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ARTICLE

Visual differentiation and recognition memory of look-alike drug names: effects of disfluent format, text enhancement and exposure time

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ABSTRACT

Three computer-based experiments were conducted to examine whether disfluent format, enhanced text, and increased exposure time improve the accuracy of visual differentiation and recognition memory of look-alike drug names. A three-way, repeated-measures look-alike drug name differentiation test assessed the visual differentiation accuracy of 30 nursing students (Experiment 1) and 15 nurses (Experiment 2). A two-way, repeated-measures recognition memory test examined the recognition memory accuracy of 15 nurses for look-alike drug names (Experiment 3). We found that making drug names disfluent did not significantly improve differentiation (Experiment 2) or memory accuracy (Experiment 3), but even impaired differentiation accuracy (Experiment 1). Enhanced text and longer exposure time significantly improved differentiation accuracy (Experiments 1 and 2). However, the enhanced text did not improve recognition memory (Experiment 3). We suggest that making look-alike drug names disfluent is not favourable. Enhanced text and longer exposure times are effective in supporting visual differentiation of look-alike drug names.

Practitioner Summary: Confusion arising from look-alike drug names may compromise patient safety. Three experiments examined the effects of disfluent format, text enhancement and increased exposure time on visual and memory performances. Making drug names more difficult to read did not improve performance. Enhancing text design and increasing exposure (i.e. reading) time improved visual differentiation between medications, but did not improve the recognition of medications from memory.

Abbreviations: SEEV: Salience-effort-expectancy-value; FDA: Food and Drug Administration; ANOVA: analysis of variance; SD: standard deviation, DF: disfluent format; TE: text enhancement; ET: exposure time.

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Look-alike drug names; disfluent format; text enhancement; exposure time; drug safety

1. Introduction

The confusion caused by drug names that look alike (e.g. hydroxyzine and hydralazine) can lead to perceptual and recognition errors in the differentiation and memory of the names, an issue which can potentially cause adverse events and harm (Hoffman and Proulx 2003; Institute of Medicine 1999). It is therefore important to find ways to avoid such errors. One way is to make the look-alike drug names more legible (e.g. by using large fonts or clear handwriting) to facilitate perception and recognition (Smither and Braun 1994; Rodríguez-Vera et al. 2002; Gabriele 2006). However, there are studies suggesting that increasing perceptual difficulty by making information hard to read can lead people to engage in deeper cognitive processing, which can, in turn, result in improved recognition and retention of information (Bjork 1994; Diemand-Yauman et al. 2011; Sungkhasettee et al. 2011). The concept of making a piece of information hard to read to achieve more careful, deeper information processing can be referred to as *disfluency* (Oppenheimer 2012; Bjork 1994).

Disfluency can be created in several ways, and its positive effects have been demonstrated in education research. For example, Diemand-Yauman et al. (2011) and Sungkhasettee et al. (2011) have reported that learning materials with hard-to-read presentation, such as upside down texts or small Comic Sans MS grey fonts (i.e. disfluent formats) were remembered more accurately than those with easy-to-read presentation, such as upright words or large Arial black fonts (i.e. fluent formats). In human-computer interaction

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research, Soboczenski et al. (2016) examined disfluency in a number-entry experiment and revealed that numbers that were presented in obscure grey fonts (as compared to clear black fonts) resulted in reduced number-entry errors although the reduction was only marginally significant. However, some studies have demonstrated that disfluent formats (e.g. blurred or small fonts) did not improve recall and recognition and even led to impairment (Lindenberger et al. 2001; Glass 2007; Rhodes and Castel 2008; Yue et al. 2013; Eitel et al. 2014). Despite these mixed results, because disfluent formats have been found to aid learning by inducing deeper processing of information, we sought to examine whether the introduction of disfluency to look-alike drug names would promote visual differentiation and improve recognition memory of drug names.

Text enhancement is another way of managing already marketed look-alike drug names for safety and has received much attention. Using enhanced text, the differing parts of look-alike drug names are rendered visually distinct, making them more salient, to support visual differentiation and recall of the names (Filik et al. 2010; Or and Wang 2014; U.S. Food and Drug Administration 2001; Institute for Safe Medication Practices 2016). This approach is in line with the salience-effort-expectancy-value (SEEV) attention model that suggests highly salient stimuli are more likely to capture one's attention via parallel processing (Wickens 2007).

Among various text enhancement methods, tall man lettering (i.e. using capital letters to highlight the primary dissimilarities between two similar drug names) has been shown to be effective in reducing name confusion errors (e.g. Filik et al. 2010) and has been recommended by various health organisations, such as the U.S. FDA (2001) and the World Health Organization (2007). However, some investigations have indicated that other text enhancement methods are more effective, such as boldface letters and inverted text (e.g. Or and Wang 2014; Gabriele 2006). The inverted text refers to switching the colour of the font and background, for example, the inverted text for "apple" would become apple (Gabriele 2006). The discrepant research results and recommendations warrant further study to add to our understanding of the effects of different text enhancement methods.

The duration of exposure to a stimulus can also affect the processing of the stimulus, and it has been shown to interact with disfluency. For instance, previous studies have illustrated that words presented for short durations can be recognised or recalled better than words presented for longer exposure times (e.g. Nairne 1988; Hirshman and Mulligan 1991). However, Yue et al. (2013) have found that when the exposure time was short, disfluent formats impaired the encoding process and resulted in lower accuracy in the recall. When the exposure time was longer, no difference in recall performance between fluent and disfluent formats was observed. These mixed results suggest that more research is required to increase understanding regarding the effect of exposure time on the perception of words presented in disfluent formats.

