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ORIGINAL RESEARCH ARTICLE

A Comparison of the Effects of Different Typographical Methods on the Recognizability of Printed Drug Names

Calvin K. L. Or · Hailiang Wang

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Abstract
Background Tall Man lettering is a text enhancement method currently recommended by various organizations for distinguishing look-alike drug names to prevent medication errors. However, the literature has suggested that other typographic styles may be more effective.
Objective Our objective was to examine the effects of text enhancements and orthographic similarity on the accuracy of look-alike drug name differentiation.
Methods We conducted two experiments that were based on a two-way, repeated-measures design with text enhancement (Tall Man, boldface, boldface plus Tall Man, colored text [red] and contrast with lowercase as a 'no text enhancement' control) and orthographic similarity (low, medium, and high) as factors. Engineering students without a pharmacy background in experiment 1 ($n = 40$) and student pharmacists in experiment 2 ($n = 40$) participated in a computer-based drug name differentiation task in which they determined whether the two drug names in each of the 336 name pairs were the same or different. Only the data generated from the pairs in which the two names were different were used in the analysis. The differentiation accuracy was measured as the proportion of correct responses.
Results In both experiments, all five text enhancements significantly improved accuracy compared with the lowercase condition; and boldface plus Tall Man and color significantly outperformed Tall Man lettering. A high degree of orthographic similarity yielded the least accuracy, followed by medium and low degrees.
Conclusions Highlighting the differing portions of confusing drug name pairs using enhanced text clearly renders differentiation easier, although Tall Man lettering may not be the most effective choice for this method.

Electronic supplementary material The online version of this article (doi:10.1007/s40264-014-0156-9) contains supplementary material, which is available to authorized users.

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Key Points

Text enhancement methods that render the differing portions of look-alike drug names more salient and visually distinct can improve the accuracy of the differentiation of the names.

Our study shows that Tall Man lettering significantly improves the differentiation accuracy; however, more importantly, other typographic styles have greater potential to further improve such accuracy.

Therefore, it is reasonable to reappraise the type of text enhancement used in look-alike drug name labeling for greater ease of differentiation and fewer medication errors.

1 Introduction

Look-alike drug names create confusion in medication dispensing and administering processes, and are a common cause of medication errors. Although the proportion of errors for which look-alike drug names alone are responsible is unknown, it has been estimated that about 15–25 % of all known medication errors are related to look-alike and sound-alike drug names [1, 2]. Such an error-prone system creates significant challenges for the healthcare workers who handle medications, and poses a serious threat to patient safety.

The literature describes two 'fixing-the-system' strategies to combat the problem. One is to control the use of new drug names that look similar to existing names [3]. For example, the European Medicines Agency suggests the use of international non-proprietary names rather than the trade/brand names when naming new drug products; when a given proprietary name is proposed, the risks involved in using it should be reviewed and verified in order to avoid confusion with existing drugs with similar names [4, 5]. The other strategy, for already marketed drugs, is to adopt safeguards to avoid confusion, such as providing warnings, stocking potentially confusing drugs in separate areas of the pharmacy, and altering the visual attributes of dissimilar letters in confusing name pairs (i.e., text enhancement) to emphasize their differences [2].

1.1 Effects of Tall Man Lettering

Many previous studies on confusing look-alike drug names have focused on the text enhancement approach. The Tall Man lettering method (the use of capital letters to highlight the primary dissimilarities between confusing drug name pairs), in particular, has received a great deal of attention in the literature. In addition, organizations such as The Joint Commission [6], the US FDA [7], and the Institute for Safe Medication Practices (ISMP) [8] recommend Tall Man lettering to reduce confusion errors. Accordingly, the use of such lettering has gained wide acceptance in medical practice [9].

Despite this general advocacy of Tall Man lettering, the empirical results on its effectiveness in drug name differentiation have been sparse and mixed. Although studies by one research group found such lettering to reduce drug name confusion errors [10, 11] and improve the accuracy of drug name perception [12], others have failed to show that it has any effect. Some have even found that it is not the most efficient way to emphasize name differences. For example, Filik et al. [13] revealed that the amount of time taken to discriminate between names containing Tall Man letters was no shorter than that taken to discriminate between those in lowercase. Schell [14] reported Tall Man lettering to have no effect on the recognition of drug names. Although Gabriele [15] found that name pairs with Tall Man lettering were unexpectedly easier to distinguish between than those containing boldface characters, name pairs presented in white characters on a black rectangle were even more distinctive. Irwin et al. [16] showed that Tall Man had no effect on the perception of drug names in a visual search task and concluded that such lettering may not be effective as an error-reducing strategy. They suggested that more research is needed to assess its usefulness.

