed an informed consent form, filled in a questionnaire about sociodemographic data, and were given task instructions. Next, they completed some practice trials, followed by the experimental trials. The session lasted about 18 min in the stationary condition and 24 minutes in the dynamic condition. They were offered a soft beverage and a snack at the end of the session in appreciation for participating in the study.

Design and analyses

The present study was initially planned and carried out as a multi-experiment study, consisting of two independent experiments: An experiment that used stationary signs, and another experiment that used dynamic signs. These experiments only differed in this particular property of signs (visual motion: stationary or dynamic). Both experiments used a unifactorial design, with word case (all-uppercase / width-matched titled-case / point size-matched titled-case) as a within-participants factor. In each experiment, word case was manipulated in blocks, in a counterbalanced order across participants, with inter-block breaks at the participant's discretion. Trials with and without the target (i.e., positive and negative trials) were randomly presented in each word case condition for every participant in each experiment. The participant's response (yes / no) and response latency (milliseconds, ms) were recorded.

Five measures were computed for each participant in each word case condition, in each experiment: a) percentage of hits: percentage of correct responses in positive trials, b) percentage of correct rejections: percentage of correct responses in negative trials, c) d': SDT measure of task accuracy (Stanislaw & Todorov, 1999), reflecting the participant's ability to discriminate between positive and negative trials (the higher the d' value, the better the accuracy is); d) β: SDT measure of response criterion (Stanislaw & Todorov, 1999), i.e., if the participant showed a tendency to respond 'yes' (liberal criterion, if $\beta < 1$), or a tendency to respond 'no' (conservative criterion, if $\beta > 1$); and e) the participant's mean latency in correct response trials.

Since the aim of the present work was to examine the differences in the word case effects between the stationary and dynamic conditions, we report the results from analyses that combined the data from the two experiments. On the one hand, following methodological recommendations for the analysis of categorical data (e.g., Jaeger, 2008), both the percentage of hits and correct rejections were submitted to generalized linear mixed models (GLMM) using JASP software (JASP Team, 2021). In particular, we performed two separate GLMM with a binomial distribution (logit), considering response accuracy (hits or correct rejections) at the trial level as the dependent variable; word case (all-uppercase / width-matched titled-case / point size-matched titled-case) and visual motion (stationary or dynamic) as fixed effects variables; and random intercept for each participant. Other models including random slopes were tested but failed to converge successfully. Post-hoc testing was performed with Bonferroni *p*-value adjustment. On the other hand, the continuous measures, *d′, β,* and mean response latency, were subjected to analyses of variance (ANOVA) using IBM SPSS 28.0.1.1. We carried out three separate mixed ANOVA with word case (all-uppercase / width-matched titled-case / point size-matched titled-case) as a within-participants factor, and visual motion (stationary or dynamic) as a between-participants factor. Bonferroni adjustment was used for post hoc tests.

Results

All data can be downloaded from https://osf.io/p3bqg/?view_only=a3c6fc484aa4460f8cea8c4522943d94. Responses were recorded in a total of 6912 trials, for all participants and conditions (24 Participants x 2 Visual motion conditions x 3 Word case conditions x 48 Signs). All response omissions (n = 6 omissions) occurred in the stationary condition (0.17 % of trials in this condition). Descriptive statistics of the measures can be found in Table 1 and Table 2 in the 'Data tables' supplementary file (Table 1 shows statistics of hits and correct rejections, and Table 2 shows statistics of *d′, β*, and mean response latency).

Hits

The GLMM analysis of the percentage of hits supported a significant main effect of visual motion (X^2 (1, 48) = 12.924, $p < .001$), showing that the accuracy in positive trials was higher in the stationary condition (90.7 %) as compared to the dynamic condition (81.7 %). The main effect of word case (X^2 (2, 48) = 11.841, $p = .003$) was also statistically significant. Further analyses with Bonferroni adjustment revealed that the accuracy in positive trials was higher in the width-matched case condition as compared to the all-uppercase condition (89.3 % vs. 84.6 %, $z = 3.290$, $p = .003$). The comparison of width-matched case condition and the point size-matched titled case condition was non-significant (89.3 % vs. 86.1 %, $z = 2.376$, $p < 0.053$), as neither was the comparison between the all-uppercase and the point size-matched case conditions (84.6 % vs. 86.1 %, $z = 0.999$, $p = .954$). Finally, the Visual motion × Word case interaction was not significant (X^2 (2, 48) = 2.359, $p = .307$).