In the present study, three experiments were conducted: Experiments 1 and 2 tested nursing students' and nurses' visual differentiation accuracy for drug names presented with different disfluent formats, text enhancements, and exposure times, using a computer-based drug name differentiation test. Experiment 3 examined nurses' recognition accuracy for drug names presented with different disfluent formats and text enhancements, using a computer-based recognition memory test.

2. Experiment 1

2.1. Method

2.1.1. Design

Experiment 1 used a three-way, repeated-measures design with the disfluent format, text enhancement, and exposure time as the three factors. The disfluent format was created by presenting drug names in 16-point Arial font in 40% greyscale on a white background. A fluent format in which drug names were presented in 16-point Arial font, with black text on a white background, served as the control condition. There were three levels of text enhancement: tall man plus boldface, inverted text (i.e. switching the colour of the font and background), and lowercase as a 'no text enhancement' control; and three levels of exposure time: 0.7, 1.5 and 3.5 s. Differentiation accuracy, measured as the proportion of correct responses, was the dependent variable. A correct response was recorded when a participant correctly indicated that the two drug names in a pair were different. The three exposure time conditions formed three blocks of 168 trials each (28 drug name pair stimuli $\times$ two disfluent format conditions $\times$ three text enhancement conditions). The order of the three blocks was counterbalanced across participants, and the order of trials within each block was randomised. A short break was given every 56 trials. In the test, half of the trials had name pairs with different names and the other half

had name pairs with identical names. As the focus of this experiment was to examine whether disfluent format, enhanced text, and longer exposure time can make differentiation of look-alike drug names easier, only data generated from pairs with different but look-alike names were analysed.

Based on previous studies demonstrating the positive effects of disfluent format (Diemand-Yauman et al. 2011; Sungkhasettee et al. 2011), enhanced text (Or and Wang 2014; Gabriele 2006), and longer exposure time (Yue et al. 2013), the following three hypotheses were tested:

Hypothesis 1: Relative to the fluent format, the disfluent format significantly increases differentiation accuracy.

Hypothesis 2: Relative to no text enhancement, enhanced texts significantly increase differentiation accuracy.

Hypothesis 3: Drug names presented for longer exposure times significantly increase differentiation accuracy.

2.1.2. Participants

The participants comprised 30 senior nursing students (mean age 21.2 ± 1.2 years, range 20–24 years) recruited via e-mail. All reported normal or corrected-to-normal vision and provided written informed consent.

2.1.3. Stimuli and apparatus

The stimuli used consisted of 28 drug name pairs (Table A1): 14 were look-alike drug name pairs selected from the lists of confusing drug names published by the U.S. FDA and Institute for Safe Medication Practices (2016) and 14 were pairs in which the two names were identical. Of the 14 look-alike drug name pairs, eight had names that were between 10 and 14 letters long and six had names that were between six and nine letters long. The lengths of the two names in each pair did not vary by more than one letter (Filik et al. 2006; Or and Wang 2014). The selection of the name pairs also considered the orthographic similarity of the two names in the pairs, which was determined using Kondrak and Dorr's BI-SIM measure (Kondrak and Dorr 2006). Five pairs had a low similarity level ($0.4 < \text{BI-SIM value} \leq 0.5$), five had a medium similarity level ($0.5 < \text{BI-SIM value} \leq 0.7$), and four had a high similarity level ($0.7 < \text{BI-SIM value} < 1.0$). Based on Or and Wang (2014), the drug names were presented on computer images of mock drug bottles (Figure 1). For each exposure time condition, each of the 28 name pairs was presented in six experimental conditions (two disfluent format conditions × three text enhancement conditions). Examples of drug name stimuli for the six experimental conditions are presented in Table 1. The differentiation test was performed on a desktop computer with a 21.5-inch monitor (1920 × 1080 pixel resolution). A computer application developed using Visual Basic 6.0 was used to present the stimuli and record the participants' responses.

2.1.4. Procedure

In the trials, the participants were presented with images with drug name pairs. After each image disappeared from the display, the participants were instructed to indicate as quickly and accurately as possible whether the two drug names in the pairs were the same by pressing a response key labelled 'same' or different by pressing a key labelled 'different'. The experiment took ~70 min to complete.

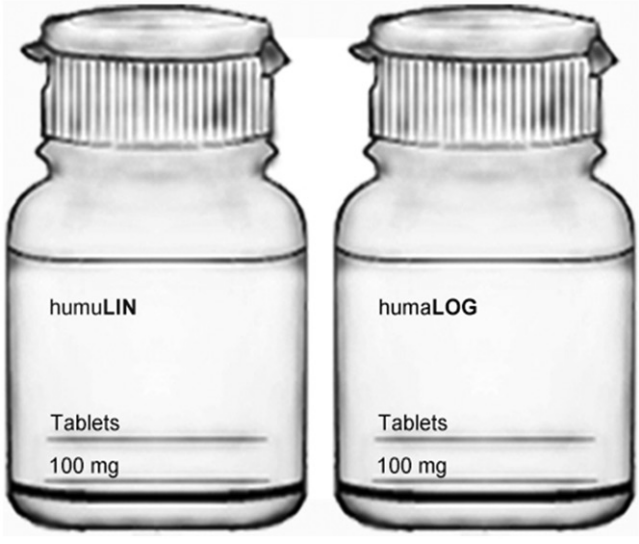

Figure 1. A pair of mock drug bottle images with look-alike drug names.

Table 1. Examples of drug name stimuli for the six experimental conditions.