1.2 Other Typographic Alternatives

Typography and visual search studies have identified various visual features of fonts (e.g., color and letter stroke width) that make them 'pop out' from homogeneous backgrounds [17, 18], improving their legibility [19–21]. Similarly, in the context of visual search and perception of look-alike drug names, text enhancement models (e.g., increasing the stroke width and contrast) that render the portions of the drug names that differ more salient and distinct should lead to better visual perception and discrimination. Given the mixed evidence for the efficacy of Tall Man lettering and the potential exhibited by other typographic styles, a number of typographic alternatives for distinguishing drug names have been proposed and examined [13–15]. For example, an experiment by Filik et al. [13] elicited participants' opinions on how confusing they found the various text enhancement methods used to emphasize drug name differences. Printing the differing letters of drug name pairs in red was judged to be a less confusing method than the others considered. The researchers subsequently tested the effect of color on recognition memory tasks, although they found no evidence that color aided recognition. Schell [14] reported that name recognition was not significantly affected by the use of lowercase, color, Tall Man, color plus Tall Man, Tall Man plus size-based type (distinctive portions increased by 33 %), or color plus Tall Man plus size-based type. The results of Gabriele's [15] word-recognition study revealed that the use of contrast (white characters on a black rectangle) was the most helpful in differentiating names. Also, The Joint Commission recommends that boldface and color be used to highlight the differing parts of look-alike drug names in order to prevent name mix-ups [22]. However, this limited body of work does not make it clear which text enhancement manipulation renders look-alike drug names most distinctive.

1.3 Study Aims and Hypotheses

The study reported herein expands on previous research by examining the influences of several text enhancement strategies and lowercase lettering (which served as a 'no text enhancement' control condition) on the accuracy of look-alike drug name differentiation in a computer-based 'same-different' differentiation task. Moreover, as previous research has found that a higher level of orthographic similarity (the extent to which the letters that make up the two names in a pair are similar to each other) increases the likelihood of drug name recognition errors [11, 13, 23], we also tested the effect of orthographic similarity on such accuracy. After a review of the literature [13–15, 24, 25], we decided to examine five text enhancement methods: Tall Man (e.g., rifaMPin vs. rifaXIMin), boldface (e.g., rifa**mp**in vs. rifa**xim**in), boldface plus Tall Man (e.g., rifa**MP**in vs. rifa**XIM**in), red text (e.g., rifa[mp]in vs. rifa[xim]in, with the letters in brackets printed in red), and contrast (e.g., rifampin vs. rifaximin). The review also led to the following hypotheses. Hypothesis 1: Relative to lowercase lettering, the five text enhancement methods significantly increase the accuracy of drug name differentiation. Hypothesis 2: Accuracy increases significantly when the drug names in each pair are less similar to each other.

2 Methods

Two experiments were conducted to examine two groups of participants: engineering students without a pharmacy background (experiment 1) and student pharmacists (experiment 2). The study design, materials, procedures, and data analysis were identical in both experiments. The study was approved by the university's institutional review board, and all of the participants gave their informed consent.

2.1 Design

The experiments were based on a two-way, repeated-measures design with text enhancement and orthographic similarity as factors. There were six levels of text enhancement: Tall Man, boldface, boldface plus Tall Man, red text, contrast, and lowercase lettering; and three levels of orthographic similarity: low, medium, and high. Kondrak and Dorr's BI-SIM measure, which has been shown to outperform other measures of similarity [26], was used to obtain a BI-SIM similarity value for each drug name pair to determine the orthographic similarity of the two names. The level of similarity was identified as low when the BI-SIM value was $\leq$0.5, medium when it was >0.5 and $\leq$0.7, and high when it was >0.7 and <1. Accuracy, as the dependent variable, was measured as the proportion of correct responses. A correct response was recorded when a participant correctly indicated that the two different drug names in a pair were different. We focused on this type of response accuracy because it corresponds more closely to a 'wrong-drug' error in the real world (where two different drugs have been confused with each other), and the effects of the various text enhancements on this type of accuracy can be extremely informative. In the differentiation test, 56 drug name pairs were used; of those, the names of 28 pairs were different and thus only the response accuracy data generated from those 28 pairs were used in the analysis.