Correct rejections

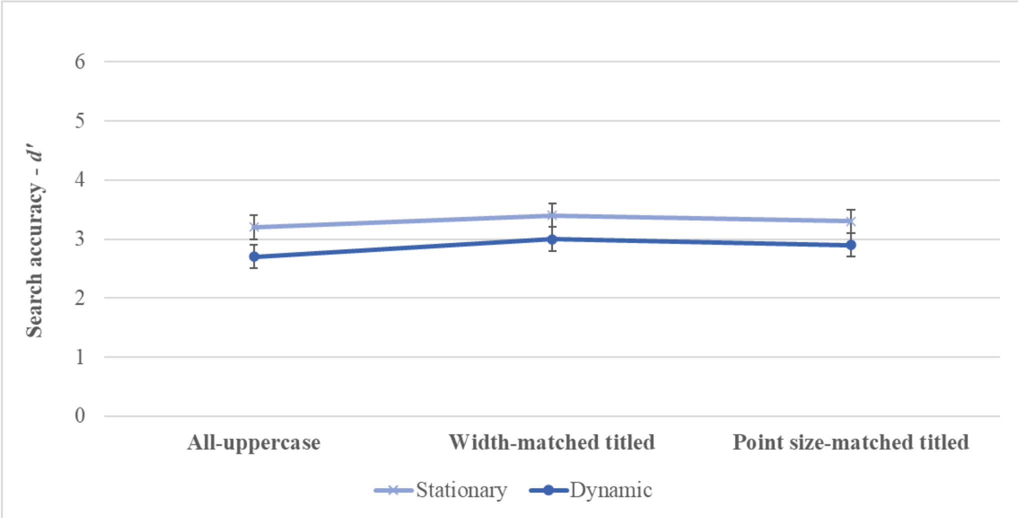
The GLMM analysis of the percentage of correct rejections did not support significant main effects, nor interaction (all $p > .280$). However, these results must be considered with care, considering that the fit for the GLMM was singular, and no other model including a more complex random effect structure successfully converged. In any case, it must be noted that accuracy in the negative trials was extremely high and there was scarce variability across the different conditions (the minimum percentage of correct rejections per condition was 98.1% and the maximum was 99.31%; see Table 2, in the 'Data tables' supplementary file).

d′

Figure 2 shows *d′* as a function of visual motion and word case. The results of the 2 × 3 ANOVA performed on *d′*, with visual motion (stationary vs. dynamic) as a between-participants factor and word case (all-uppercase, width-matched titled case, and point size-matched titled case) as a within-participants factor, supported a significant main effect of visual motion ($F_{(1,46)} = 11.853$, $p = .001$, $\eta_p^2 = .205$), showing that *d′* was higher (i.e., better task accuracy) in the stationary condition (see Table 3 in the 'Data tables' supplementary file). The effect of word case was significant ($F_{(2,92)} = 6.883$, $p = .002$, $\eta_p^2 = .130$ (see Table 4 in the 'Data tables' supplementary file). Paired comparison tests supported lower *d′* (i.e., worse task accuracy) in signs using all-uppercase than in signs using width-matched titled-case ($p < .001$), whereas the differences in the other comparisons did not reach the significance level (for point size-matched titled-case *versus* all-uppercase: $p = .083$; for point size-matched *versus* width-matched titled-case: $p = .062$). The interaction effect was not significant ($F_{(2,92)} = .310$, $p = .734$, $\eta_p^2 = .007$).

Figure 2

Mean *d′* for each word case condition (all-uppercase, width-matched titled case, and point size-matched titled case) at each visual motion condition (stationary vs. dynamic). Error bars represent the 95% confidence interval of the mean.

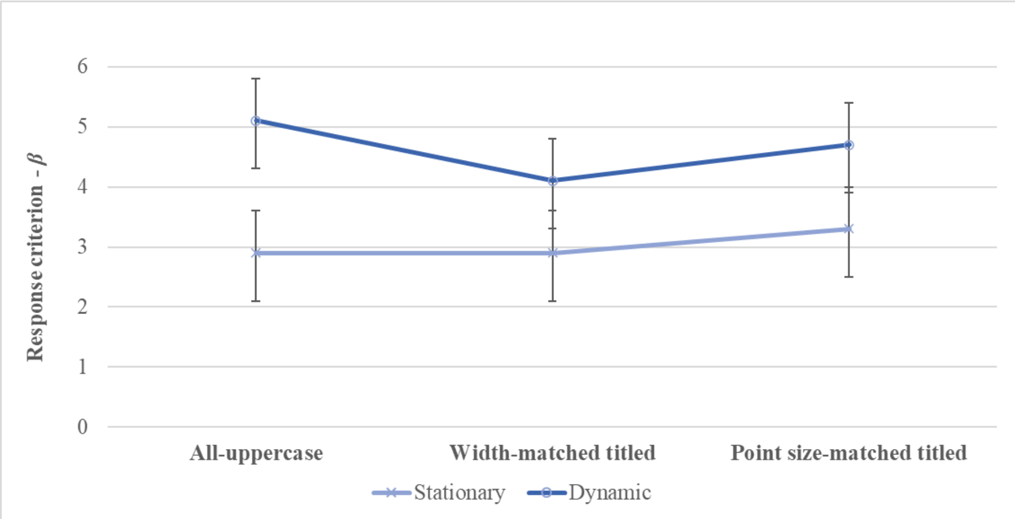


β

Figure 3 shows *β* as a function of visual motion and word case. The results of the 2 × 3 ANOVA performed on *β*, with visual motion (stationary vs. dynamic) as a between-participants factor and word case (all-uppercase, width-matched titled case, and point size-matched titled case) as a within-participants factor, did not support a main effect of word case ($F_{(2,92)} = 2.062$, $p = .133$, $\eta_p^2 = .043$). The main effect of visual motion was significant ($F_{(1,46)} = 15.717$, $p < .001$, $\eta_p^2 = .255$). Overall, the response criterion was more conservative in the dynamic condition (see Table 5 in the 'Data tables' supplementary file). The interaction effect was not significant ($F_{(2,92)} = 1.618$, $p = .204$, $\eta_p^2 = .034$).