Disfluent format	Text enhancement	Example
fluent format	lowercase	humulin vs. humalog
	tall man plus boldface	humu**LIN** vs. huma**LOG**
	inverted text	humu**lin** vs. huma**log**
disfluent format	lowercase	humulin vs. humalog
	tall man plus boldface	humu**LIN** vs. huma**LOG**
	inverted text	humu**lin** vs. huma**log**

Table 2. Mean differentiation accuracy, *SD*, *F* statistic, significance level and partial eta-squared value for each independent variable and interaction term for the nursing students (Experiment 1).

	Mean differentiation accuracy (%)	*SD*	*F* test and significance level	ηp^2
Disfluent format (DF)			$F(1, 29) = 5.96$; $p = .02$*	.17
Fluent format	96.3	0.07		
Disfluent format	95.4	0.08		
Text enhancement (TE)			$F(1.47, 42.72) = 37.10$; $p < .001$**	.56
Lowercase	93.2	0.10		
Tall man plus boldface	97.1	0.06		
Inverted text	97.3	0.05		
Exposure time (ET)			$F(1.24, 35.98) = 30.89$; $p < .001$**	.52
0.7 s	91.0	0.10		
1.5 s	97.8	0.04		
3.5 s	98.8	0.03		
DF × TE			$F(2, 58) = 2.36$; $p = .10$	.08
DF × ET			$F(1.57, 45.38) = 5.27$; $p = .01$*	.15
TE × ET			$F(2.89, 83.80) = 22.22$; $p < .001$**	.43
DF × TE × ET			$F(2.37, 68.84) = 0.39$; $p = .72$	.01

*Significant at $p < .05$; **significant at $p < .01$.

2.1.5. Data analysis

A three-way repeated-measures analysis of variance (ANOVA) was used to examine the main effects of the independent variables. For each significant interaction, a t-test or one-way/two-way repeated-measures ANOVA was performed to assess the simple effects of the variables. Post hoc multiple comparisons were performed with Bonferroni adjustments. Partial eta-squared (ηp^2) was used as a measure of effect size, with values of .01, .06 and .14 indicating small, medium and large effects, respectively (Cohen 1988; Filik et al. 2006).

2.2. Results

Table 2 presents the means, SDs, *F* statistics, significance levels, and partial eta-squared values for each independent variable and interaction term for the nursing students. Contrary to Hypothesis 1, the results showed that the disfluent format led to significantly lower differentiation accuracy (95.4%) than the fluent format (96.3%). The results for text enhancement showed that tall man plus boldface and inverted text yielded significantly higher accuracy (97.1 and 97.3%) than lowercase (93.2%). Thus, Hypothesis 2 was supported. Longer exposure times (1.5 and 3.5 s) produced higher accuracy (97.8 and 98.8%) in comparison with the shorter exposure time (0.7 s), which yielded 91% accuracy; however, no evidence of a significant difference in accuracy was found between the 1.5 and 3.5 s exposure times. Thus, Hypothesis 3 was only partially supported.

Post-hoc analyses showed that for the interaction between disfluent format and exposure time (DF × ET), there was a significant simple effect for disfluent format only when the exposure time was 0.7 s ($t(89) = 2.75$, $p = .007$), with the disfluent format resulting in significantly lower accuracy than the fluent format (Figure 2, left panel). For the interaction between text enhancement and exposure time (TE × ET), a significant simple effect for text enhancement was observed only when the exposure time was 0.7 ($F(1.80, 106.45) = 38.45$, $p < .001$) or 1.5 s ($F(1.71, 100.90) = 11.31$, $p < .001$): tall man plus boldface and inverted text resulted in significantly higher accuracy than lowercase (Figure 2, right panel).

2.3. Discussion

Contrary to previous findings that disfluent format improved recognition of information due to the engagement in deeper cognitive processing of the information, our experiment showed that disfluent format not only had no impact on improved differentiation performance, but it even led to worse performance when the disfluent stimuli were

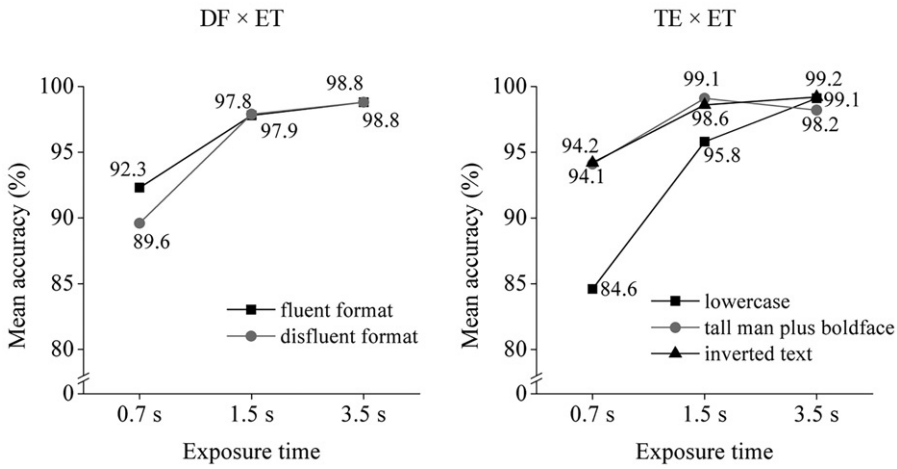

Figure 2. Disfluent format (DF) by exposure time (ET) interaction (left panel) and text enhancement (TE) by exposure time (ET) interaction (right panel) for Experiment 1.

presented in a short time interval (0.7 s), as observed in the result of the disfluent format by exposure time interaction. This observation may be due to participants not spending effort reading the stimuli because they were too difficult to read in such a short time interval, or they were simply unable to read the unclear stimuli during such a short exposure time. Without the perception of the stimuli, there would be no engagement in deeper processing of the information. Also, the interaction results showed that when the exposure time was longer (1.5 and 3.5 s), differentiation accuracy improved, but still was not significantly better than the fluent format. This effect could be because the disfluent manipulation that our experiment used was insufficiently strong to cause deeper cognitive engagement that could be achieved by a more disfluent manipulation (e.g. upside down texts) (Hirshman et al. 1994; Yue et al. 2013), or disfluency indeed had no effect on the differentiation of look-alike drug names.