2.2 Participants

Engineering students without a pharmacy background (n = 40; 23 females and 17 males) with a mean age of 24.2 years (standard deviation [SD] 2.14) participated in experiment 1. In experiment 2, student pharmacists (n = 40; 21 females and 19 males) with a mean age of 21.3 years (SD 2.45) participated; of them, 21 (52.5 %) were sophomores, 12 (30.0 %) were juniors, and seven (17.5 %) were seniors or graduate students. They were recruited through flyers and direct personal contact. All of the participants described themselves as right-handed and reported normal or corrected-to-normal vision and normal color vision.

2.3 Materials

Apparatus. The participants performed the drug name differentiation task on a desktop computer with a 21.5-inch flat-screen color monitor with 1,920 × 1,080-pixel resolution in a university laboratory. A computer application was developed using Visual Basic 6.0 to present the drug name stimuli, record participants' responses, and measure response accuracy.

Stimuli. A total of 28 drug names and their matched, confusable names were selected from the confusing drug name lists published by the US FDA and ISMP [27]. We also randomly selected another 28 drug names from the lists and paired each of them with their own names to create 28 pairs in which the two names were identical. Hence, 56 pairs were used as the study stimuli (see Appendix Table A1 [Online Electronic Supplementary Material]). To avoid the participants using word length as a cue for differentiation, we ensured that the first 28 drug names and their matched names differed in length by no more than one letter [13]. Moreover, as longer drug names can increase the risk of confusion [28], our selection of the drug name stimuli also considered length, with 12 names that were between six and seven letters long, 12 that were between eight and nine, 16 that were between 10 and 11, and 16 that were between 12 and 19. Of the first 28 name pair stimuli, the BI-SIM similarity values of nine pairs were low (mean 0.46, SD 0.03), those of nine pairs were medium (mean 0.61, SD 0.04), and those of ten pairs were high (mean 0.78, SD 0.04). The decisions regarding which letters to highlight in each name pair were made in accordance with the US FDA and ISMP drug name lists.

Based on the methods used by Filik et al. [11] and Irwin et al. [16], we created computer images of mock drug bottles with labels displaying essential drug information for

Fig. 1 Example of a look-alike drug name pair presented in boldface plus Tall Man

use in the experiment (Fig. 1). All of the drug name pairs were presented in Arial font size 12 [12], and each pair was presented in the six aforementioned textual formats.

2.4 Procedure

A trained research assistant began by explaining the study's background to the participants. Seated at computer terminals, the participants completed a questionnaire that collected their demographic information. Next, they were asked to read the on-screen instructions for the drug name differentiation tasks and procedures. The experiment comprised two phases: a 25-trial practice phase containing 25 pairs of non-drug words (e.g., message and massage), followed by a 336-trial test phase containing 336 drug name pair stimuli (56 name pair stimuli × six enhancement conditions). Only data from the test phase were used for analysis.

During the experiment, upon presentation of the stimuli, the participants were instructed to indicate as accurately as possible whether the two stimulus items in a pair were the same or different by pressing either the D (labeled 'Same') or K (labeled 'Different') key on a computer keyboard with their left and right index fingers, respectively. Each trial began with the phrase "Get ready for the next pair" appearing in the center of the screen for 3 s. Two 'plus' signs were then displayed onscreen for 1 s to indicate where the two drug names would appear. The mock drug bottle images with the two drug names then appeared for 700 ms before being replaced with a screen asking "Are the two drug names the same?" This length of time was deemed sufficient to allow the participants to view the target names. The next trial began after they had indicated their response. The order in which the stimuli were presented was randomized. A 1-minute break was given to the participants after they finished the first and second set of 112 trials. The entire test took 40–50 min to complete.

2.5 Data Analysis

The accuracy data were analyzed using two-way repeated-measures analysis of variance (ANOVA), and Fisher's least significant difference post hoc comparison tests were used to evaluate the pair-wise means.

3 Results

3.1 Experiment 1 (Students without a Pharmacy Background)

Mauchly's test of sphericity indicated that sphericity could be assumed for orthographic similarity (χ^2 (2) = 0.39, $p = 0.82$). However, the assumption was violated for text enhancement (χ^2 (14) = 84.21, $p < 0.05$) and the interaction term (χ^2 (54) = 106.24, $p < 0.05$); therefore, the degrees of freedom were corrected for the effects using Greenhouse–Geisser estimates of sphericity ($\varepsilon = 0.44$ for text enhancement and $\varepsilon = 0.65$ for the interaction term). The ANOVA results showed significant main effects on accuracy for text enhancement, $F(2.21, 86.10) = 47.66$, $MS_E = 0.035$, $p < 0.001$, and similarity, $F(2, 78) = 47.57$, $MS_E = 0.007$, $p < 0.001$, and a significant interaction between text enhancement and similarity, $F(6.53, 254.69) = 13.50$, $MS_E = 0.011$, $p < 0.001$.