Figure 3

Mean *β* for each word case condition (all-uppercase, width-matched titled case, and point size-matched titled case) at each visual motion condition (stationary vs. dynamic). Error bars represent the 95% confidence interval of the mean.



Response latency

Figure 4 shows the mean latencies in correct responses, as a function of visual motion, word case, and target presence. Mean response latency was shorter in the stationary condition (stationary: M = 1965.01, SD = 361.77, *95 % CI*= [1828.28, 2101.74]; dynamic: M = 4212.07, SD = 300.99, *95 % CI*= [4075.34, 4348.80]), which is not surprising, considering that the words in the signs were legible from the beginning of trial in the stationary condition, but not so in the dynamic condition. Therefore, considering that the stationary and dynamic conditions were manipulated between participants, the analysis of response latency was performed using z-scores of the correct response latencies, computed following Faust et al.'s indications (1999). Figure 5 shows these z-scores as a function of visual motion, word case, and target presence. Some descriptive statistics of these z-scores can be found in Table 6 (in the 'Data tables' supplementary file).

The 2 × 3 × 2 mixed ANOVA on the latency z-scores, with visual motion as a between-participants factor and word case and target presence as within-participants factors, showed significant results for the main effect of word case ($F_{(2,92)}$ = 43.022, $p < .001$, η_p^2 = .483; see Table 7 in the 'Data tables' supplementary file). According to pair comparisons, slower responses were observed in the all-uppercase condition than in the width-matched titled-case condition ($p < .001$), and the point size-matched titled-case condition showed slower responses than the all-uppercase condition (p = .009) or the width-matched titled-case condition ($p < .001$). The main effect of target presence was significant ($F_{(1,46)}$ = 2765.256, $p < .001$, η_p^2 = .984), with slower responses in the trials without the target. As expected after the normalization of the latencies, the main effect of visual motion was not significant ($F_{(1,46)} < .001$, $p = 1.000$, $\eta_p^2 = .000$).

A significant effect was found for the interaction Visual motion × Word case ($F_{(2,92)} = 35.634$, $p < .001$, $\eta_p^2 = .437$; see Table 8 in the 'Data tables' supplementary file). The analysis of the simple effects of the word case condition across the levels of visual motion condition showed that, in the stationary condition, response latency was higher in the all-uppercase condition, as compared to the point size-matched titled-case ($t_{(1,92)} = 2.79$, $p = .006$) and the width-matched titled-case conditions ($t_{(1,92)} = 3.91$, $p < .001$), whereas there was no significant difference between the two latter ($t_{(1,92)} = 1.12$, $p = .026$). In contrast, in the dynamic condition, latency was lower in width-matched titled-case condition, as compared to the all-uppercase ($t_{(1,92)} = -5.58$, $p < .001$) and point size-matched titled-case ($t_{(1,92)} = -11.78$, $p < .001$) conditions, and it was also lower in the all-uppercase condition as compared to the point size-matched titled-case condition ($t_{(1,92)} = -7.20$, $p < .001$). We compared the reported simple effects and such analysis revealed that the differences between the point size-matched titled-case and the all-uppercase conditions ($t_{(1,92)} = 7.06$, $p < .001$) and between the point size-matched titled-case and the width-matched titled-case conditions ($t_{(1,92)} = 7.54$, $p < .001$) actually diverged between the two visual motion conditions. In contrast, the difference reported between the width-matched titled-case and the all-uppercase conditions ($t_{(1,92)} = 0.48$, $p = .64$) was similar in both stationary and dynamic visual motion conditions.

The two-way interaction Visual motion × Target presence was significant ($F_{(1,46)} = 11.602$, $p = .001$, $\eta_p^2 = .201$; see Table 9 in the 'Data tables' supplementary file). The analysis of the simple effects of target presence across the levels of visual motion revealed that the mean differences between positive and negative trials were greater in the stationary ($F_{(1,46)} = 1567.543$, $p < .001$, $\eta_p^2 = .971$) than in the dynamic condition ($F_{(1,46)} = 1209.315$, $p < .001$, $\eta_p^2 = .963$).

The two-way interaction Word case × Target presence was not significant ($F_{(2,92)} = .605$, $p = .548$, $\eta_p^2 = .013$), nor the three-way interaction ($F_{(2,92)} = 1.776$, $p = .175$, $\eta_p^2 = .037$).

Figure 4

Mean response latency (ms) for each word case condition (all-uppercase, width-matched titled case, and point size-matched titled case) at each visual motion condition (stationary vs. dynamic), in each target presence condition (positive vs. negative trials). Error bars represent the 95% confidence interval of the mean.