However, results on text enhancement are consistent with previous findings (e.g. Or and Wang 2014), tall man plus boldface and inverted text improved differentiation accuracy, compared with lowercase, indicating that the two text enhancements could help individuals notice differences more easily by increasing the perceptual salience of differing parts of look-alike drug names. Moreover, the text enhancement by exposure time interaction indicates that the effectiveness of the enhanced texts is more pronounced with shorter exposures. According to the SEEV attention model (Wickens 2007), the advantage of enhanced text at shorter exposure times is most likely because the highlighted letters attracted the participants' attention immediately so that the drug names could be compared and processed simultaneously (i.e. parallel search). But when no text enhancement was used (i.e. lowercase), in order to make the judgement, the participants needed to actually read the drug names letter by letter (i.e. serial search).

In addition, differentiation accuracy improved when the exposure time was longer, an observation which is probably due to longer exposure times allowing the nursing students to compare the two presented drug names more carefully.

3. Experiment 2

Given the effects of the three variables on differentiation accuracy among nursing students, this experiment aimed to replicate Experiment 1 with a different population sample, namely, practicing nurses.

3.1. Method

The study design, hypotheses, stimuli, apparatus, procedure, and data analysis method were identical to those of Experiment 1. Fifteen nurses recruited through e-mail were examined (mean age 23.1 ± 1.7 years, range 21–28 years; mean working experience in nursing 1.3 ± 1.2 years, range 0.5–3 years) in this experiment. All reported normal or corrected-to-normal vision and all provided written informed consent.

3.2. Results

Table 3 presents the means, *SD*s, *F* statistics, significance levels and partial eta-squared values for each independent variable and interaction term for the nurses. No evidence of a difference in differentiation accuracy was found between the disfluent (95.1%) and fluent (95.5%) formats. Hypothesis 1 was not supported. Tall man plus

Table 3. Mean differentiation accuracy, *SD*, *F* statistic, significance level and partial eta-squared value for each independent variable and interaction term for the nurses (Experiment 2).

	Mean differentiation accuracy (%)	*SD*	*F* test and significance level	ηp^2
Disfluent format (DF)			$F(1, 14) = 0.30$; $p = .59$	.02
Fluent format	95.5	0.07		
Disfluent format	95.1	0.07		
Text enhancement (TE)			$F(2, 28) = 24.31$; $p < .001^{**}$	.64
Lowercase	92.7	0.09		
Tall man plus boldface	96.2	0.05		
Inverted text	97.0	0.04		
Exposure time (ET)			$F(1.45, 20.25) = 15.53$; $p < .001^{**}$	.53
0.7 s	91.5	0.08		
1.5 s	96.7	0.05		
3.5 s	97.7	0.05		
DF × TE			$F(1.11, 15.56) = 0.28$; $p = .63$	.02
DF × ET			$F(2, 28) = 2.42$; $p = .11$	.15
TE × ET			$F(4, 56) = 5.61$; $p = .001^{**}$	.29
DF × TE × ET			$F(4, 56) = 0.88$; $p = .48$	.06

**Significant at $p < .01$.

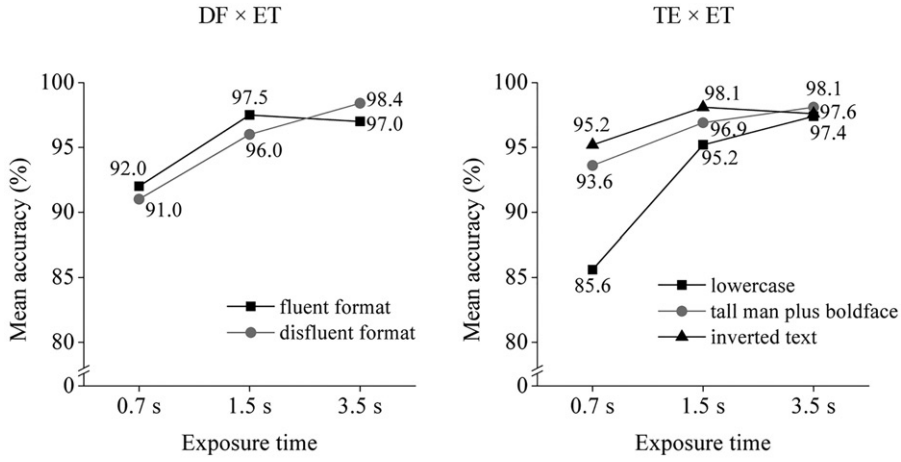

Figure 3. Disfluent format (DF) by exposure time (ET) interaction (left panel) and text enhancement (TE) by exposure time (ET) interaction (right panel) for Experiment 2.

boldface and inverted text produced significantly higher accuracy (96.2 and 97%) than lowercase (92.7%). Thus, Hypothesis 2 was supported. Significantly higher differentiation accuracy was achieved in the 1.5 and 3.5 s exposure times (96.7 and 97.7%) compared with 0.7 s (91.5%), but there was no evidence of a significant difference between 1.5 and 3.5 s. Thus, Hypothesis 3 was partially supported. For the interactions, the post-hoc analyses showed a significant simple effect for text enhancement only when the exposure time was 0.7 s, ($F(2, 58) = 16.78$, $p < .001$), with tall man plus boldface and inverted text resulting in significantly higher differentiation accuracy compared to lowercase (Figure 3, right panel).