The results of the post hoc comparison test revealed that, relative to the accuracy of the lowercase lettering condition, that of all five text enhancement conditions was significantly higher (all p values <0.001), with boldface plus Tall Man producing the highest degree of accuracy, followed by color, boldface, contrast, and Tall Man (see Table 1 for mean accuracy and percentage improvement in differentiation accuracy). Hypothesis 1 was thus supported for students without a pharmacy background.

We also compared the accuracy of Tall Man with that of the other four text enhancement methods. Relative to Tall Man lettering, boldface plus Tall Man, color, and boldface all produced significantly higher degrees of accuracy (all p values <0.05) (see also Table 1). In addition, boldface plus Tall Man was significantly better than contrast ($p < 0.05$). No significant differences were found in the other pair-wise comparisons.

Regarding the effect of orthographic similarity on accuracy, the results of the post hoc comparison test showed that the degree of accuracy in the low similarity condition (mean 0.937 [or 93.7 %], SD 0.104) was slightly higher than that in the medium condition (mean 0.935 [or

Table 1 Mean accuracy for text enhancement and percentage improvement in drug name differentiation accuracy relative to lowercase and Tall Man lettering among students without a pharmacy background

Text enhancement	Mean (%)	SD	Percentage improvement in differentiation accuracy (%)	
			Relative to lowercase	Relative to Tall Man
Lowercase	75.8	0.211	–	–
Tall Man	92.0	0.107	16.2[a]	–
Boldface	94.9	0.078	19.1[a]	2.9[b]
Boldface plus Tall Man	96.7	0.059	20.9[a]	4.7[a]
Color	95.2	0.071	19.4[a]	3.2[b]
Contrast	94.2	0.089	18.4[a]	2.2

SD standard deviation

[a] Improvement is statistically significant at the 0.01 level

[b] Improvement is statistically significant at the 0.05 level

Table 2 Interactions between text enhancement and orthographic similarity for students without a pharmacy background

Orthographic similarity (BI-SIM value)	Text enhancement	Mean (%)	SD
Low (≤0.5)	Lowercase	85.8	0.174
	Tall Man	92.2	0.104
	Boldface	97.2	0.049
	Boldface plus Tall Man	97.2	0.055
	Color	95.3	0.061
	Contrast	94.4	0.083
Medium (>0.5 and ≤0.7)	Lowercase	80.8	0.185
	Tall Man	94.7	0.091
	Boldface	96.1	0.069
	Boldface plus Tall Man	97.5	0.053
	Color	96.7	0.052
	Contrast	95.0	0.083
High (>0.7 and <1.0)	Lowercase	60.8	0.187
	Tall Man	89.0	0.119
	Boldface	91.5	0.098
	Boldface plus Tall Man	95.2	0.068
	Color	93.7	0.093
	Contrast	93.0	0.099

SD standard deviation

93.5 %], SD 0.114), but the difference was not significant. However, the degrees of accuracy in both the low and medium conditions were significantly higher than the accuracy in the high condition (mean 0.872 [or 87.2 %], SD 0.167) (at 0.001 level). Thus, hypothesis 2 was partially supported.

The interaction between text enhancement and orthographic similarity was also significant (see Table 2). When the participants distinguished between look-alike drug names that were low in similarity, a higher level of accuracy was achieved when boldface plus Tall Man and boldface were used, followed by color, contrast, Tall Man, and lowercase. At the medium similarity level, boldface plus Tall Man also yielded the highest accuracy, followed by color, boldface, contrast, Tall Man, and lowercase. Boldface plus Tall Man maintained its top position in the high similarity condition, yielding the highest degree of accuracy, followed by color, contrast, boldface, Tall Man, and lowercase.