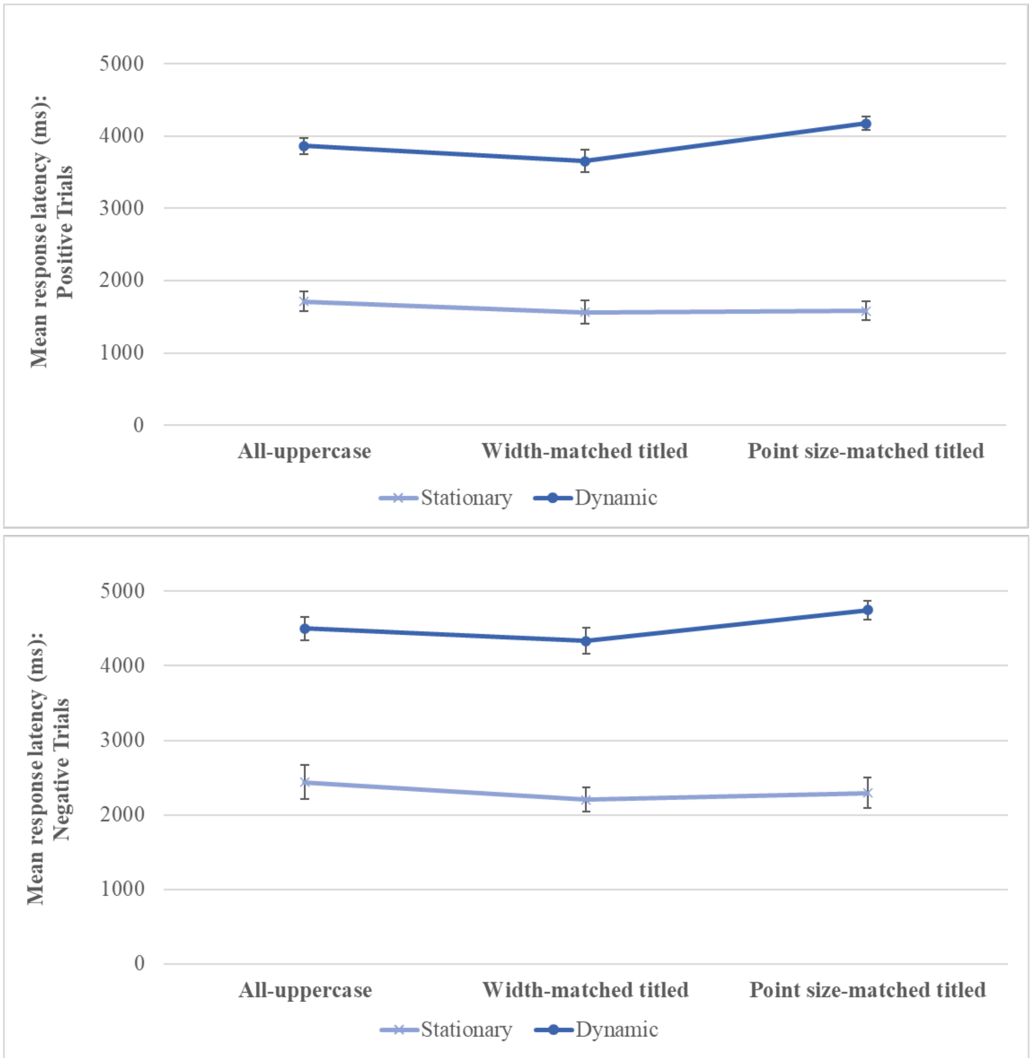
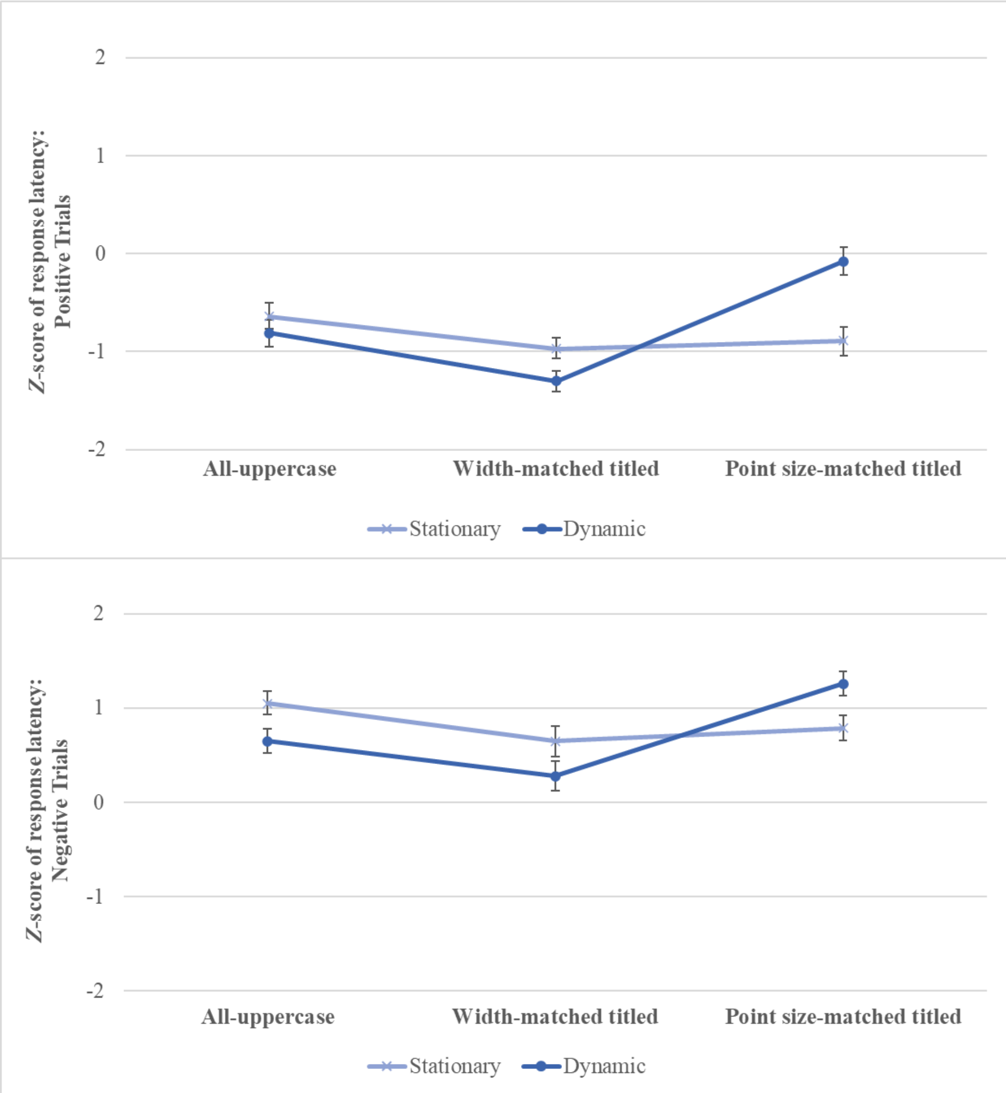