3.3. Discussion

Similar to Experiment 1, the nurses' data suggest that the disfluent format did not improve visual differentiation of look-alike drug names. However, in contrast to Experiment 1, the nurses' differentiation performance was not significantly impaired by the disfluent format. According to the SEEV attention model (Wickens 2007), this result may be due to nurses' experience with medications enabled them to become more sensitive in terms of expecting where the differentiating feature was employed between the drug names. However, this explanation should be interpreted with caution for two reasons. First, given that the nurses participating in this experiment had mean work experience in nursing of 1.3 years, there might be little difference between their familiarity with drug names and that of the nursing students in Experiment 1. Second, the small sample size of this experiment may have limited the study's statistical power.

The overall effect of text enhancement or exposure time showed that the nurses' differentiation accuracy was improved by enhanced texts or longer exposure

times, consistent with Experiment 1. The interaction of text enhancement and exposure time (Figure. 3, right panel) revealed that the nurses' differentiation accuracy benefited from the use of enhanced texts only when the exposure time was 0.7 s. Contrary to expectation, enhanced texts did not significantly improve the accuracy when the exposure time was extended to 1.5 s. This result may be because the nurses' clinical experience allowed them to differentiate between look-alike drug names even with non-enhanced text when the exposure time was longer (or long enough).

Overall, enhanced texts can improve drug name differentiation. In particular, the use of enhanced texts is effective when the exposure time is short. This observation is important because in real practice, oftentimes nurses' work is fast-paced, and there may not be sufficient time to spend to examine drug names and make decisions. The current result, therefore, emphasises the importance of using enhanced texts when nurses are working under time pressure.

4. Experiment 3

4.1. Method

4.1.1. Design

Experiment 3 used a recognition memory test to examine the effects of disfluent format and text enhancement on memory performance in the context of remembering drug names. Each experimental trial had a study phase that required participants to memorise a target drug name, followed by a test phase that tested for recognition of the target name among distractors. This task can better reflect the real-life drug name selection processes in which a nurse first needs to read a drug name from a document/record, remember the name, and then compare the memory of the name to the name printed on a drug package/label in order to determine whether the two names are the same for drug selection.

The experiment used a two-way repeated-measures design with the disfluent format and text enhancement as factors. The levels of the factors were identical to those used in Experiments 1 and 2. Based on signal detection theory (Davies and Parasuraman 1982), we measured the accuracy of recognition memory using hit rate (the ratio of hits to the sum of hits and misses) and correct rejection rate (the ratio of correct rejections to the sum of correct rejections and false alarms). A hit was recorded when a target name was correctly recognised as a target, a miss was recorded when a target name was falsely recognised as a distractor, a correct rejection was recorded when a distractor was correctly recognised as a distractor, and a false alarm was recorded when a distractor was falsely recognised as a target. The hit rate represents how memorable a drug name was and the correct rejection rate associates with how confusable the drug names were in memory. Based on the positive effects of disfluent format and enhanced text reported in previous research (as noted above), the following two hypotheses were formulated:

Hypothesis 1: Relative to the fluent format, the disfluent format significantly increases the hit rate and correct rejection rate.

Hypothesis 2: Relative to no text enhancement, enhanced texts significantly increase the hit rate and correct rejection rate.

4.1.2. Participants

Fifteen nurses (mean age 28.9 ± 3.8 years, range 22–37 years; mean working experience in nursing 4.8 ± 4.1 years, range 1.2–18 years) were recruited via e-mail participated in this experiment. None of the participants had taken part in Experiment 2 and all reported normal or corrected-to-normal vision. They all provided written informed consent.

4.1.3. Stimuli and apparatus

Thirty-six look-alike drug name pairs were selected from the drug name stimuli used in Irwin et al. (2013) and lists of confusable drug names jointly published by the Institute for Safe Medication Practices and the U.S. FDA (2016) (Table A2). As with Experiment 1, the selection of the 36 drug name pairs also considered name length (two levels: 10–14 letters long and 6–9 letters long; 18 pairs for each level) and the orthographic similarity of the two names in each pair (three levels: $0.4 <$ BI-SIM value ≤ 0.5, $0.5 <$ BI-SIM value ≤ 0.7, and $0.7 <$ BI-SIM value < 1.0; 12 pairs for each level). One drug name from each pair was selected as the target name. For each target name, we also selected two drug names that were dissimilar to the target name (BI-SIM value < 0.20). The two dissimilar names and the paired similar name were used as distractors. In the study phase, target names were presented in one of the six experimental conditions (two disfluent format conditions $\times$ three text enhancement conditions). Computer images of mock drug bottles were created to present the drug names in the test phase. All of the names used in the test phase were presented in lowercase 16-point Arial font in black with no text enhancements. The apparatus used was the same as in Experiments 1 and 2.