3.2 Experiment 2 (Student Pharmacists)

Mauchly's test of sphericity revealed that sphericity could be assumed for orthographic similarity (χ^2 (2) = 5.52, $p = 0.06$). However, the assumption was violated for text enhancement (χ^2 (14) = 52.82, $p < 0.001$) and the interaction term (χ^2 (54) = 113.70, $p < 0.001$); therefore, the degrees of freedom were corrected for the effects using

Table 3 Mean accuracy for text enhancement and percentage improvement in drug name differentiation accuracy relative to lowercase and Tall Man lettering among student pharmacists

Text enhancement	Mean (%)	SD	Percentage improvement in differentiation accuracy (%)	
			Relative to lowercase	Relative to Tall Man
Lowercase	90.2	0.141	–	–
Tall Man	95.5	0.068	5.3[a]	–
Boldface	96.7	0.066	6.5[a]	1.2
Boldface plus Tall Man	97.5	0.057	7.3[a]	2.0[a]
Color	97.2	0.056	7.0[a]	1.7[b]
Contrast	97.2	0.057	7.0[a]	1.7[b]

SD standard deviation

[a] Improvement is statistically significant at the 0.01 level

[b] Improvement is statistically significant at the 0.05 level

Table 4 Interactions between text enhancement and orthographic similarity for student pharmacists

Orthographic similarity (BI-SIM value)	Text enhancement	Mean (%)	SD
Low (≤0.5)	Lowercase	96.4	0.073
	Tall Man	98.3	0.040
	Boldface	97.8	0.045
	Boldface plus Tall Man	98.9	0.034
	Color	98.1	0.050
	Contrast	98.1	0.050
Medium (>0.5 and ≤0.7)	Lowercase	94.7	0.091
	Tall Man	96.7	0.057
	Boldface	98.9	0.034
	Boldface plus Tall Man	97.8	0.057
	Color	97.8	0.052
	Contrast	98.3	0.040
High (>0.7 and <1.0)	Lowercase	79.5	0.171
	Tall Man	91.5	0.080
	Boldface	93.5	0.092
	Boldface plus Tall Man	95.7	0.071
	Color	95.7	0.064
	Contrast	95.2	0.072

SD standard deviation

Greenhouse–Geisser estimates of sphericity ($\varepsilon = 0.56$ for text enhancement and $\varepsilon = 0.57$ for the interaction term). The ANOVA results showed significant main effects on accuracy for text enhancement, $F(2.79, 108.79) = 18.83$, $MS_E = 0.009$, $p < 0.001$, and similarity, $F(2, 78) = 38.58$, $MS_E = 0.007$, $p < 0.001$, and a significant interaction between text enhancement and similarity, $F(5.70, 222.26) = 9.95$, $MS_E = 0.007$, $p < 0.001$.

The post hoc comparison results showed that, relative to the accuracy of the lowercase lettering condition, all five of the text enhancement conditions were significantly more accurate (all p values <0.001), with boldface plus Tall Man generating the highest degree of accuracy, followed by color, contrast, boldface, and Tall Man (see Table 3 for mean accuracy and percentage improvement in differentiation accuracy). Hypothesis 1 was thus supported for student pharmacists.

Relative to Tall Man lettering, boldface plus Tall Man, color, and contrast all produced significantly higher degrees of accuracy (all p values <0.05) (see also Table 3). No significant differences were found among boldface plus Tall Man, color, contrast, and boldface.

Regarding orthographic similarity, the results of the post hoc comparison test for student pharmacists revealed that the degree of accuracy in the low similarity condition (mean 0.979 [or 97.9 %], SD 0.050) was slightly higher than that in the medium condition (mean 0.974 [or 97.4 %], SD 0.059), but the difference was not significant.

The degrees of accuracy in the low and medium conditions were significantly higher than the accuracy in the high similarity condition (mean 0.919 [or 91.9 %], SD 0.113) (at 0.001 level). Hence, hypothesis 2 was partially supported.

A significant interaction between text enhancement and orthographic similarity was also found in experiment 2 (see Table 4). At the low similarity level, a higher level of accuracy was achieved using boldface plus Tall Man, followed by Tall Man, color, contrast, boldface, and lowercase. At the medium similarity level, boldface yielded the highest accuracy, followed by contrast, boldface plus Tall Man, color, Tall Man, and lowercase. At the high similarity level, boldface plus Tall Man and color yielded the highest degree of accuracy, followed by contrast, boldface, Tall Man, and lowercase.