Figure 5

Z-score of response latency for each word case condition (all-uppercase, width-matched titled case, and point size-matched titled case) at each visual motion condition (stationary vs. dynamic), in each target presence condition (positive vs. negative trials). Error bars represent the 95% confidence interval of the mean.



Discussion

Word recognition in stationary versus dynamic situations

As expected, the task performance in the dynamic condition was worse than in the stationary condition, at least in terms of hits, *d′*, and response latency. In addition, participants in the dynamic condition showed a reduction of the mean difference between the correct response latencies in positive and negative trials. Altogether, these results are consistent with the idea that the dynamic presentation of the signs affected the quality of the visual input, which increased the difficulty of the search for the targeted word with respect to the stationary condition.

The dynamic condition was also associated with a more conservative response criterion than the stationary condition. This result was observed despite the visual motion conditions not differing in any of the factors typically mentioned when discussing differences in response criterion, such as the instructions given to participants, relative frequency of positive and negative trials, or the consequences of correct and wrong responses. Still, considering that the response criterion tends to be more conservative in prolonged or boring tasks (McCarley & Yamani, 2021), we can speculate that the more conservative criterion in the dynamic condition was observed because, overall, the completion of the task took the participant longer time, as a consequence of the gradual presentation of the signs.

Recognition of city names with all-uppercase versus titled-case

We expected that in both situations, stationary and dynamic, hits, correct rejections, and d' would be lower and/or the latency of correct responses would be slower in signs using all-uppercase than in signs using width-matched titled-case, whereas β would not vary with the word case. The results regarding hits, d', and response latency supported these predictions. We also expected that the advantage of titled-case over all-uppercase in response latency, for words equal in size, would be bigger in the dynamic condition than in the stationary condition. The results showed a significant effect of the interaction between word case and visual motion on response latency, but contrary to our expectation, the disadvantage of all-uppercase over width-matched titled-case was not greater in the dynamic than in the stationary condition. This expectation was derived from the idea that visual motion, as a factor that impairs the visual quality of the word input, should affect more the recognition of all-uppercase words than width-matched titled-case words, which was suggested by some related results showing that the visual degradation of a word affects more the recognition of all-uppercase than all-lowercase words (Garner, 1981). It might be that our experimental manipulation of visual motion was insufficient to generate differences in word input quality between all-uppercase and width-matched titled-case words. For example, these differences might appear in situations where the visual expansion of the sign is faster than in the present study. In addition, or alternatively, there might be other factors behind the lack of support for our hypothesis regarding the details of the interaction between visual motion and word case. For example, it might be that the concurrence of two difficult circumstances, such as an all-uppercase format and a dynamic viewing situation, led to participants increasing their mental effort to perform the task, compared to the effort made to respond to width-matched titled-case signs in the dynamic condition. In any case, from a practical perspective, altogether, these results suggest that the titled-case format be recommended both in steady and dynamic reading circumstances.

When the signs differed in word case and word size (i.e., signs using all-uppercase words versus signs using point size-matched titled-case words), the differences in response latency showed opponent patterns in the stationary and dynamic conditions. In the stationary condition, the search was slower in all-uppercase than in point size-matched titled-case, whereas in the dynamic condition, the search was faster in all-uppercase than in point size-matched titled-case. Therefore, in the stationary condition, the size advantage of the words in all-uppercase was not enough to cancel the effects of word case, while in the dynamic condition, word size seemed to be more important than word case. Consistent with this interpretation, we did not find significant differences in response latency between width-matched titled case and point size-matched titled-case in the stationary condition, whereas in the dynamic condition, the response was faster in signs using width-matched titled case than signs using point size-matched titled-case. All these results should be interpreted considering that in each word case condition, responses to dynamic signs were generally given before the size of each word in the sign reached the size of each word in stationary signs (as previously noted, in the stationary condition, word size was constant during trial and far above threshold, whereas in the dynamic condition, the sign expanded during trial, from a level so small that the words were not even visible, to the size level used for words in stationary signs). Thus, the results pertaining the dynamic condition would suggest that word size is more important than word case when the visual input for the word is small. This interpretation is consistent with results from previous studies on the threshold of identification of the letters in a word, i.e., the smallest letter point size at which a person can identify most of the letters in the word, using letter fonts that were larger with uppercase than lowercase, as the letter font used in the present study. For example, Arditi & Cho (2007) found that the point size threshold in letter identification was lower (i.e., better) for all-uppercase words than all-lowercase words using Arial.