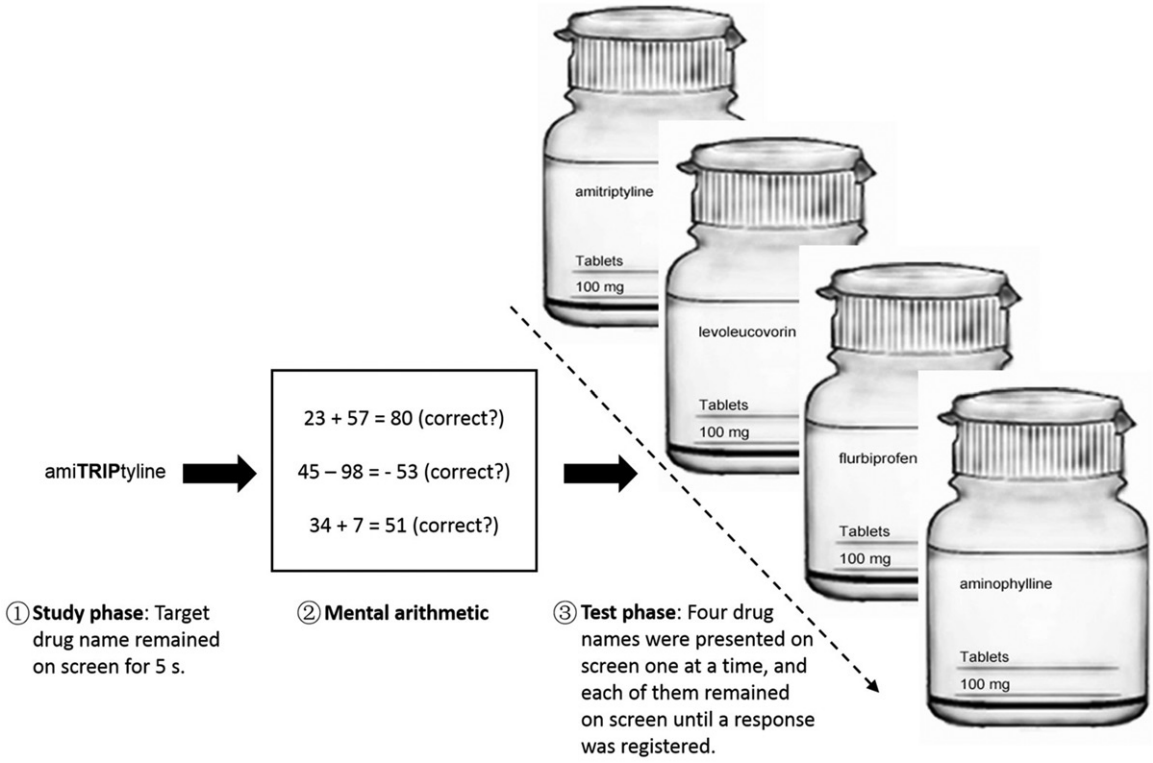

Figure 4. Sequence of the phases for the trials in Experiment 3.

4.1.4. Procedure

Figure 4 illustrates the sequence of the three phases involved in each test trial. First, in the study phase, the participants were presented with a target drug name for 5 s and asked to memorise it for later recognition. Second, they were presented with three arithmetic questions one at a time, asked to check the answers to the questions, and indicate whether the answer provided for each question was correct by pressing either a button labelled 'Yes' or another labelled 'No.' The use of an interrupting arithmetic task was to prevent participants encoding the target drug name into their long-term memory, an issue which would likely lead to ceiling performance in the test phase. Third, the test phase began after the response to the last arithmetic question was given. During the test phase, four mock drug bottles with different drug names, one being the target drug name and the other three being distractor drug names, were presented to the participants one at a time in random order. The participants were instructed to indicate, as quickly and accurately as possible, whether the name presented was the target name by pressing the 'Yes' or 'No' key as appropriate. There were 36 trials in total and their testing order was randomised. A short break was provided after every 12 trials. The experiment took ~40 min to complete.

4.1.5. Data analysis

Data were analysed using a two-way ANOVA followed by post-hoc multiple comparisons performed with Bonferroni adjustments.

4.2. Results

Table 4 presents the means, *SD*s, *F* statistics, significance levels, and partial eta-squared values for each independent variable and interaction term. We report the results for hit rate and correction rejection rate correspondingly.

In terms of hit rate, there was no evidence of a significant difference between disfluent (92.5%) and fluent (90%) formats. Therefore, hypothesis 1 was not supported. The main effect of text enhancement was found to be significant, that lowercase (96.6%) resulted in a significantly higher hit rate than tall man plus boldface (87.2%). However, no evidence of a significant difference was observed between lowercase (96.6%) and inverted text (90.0%) and between a tall man plus boldface (87.2%) and inverted text (90.0%). The interaction between disfluent format and text enhancement (DF × TE) was not statistically significant.

For correct rejection rate, there was no evidence of a significant difference between disfluent (98.8%) and fluent (98.8%) formats. The main effect of text

Table 4. Mean hit rate and correct rejection rate, *SD*, *F* statistic, significance level and partial eta-squared value for each independent variable and interaction term (Experiment 3).

	Mean (%)	*SD*	*F* test and significant level	ηp^2
Hit rate				
Disfluent format (DF)			$F(1, 14) = 0.94$, $p = .35$	
Fluent format	90.0	0.16		.06
Disfluent format	92.5	0.11		
Text enhancement (TE)			$F(2, 28) = 4.52$, $p = .02$*	.24
Lowercase	96.6	0.08		
Tall man plus boldface	87.2	0.16		
Inverted text	90.0	0.14		
DF × TE			$F(2, 28) = 1.13$, $p = .31$	.08
Correct rejection rate				
Disfluent format (DF)			$F(1, 14) = 0$, $p = 1.00$	.00
Fluent format	98.8	0.03		
Disfluent format	98.8	0.02		
Text enhancement (TE)			$F(2, 28) = 0.95$, $p = .40$	.06
Lowercase	98.7	0.03		
Tall man plus boldface	98.3	0.03		
Inverted text	99.3	0.02		
DF × TE			$F(2, 28) = 1.18$, $p = .32$	.08

*Significant at $p < .05$.

enhancement was also not significant, indicating that there was no significant difference between lowercase (98.7%), tall man plus boldface (98.3%), and inverted text (99.3%). The interaction between disfluent format and text enhancement (DF × TE) was not statistically significant.