3.3 Differentiation Accuracy between the Two Groups of Participants

Although comparing the differentiation accuracy of participants with and without a pharmacy background was not a primary objective of the study, our results showed that both groups of participants could correctly differentiate two different drug names more easily when text enhancements were applied, when other typographic styles were used (compared with Tall Man lettering), and when the names were less similar. Figure A1 and A2 in the Appendix (Online Electronic Supplementary Material) present a graphic illustration of the differentiation accuracy of the two groups based on various textual enhancements and orthographic similarity.

4 Discussion

In this study, we aimed to expand our knowledge of drug name confusion, as a better understanding is critical to medication error prevention. We examined the use of various text enhancement methods to improve the accuracy of differentiating confusing look-alike drug names, and tested two groups of participants. In support of the US FDA recommendation that Tall Man lettering be used to improve such accuracy, our findings reveal that this lettering significantly improved the participants' ability to differentiate drug names that looked alike: 16.2 and 5.3 % improvement in accuracy for students without a pharmacy background and student pharmacists, respectively, compared with lowercase. More importantly, our results show that the use of the other typographic styles to visually increase the salience of the differing letters in the names further facilitated the detection of name differences. Overall, the use of boldface plus Tall Man lettering resulted in the fewest omission errors in the differentiation test, improving accuracy 20.9 % (among students without a pharmacy background) and 7.3 % (among student pharmacists) relative to no text enhancement, and 4.7 % (among students without a pharmacy background) and 2 % (among student pharmacists) compared with Tall Man lettering. These results suggest that combining the use of capital letters and greater stroke widths increases the salience of highlighted letters, decreasing the difficulty of the visual search and detection, which improves name differentiation.

At first glance, some of the percentage improvements in accuracy seem to be low. However, given that 3 billion prescriptions are written annually in the USA alone [29], and the wrong drug error rate is estimated to be 0.13 % [30], with about 15–25 % attributed to drug name confusion [1, 31, 32], even a small improvement would significantly reduce the number of wrong drug errors.

Furthermore, this study expands the literature on the use of color and contrast as a means of reducing look-alike drug name confusion. The issue of color blindness may be a consideration in using color in drug labeling to improve safety [33, 34], although it might not be if color is used purely to distinguish the product, not to convey any specific information. However, our results indicate that color is a viable alternative for emphasizing drug name differences, as it helps them to stand out from the background, rendering confusing names easier to search and detect [35, 36]. Similarly, consistent with Gabriele [15], our findings suggest that individuals can discriminate more easily between drug names that are highlighted using contrast than between those printed in Tall man lettering.

We also examined the effects of orthographic similarity. Previous studies have shown the accuracy of look-alike drug name recognition to be adversely affected by highly similar names [11, 13, 23], and our findings are consistent. In addition, our interaction results indicate that the differentiation accuracy of all text enhancement methods is compromised when the two drug names in a pair are highly similar. Thus, the effectiveness of the methods may be weak in high-risk situations where the drug names are very similar, suggesting the need for concurrent use of other reliable controls such as preventing name confusion at the source. For instance, in addition to text enhancements, the organizations in charge of naming new drugs should also follow strict operational procedures in approving new names that are similar to the names of already marketed medications. Other potentially reliable error-reduction strategies include the use of technology, such as automated dispensing equipment [37].

Some degree of caution is warranted in making use of our findings in any setting. Our study's outcome measure of the differentiation accuracy (i.e., proportion of correct responses) should not be used as an indication of medication error rates. Also, our experiment took place in a controlled laboratory environment with adequate lighting and little to no noise or distraction. Such a quiet, distraction-free work environment is unlikely to exist in real-life healthcare facilities. The look-alike drug name issue should be further investigated in a real-world setting to produce additional informative findings.

5 Conclusion

Highlighting the primary dissimilarities between confusing drug name pairs through various text enhancement methods makes the names easier to differentiate. Many organizations (e.g., the US FDA and The Joint Commission) currently recommend the use of Tall Man lettering to reduce medication errors. However, our results demonstrate that other typographic styles have greater potential to reduce these errors by rendering confusing look-alike names more visually distinct. It would thus be reasonable to reappraise the type of text enhancement, if any, used in look-alike drug name labeling for greater ease of differentiation and fewer medication errors. Differentiation accuracy declines when the similarity of drug names increases, thereby increasing the risk of drug selection error. Particular attention should thus be paid to drug names that are highly similar, as they pose a greater threat to safety. The findings of this study constitute a knowledge base for possible future drug labeling solutions, strategies, and policies.

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Conflict of interest Calvin K. L. Or and Hailiang Wang have no conflicts of interest that are directly relevant to the content of this study.

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