In sum, the results supported that the all-uppercase format would be worse than the titled-case format to recognize a city name in multiple-word traffic signs, all other things being equal, and visual motion would not produce significant differences in this effect. The recognition of the word would be still worse in all-uppercase than in a (smaller) point size-matched titled word if the situation is stationary, but not in a dynamic condition, where the recognition would be better in all-uppercase than in a (smaller) point size-matched titled word.

The first word letter can be particularly important to recognize a word visually (Scaltritti & Balota, 2013), and in the present study, in all the words in the sign, the first letter was slightly larger if the sign used width-matched titled-case than if it used all-uppercase, so we cannot rule out that this factor could have contributed to the study results. Still, we think that the main reason that word recognition was better in signs using titled-case than in signs using all-uppercase was word case, at least in the stationary condition, which is the option generally used in studies on the role of the first letter in word recognition. We think so because, in the stationary condition, task performance in the width-matched titled-case condition was better than in the all-uppercase condition, whereas the differences in task performance between width-matched titled-case and point size-matched titled-case were not significant. The expectation based on the differences in the size of the first word letter would be that the pattern of results for the comparison width-matched titled-case versus all-uppercase should be similar than the pattern for the comparison width-matched titled-case versus point size-matched titled-case, given that the differences in the size of the first word letter between width-matched titled-case and all-uppercase were exactly same as the differences between width-matched titled-case and point size-matched titled-case. Even so, there is another point that could be argued regarding the potential role of the first letter of the word to explain the present results: in the titled-case condition (both in the width-matched and the point-size matched condition), in all the words in the sign, the first letter was larger than the other letters of the word, whereas in the all-uppercase condition, all the letters in the word were same size. Yet still, the argument fits with the results in the stationary condition, but not so with the results in the dynamic condition, in which the task performance in the point size-matched condition was worse than in the all-uppercase condition.

Limitations

The conclusions from our study are limited to the search for a given word in multiple-word traffic signs. In this situation, the performance of the task can be influenced by the word legibility, but also by the discriminability of the word from the other words. Further research can address the question of the effects of all-uppercase or titled-case on the recognition of words in single-word signs, in which word discriminability is not involved. Further studies are also needed to know if the present results generalize to situations in which the person did not know the word/s in the traffic sign, for example, in the reading of unknown names of cities shown in traffic signs posted along the way to our destination. According to Garvey et al. (1997), the word processing in such situations is more dependent on the letter legibility, whereas the word processing in word recognition tasks (such as our word search task) would be guided by the mental representation of the targeted word and it might be influenced by ad hoc strategies.

We only recruited young adults, and the sample size of the present study may be considered as limited to guarantee properly powered analyses according to current standards of excellence (see, for example, Brysbaert, 2019). Therefore, we cannot rule out that some of the effects reported as non-significant would actually be present in a more powered study.

The current experiment was completed in a highly controlled lab setting, and we only evaluated the performance of the task in a single-task condition. Therefore, the reported results may present limited ecological validity in comparison to driving simulator or field studies. First, as described in the methods section, the traffic signs were designed using a professional software used by road engineers, but it is possible that the presentation format (i.e., a digital image or video shown on a computer monitor) would introduce a potential bias. Second, the use of experimental methods in a lab setting made it possible to control for some critical variables, but a number of other potentially influential variables were not considered in the current study. For example, we only presented direction traffic signs containing city names. Similarly, all signs were presented at the center on the screen monitor (thus foveal vision was mainly involved), and no other task was required (thus participants were able to pay full attention). These circumstances may not be present in real driving situations (e.g., when driving through heavy traffic). Therefore, additional studies using more complex situations should be also performed, for example, driving simulation studies in which participants are asked to make decisions considering the information provided by traffic signs that use titled-case or all-uppercase.

Conclusions

It is recommended that city names use titled-case in traffic signs, if all other relevant factors are held constant. The study's results indicate road users will likely search more slowly and be less accurate to find a city name among other destinations in a traffic sign when all of the word letters are in uppercase than when the word uses the titled-case format. In stationary viewing conditions, the advantage of titled-case over all uppercase can persist even when the words are slightly smaller with titled-case. In addition, this study demonstrates that results from visual word recognition research using a stationary stimulus presentation may not apply to dynamic situations.

Practical implications

The titled-case format should be prioritized over the all-uppercase format for city names in traffic signs, and it seems plausible to extend this recommendation to other contexts, in which city names should be recognized rapidly, for example, on the displays of in-vehicle devices. In dynamic situations, the word design should consider size and case jointly. Importantly, a straightforward application of the results from research on visual word recognition using a stationary stimulus presentation to dynamic situations should be avoided.