4.3. Discussion

Compared to the fluent format, the disfluent format did not significantly increase hit rate, indicating that the disfluent format did not make the drug names more memorable. This result may be because the 5-s exposure time was sufficient to enable the nurses to process and memorise the drug names in both fluent and disfluent formats. Another explanation was that the disfluent format used in our study was a minor manipulation of visual acuity which did not result in more attentive or deeper information processing. There was no significant difference in correct rejection rate between the disfluent and fluent formats, indicating that the disfluent format did not affect how the drug names might be confused in memory.

Neither tall man plus boldface nor inverted text increased the hit rate. Instead, the tall man plus boldface resulted in a significantly lower hit rate than lowercase, indicating that tall man plus boldface made the drug names less memorable. The negative effects of tall man plus boldface on memory may be due to the following reasons: in order to make a correct judgement in the test phase, the participants had to process and remember the entire drug name presented in the study phase. However, when the names were processed by using a more top-down approach, enhanced texts may impede the processing of the names due to the artificial dichotomy on the name (Schell 2009). In addition, the tall man lettering changed the overall shape of the words, disrupting visual coding and thus impeding memory (Mayall and Humphreys 1996; Schell 2009). This means that the participants may not have been familiar with the drug names with changed shapes (i.e. in the study phase), and it was, therefore, difficult for them to leverage information when attempting to recognise drug names from a list that did not feature any text enhancement (i.e. in the test phase). In contrast, the inverted text did not result in significantly lower hit rate, most likely because the text enhancement merely highlighted the letters by switching the colour of the font and the background, while retaining the overall shape of the name. Enhanced texts also did not result in significant changes in correct rejection rate, indicating that enhanced texts did not make drug names more confusable in the memory.

5. General discussion

The present study examined how disfluent format, text enhancement, and exposure time affected the accuracy of visual differentiation and recognition memory for look-alike drug names. Inconsistent with the positive effects of disfluent format observed in education contexts, no benefit for the disfluent format was observed in our three experiments (i.e. impairment for Experiment 1 and no effect for Experiments 2 and 3). The negative impact of the disfluent format is likely due to the short exposure time (i.e. 0.7 s in Experiment 1) that did not allow the participants to read the drug names presented in the disfluent format; therefore, they were unable to engage in deeper

processing of the information. However, even when the exposure duration was longer, there was no significant difference between the disfluent and fluent formats in terms of accuracy of visual differentiation and recognition memory. It could be possible that the disfluent format used in this study may be a minor manipulation of visual acuity, only affecting visual perception and not inducing more effortful and deeper information processing.

Consistent with previous studies, using tall man plus boldface and inverted text are effective approaches for improving differentiation accuracy (Or and Wang 2014; Gabriele 2006). The enhanced texts led readers to utilise those letters first when comparing the drug names by increasing the salience of differing letters. Moreover, the text enhancement by exposure time interaction reveals that the enhanced texts were more effective when the drug names were presented for short exposure times, suggesting the utility of using enhanced texts when nurses are working under time pressure. In Experiment 3, overall, drug names using tall man plus boldface and inverted text were not recognised more accurately than names using lowercase. Additionally, as previously discussed, tall man plus boldface even made drug names less memorable, most likely because it changed the overall shape of the name and made it more difficult to be processed.

Our results from Experiments 1 and 2 also indicate that longer exposure times helped individuals discriminate between look-alike drug names. The results, therefore, emphasise that sufficient time for the drug-selection process is always necessary, irrespective of which format is used to present the names.

There were a number of limitations in this study. First, the small sample sizes may have restricted the significance of some of the analyses due to low statistical power. Second, some of the nurses participating in the study did not have rich clinical experience: the mean work experience in nursing was 1.3 years in Experiment 2 and 4.8 years in Experiment 3. Therefore, one should be cautious when generalising the results to the broader population of nurses and pharmacists. In addition, some relevant characteristics were not collected prior to the experiments, such as the participants' level of familiarity with drug names, making it difficult to perform assessments of the specific effects of familiarity with drug names. The inclusion of characteristics like this would add value to analyses in future studies. Third, although the participants' visual acuity was collected through self-reporting, their abilities to perceive contrast and decipher stimulus materials were not assessed. Future studies should devise ways to determine whether participants have the ability to successfully perceive the stimuli, ensuring that the disfluent texts indeed lead to the later stages of information processing. Fourth, the mock drug bottles used in our study contained only drug names and dose information, whereas the drug bottles in actual clinical practice contain other information that may affect drug name differentiation and memory performance. Finally, visual differentiation and memory recognition tasks were used to examine the effects of different presentation formats. However, experimental tasks that are much closer to real practice could be used. For example, a visual search task can be employed to more accurately simulate the drug-selection process by having nurses visually scan the shelves and search for the desired drugs after reading prescriptions. Further studies could consider employing identical presentation formats on the prescriptions and drug packages in the test.

The current results have a number of implications. First, although previous research suggested that disfluent formats improved recognition and retention of learning materials, our study contributes to the drug safety literature that disfluent format had no effect on visual differentiation or memory accuracy for look-alike drug names, and it was even detrimental to visual differentiation when the exposure time was short. Thus, making look-alike drug names disfluent is not a favourable approach. Second, this study offers support for the use of tall man plus boldface and inverted text in drug labelling and packaging because the two text enhancement methods can make look-alike drug names more distinct when compared side by side. Third, longer exposure time can facilitate the processing of look-alike names, particularly when no text enhancement is used. Overall, our study demonstrated presentation strategies that would work for or against look-alike drug names.

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Appendix

Table A1. The 28 drug name pairs used in Experiment 1 and Experiment 2.

The 14 pairs of look-alike drug names by name length and orthographic similarity				
Name length	Orthographic similarity level	Look-alike drug name pair		BI-SIM value
10–14 letters	Low (0.4 < BI-SIM value ≤ 0.5)	Medroxyprogesterone	Methylprednisolone	0.45
		Quetiapine	Olanzapine	0.45
		Levocarnitine	Levetiracetam	0.46
	Medium (0.5 < BI-SIM value ≤ 0.7)	Methyltestosterone	Medroxyprogesterone	0.58
		Lamotrigine	Lamivudine	0.59
		Zolmitriptan	Sumatriptan	0.63
	High (0.7 < BI-SIM value < 1.0)	Chlorpromazine	Chlorpropamide	0.79
		Cycloserine	Cyclosporine	0.83
6–9 letters	Low (0.4 < BI-SIM value ≤ 0.5)	Sinequan	Seroquel	0.44
		Nexium	Nexavar	0.50
	Medium (0.5 < BI-SIM value ≤ 0.7)	Humulin	Humalog	0.64
		Cefotetan	Cefoxitin	0.67
	High (0.7 < BI-SIM value < 1.0)	Oxycodone	Oxycontin	0.72
		Novolog	Novolin	0.79
The 14 drug names used to create the 14 name pairs with two identical drug names Aripiprazole, chlorpromazine, clozapine, docetaxel, duloxetine, klonopin, medroxyprogesterone, methylprednisolone, nexium, nicardipine, novolin, pentobarbital, sumatriptan, and zyrtec				

Table A2. The 36 sets of drug names used in Experiment 3, each containing a target name, a paired similar name, and two dissimilar drug names.

		Look-alike drug name pairs			Dissimilar drug names†	
Length of the target name	Orthographic similarity level	Target name	Paired similar name	BI-SIM value*	Dissimilar drug name 1	Dissimilar drug name 2
10–14 letters	Low (0.4 < BI-SIM value ≤ 0.5)	Fluoxetine	Fluvastatin	0.50	Sorafenib	Risperdal
		Alprostadil	Alprazolam	0.50	Clomiphene	Doxorubicin
		Levocarnitine	Levetiracetam	0.46	Escitalopram	Valacyclovir
		Sandostatin	Sandlmmune	0.45	Ketoprofen	Clomiphene
		Dipyridamole	Disopyramide	0.50	Acetaminophen	Valacyclovir
		Ropinirole	Risperidone	0.45	Hydralazine	Clonazepam
	Medium (0.5 < BI-SIM value ≤ 0.7)	Calcitonin	Calcitriol	0.65	Doxazosin	Buspirone
		Sulfisoxazole	Sulfadiazine	0.54	Carbamazepine	Procyclidine
		Dimenhydrinate	Diphenhydramine	0.67	Betamethasone	Rosiglitazone
		Amitriptyline	Aminophylline	0.54	Levoleucovorin	Flurbiprofen
		Tizanidine	Tiagabine	0.60	Flurastor	Omeprazole
		Ceftazidime	Ceftriaxone	0.55	Noristerat	Amiodarone
	High (0.7 < BI-SIM value < 1.0)	Vinblastine	Vincristine	0.73	Ketoprofen	Hydrogesic
		Acetazolamide	Acetohexamide	0.73	Liothyronine	Mifepristone
		Nimodipine	Nicardipine	0.73	Flumazenil	Glucotrol
		Pentobarbital	Phenobarbital	0.85	Sulfasalazine	Valacyclovir
		Tolazamide	Tolbutamide	0.73	Mdriacyl	Sunitinib
		Cholorpromazine	Chlorpropamide	0.79	Valganciclovir	Betamethasone
6–9 letters	Low (0.4 < BI-SIM value ≤ 0.5)	Cefazolin	Cefotetan	0.50	Mydrilate	Buspirone
		Cordilox	Corguard	0.44	Glipizide	Stelazine
		Nexavar	Nexnum	0.50	Zolpidem	Rifadin
		Inderal	Indocid	0.50	Paroven	Tagamet
		Clonidine	Clonazepam	0.50	Seroquel	Tegretol
		Franol	Frumil	0.42	Zyrtec	Losec
	Medium (0.5 < BI-SIM value ≤ 0.7)	Proscar	Prostrap	0.69	Lamisil	Moditen
		Humulin	Humalog	0.64	Eldepryl	Ponstan
		Buspirone	Bupropion	0.61	Amiloride	Steemetil
		Lorazepam	Loprazolam	0.65	Cefoxitin	Periactin
		Dytide	Dytac	0.67	Lescol	Xatral
		Tramadol	Trazodone	0.61	Clozapine	Wellvone
	High (0.7 < BI-SIM value < 1.0)	Maxedex	Maxtrex	0.72	Piriton	Cytacon
		Persantin	Periactin	0.78	Glyburide	Tamoxifen
		Velosef	Venofer	0.79	Keppra	Oxynorm
		Novolog	Novolin	0.79	Kaletra	Rapitil
		Oxycodone	Oxycontin	0.72	Amiloride	Temazepan
		Ursofalk	Ursogal	0.75	Bupropion	Cefotetan

*The BI-SIM values are for the similarity between the target names and paired similar names.
†The orthographic similarity value between a target drug name and each of its corresponding two dissimilar drug names was below 0.20.