Key points

- Traffic signs use all-uppercase or titled-case for city names.
- The case effects on word search in stationary and dynamic conditions were compared.
- Accuracy and response latency were worse in all-uppercase than titled-case (same word size).
- In stationary viewing conditions, the advantage of titled-case persisted with slight differences in the signs' word size.
- In dynamic viewing conditions, word size differences produced the reversed pattern in the effects of case.

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Compliance with Ethical Standards

All procedures performed in the study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all participants in the study. The study was approved by the University of Valencia (Spain) ethics committee for research involving humans. The data reported in this manuscript have not been used in other previous articles.

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Conflict of Interest

The authors have no competing interests to declare that are relevant to the content of this article.

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Author contribution

P.T.G. and J.R.R. conceived the study, designed the methods, processed and analyzed data, and worked on the acquisition of financial support. L.R.S. recruited participants, performed the experiments, and prepared the figures for the manuscript. P.T.G. prepared the manuscript, with the assistance of J.R.R.

Supplementary materials

Finding a city name in a traffic sign: Effects of word case and visual motion

Description of the stimulus selection process

Stimuli (simulated traffic signs) were generated by using a list of 121 different place names, including the target. Two different resources were used to obtain this list: A database provided by the Spanish National Statistics Institute (*Instituto Nacional de Estadística*, INE) containing names of inhabited locations (https://www.ine.es/daco/daco42/codmun/codmunmapa.htm), and the EsPal word database based on written data from the web, government sources, newspapers, and literature (https://www.bcbl.eu/databases/espal/), which provides a number of properties of Spanish words.

Firstly, we obtained all location names consisting of a single 9-letter word from the INE database, which produced an initial pool of 622 words. The places in the area of the study with same two first letters as the target ('Ca') were removed from the initial pool. From the remaining words, those that met the following criteria were chosen as distractors: a) Low-difficulty distractors (N = 24): Names of places in the area of the study, or names with a frequency equal to or higher than 10 times per million words in the EsPal database which did not start with 'Ca'; b) Medium-difficulty distractors (N = 48): Words with a frequency equal to or lower than 8 times per million words in EsPal which did not start with 'Ca'; and c) High-difficulty distractors (N = 48): Words with 8 or fewer times per million words in EsPal starting by 'Ca'.

In positive trials, every word set included the target and seven additional words randomly chosen as follows: Two words from the low-difficulty distractor set, two words from the medium-difficulty distractor set, and three words from the high-difficulty distractor set. Both in low-difficulty and medium-difficulty distractors, the selection was restricted to avoid having two words begin with the same letter. The likelihood of presenting a high-difficulty distractor was the same for all word locations. The target was presented the same number of trials at each word location, and thus it appeared the same number of times in either the left and the right visual field. The word sets in negative trials were the same as in positive trials, excepting that the target was replaced by another distractor from the high-difficulty distractor set.

Stimulus size

A stationary stimulus subtended 9.24° x 3.41° of visual angle (418 x 154 pixels) at the viewing distance (51 cm). The target word subtended approximately 2.52° (114 pixels) wide in both all-uppercase and width-matched titled-case conditions, and 2.06° (93 pixels) in the point size-matched titled-case condition. Therefore, the average width of the letters in the target was, respectively, 0.28° (13 pixels) and 0.23° (10 pixels). In consequence, in all three case conditions, letter size was within the range for maximum reading speed (0.2° - 2.0°, as estimated by Legge & Bigelow, 2011). In the dynamic presentation, at the beginning of the trial, the target word subtended 0.54° of visual angle in the all-uppercase and width-matched titled-case conditions, reaching a maximum size of 8.51° at the trial end. In the point size-matched titled-case condition, the target subtended 0.44° at the trial beginning, and a maximum of 6.92° at the trial end.

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Supplementary Table 1

Percentage (%), standard deviation (SD), and confidence intervals (95 % CI, Lower and Upper) of hits (correct responses in positive trials) and correct rejections (correct responses in negative trials), by visual motion (stationary or dynamic) and word case (all-uppercase, width-matched titled-case, or point size-matched titled-case).

	Stationary				Dynamic			
			95 % CI				*95 % CI*	
	%	*SD*	*Lower*	*Upper*	*%*	*SD*	*Lower*	*Upper*
Hits								
All-uppercase	88.54	31.88	85.65	91.03	75.52	43.03	71.8	78.98
Width-matched titled	90.97	28.68	88.33	93.18	84.03	36.67	80.78	86.93
Point size-matched titled	88.02	32.5	85.09	90.56	80.21	39.88	76.72	83.39
Correct rejections								
All-uppercase	98.09	13.7	96.61	99.04	98.96	10.16	97.75	99.62
Width-matched titled	99.31	8.31	98.23	99.81	98.96	10.16	97.75	99.62
Point size-matched titled	99.13	9.28	97.99	99.72	99.31	8.31	98.23	99.81

Supplementary Table 2

Mean (M), standard deviation (SD), and confidence intervals (95 % CI, Lower and Upper) of d', β, and response latency (ms) by visual motion (stationary or dynamic), word case (all-uppercase, width-matched titled-case, or point size-matched titled-case), and target presence (positive vs. negative trials).

	Stationary				Dynamic			
			95 % CI				*95 % CI*	
	M	*SD*	*Lower*	*Upper*	*M*	*SD*	*Lower*	*Upper*
d'								
All-uppercase	3.2	0.5	3.0	3.4	2.7	0.5	2.5	2.9
Width-matched titled	3.4	0.5	3.2	3.6	3.0	0.5	2.8	3.2
Point size-matched titled	3.3	0.5	3.1	3.5	2.9	0.5	2.7	3.1
β								
All-uppercase	2.9	1.7	2.1	3.6	5.1	1.9	4.3	5.8
Width-matched titled	2.9	1.6	2.1	3.6	4.1	1.9	3.3	4.8
Point size-matched titled	3.3	2.0	2.5	4.0	4.7	1.7	3.9	5.4
Response latency (ms)								
Positive trials								
All-uppercase	1713.5	322.0	1577.6	1849.5	3859.6	271.3	3745.0	3974.2
Width-matched titled	1560.9	380.0	1400.4	1721.3	3652.8	371.4	3496.0	3809.7
Point size-matched titled	1579.9	308.5	1449.7	1710.2	4172.4	225.0	4077.4	4267.5
Negative trials								
All-uppercase	2439.7	554.8	2205.4	2674.0	4500.3	368.3	4344.8	4655.8
Width-matched titled	2205.2	384.3	2042.9	2367.5	4336.6	426.3	4156.6	4516.6
Point size-matched titled	2290.9	483.6	2086.7	2495.1	4750.6	302.7	4622.8	4878.5

Supplementary Table 3

Descriptive statistics regarding the effect of visual motion (stationary or dynamic) on d′

	Stationary				Dynamic			
			95 % CI				95 % CI	
	M	*SD*	Lower	Upper	*M*	*SD*	Lower	Upper
d′	3.3	.4	3.1	3.5	2.9	.4	2.7	3.1

Supplementary Table 4

Descriptive statistics regarding the effect of word case (all-uppercase, width-matched titled-case, or point size-matched titled-case) on d′

			95 % CI	
	M	*SD*	Lower	Upper
d′				
All-uppercase	3.0	.6	2.8	3.1
Width-matched titled	3.2	.5	3.1	3.4
Point size-matched titled	3.1	.5	2.9	3.2

Supplementary Table 5

Descriptive statistics regarding the effect of visual motion (stationary or dynamic) on β

	Stationary				Dynamic			
			95 % CI				95 % CI	
	M	*SD*	Lower	Upper	*M*	*SD*	Lower	Upper
β	3.0	1.4	2.5	3.6	4.6	1.4	4.0	5.2

Supplementary Table 6

Mean (M), standard deviation (SD), and confidence intervals (95 % CI, Lower and Upper) of the normalized response latency (z-scores) by visual motion (stationary or dynamic), word case (all-uppercase, width-matched titled-case, or point size-matched titled-case), and target presence (positive vs. negative trials).

	Stationary				Dynamic			
			95 % *CI*				95 % *CI*	
Response latency z score	*M*	*SD*	Lower	Upper	*M*	*SD*	Lower	Upper
Positive trials								
All-uppercase	-.64	.37	-.77	-.50	-.81	.28	-.95	-.68
Width-matched titled	-.97	.26	-1.07	-.86	-1.30	.25	-1.41	-1.20
Point size-matched titled	-.89	.29	-1.04	-.75	-.08	.41	-.22	.07
Negative trials								
All-uppercase	1.05	.34	.93	1.18	.65	.28	.52	.78
Width-matched titled	.65	.42	.49	.81	.28	.37	.12	.44
Point size-matched titled	.79	.39	.66	.92	1.26	.21	1.13	1.39

Supplementary Table 7

Descriptive statistics regarding the effect of word case (all-uppercase, width-matched titled-case, or point size-matched titled-case) on response latency z score

			95 % CI	
Response latency z score	*M*	*SD*	Lower	Upper
All-uppercase	.06	.30	-.01	.14
Width-matched titled	-.33	.32	-.41	-.25
Point size-matched titled	.27	.42	.19	.35

Supplementary Table 8

Descriptive statistics regarding the interaction effect of visual motion (stationary or dynamic) and word case (all-uppercase, width-matched titled-case, or point size-matched titled-case) on response latency z score

	Stationary				Dynamic			
			95 % *CI*				95 % *CI*	
Response latency z score	*M*	*SD*	Lower	Upper	*M*	*SD*	Lower	Upper
All-uppercase	.21	.31	.10	.32	-.08	.22	-.19	.03
Width-matched titled	-.16	.26	-.27	-.05	-.51	.27	-.62	-.40
Point size-matched titled	-.05	.25	-.16	.06	.59	.27	.49	.70

Supplementary Table 9

Descriptive statistics regarding the interaction effect of visual motion (stationary or dynamic) and target presence (positive vs. negative trials) on response latency z score

	Stationary				Dynamic			
			95 % *CI*				95 % *CI*	
Response latency z score	*M*	*SD*	Lower	Upper	*M*	*SD*	Lower	Upper
Positive trials	-.83	.08	-.87	-.79	-.73	.12	-.77	-.69
Negative trials	.83	.08	.79	.87	.73	.12	.69	.77