The Effect of Proximity, Tall Man Lettering, and Time Pressure on Accurate Visual Perception of Drug Names

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Objective: The aim of this study is to assess the effect of proximity and time pressure on accurate and effective visual search during medication selection from a computer screen.

Background: The presence of multiple similar objects in proximity to a target object increases the difficulty of a visual search. Visual similarity between drug names can also lead to selection error. The proximity of several similarly named drugs within a visual field could, therefore, adversely affect visual search.

Method: In Study 1, 60 nonpharmacy participants selected a target drug name from an array of mock drug packets shown on a computer screen, where one or four similarly named nontargets might be present. Of the participants, 30 completed the task with a time constraint, and the remainder did not. In Study 2, the same experiment was repeated with 28 pharmacy staff.

Results: In Study 1, the proximity of multiple similarly named nontargets within the specified visual field reduced selection accuracy and increased reaction times in the nonpharmacists. Time constraint also had an adverse effect. In Study 2, the pharmacy participants showed increased reaction times when multiple nontargets were present, but the time constraint had no effect. There was no effect of Tall Man lettering.

Conclusion: The presence of multiple similarly named medications in close proximity to a target medication increases the difficulty of the visual search for the target. Tall Man lettering has no impact on this adverse effect.

Application: The widespread use of the alphabetical system in medication storage increases the risk of proximity-based errors in drug selection.

Keywords: pharmacy, Tall Man, time pressure, proximity, drug name similarity

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INTRODUCTION

Medication error is defined as "a failure in the treatment process that leads to, or has the potential to lead to, harm to the patient" (Aronson, 2009, p. 601). Considerable research on medication error has focused on the provision of an incorrect drug to a patient caused by confusion between orthographically similar drug names (Davis, 1997; Lambert, Chang, & Lin, 2001) or similar drug packaging (Hellier, Edworthy, Derbyshire, & Costello 2006). This type of error could result in a patient's treatment plan being disrupted or patient harm. Such errors are usually reported by health care staff (e.g., anesthetists; Orser, Chen, & Yee, 2001), but patients are equally susceptible to confusing similarly named and packaged products when purchasing medication or recalling the name of their prescribed drugs (Akici et al., 2004; Brass & Weintrub, 2003; Lambert et al., 2001).

Orthographic Similarity, Neighborhood Density, and Proximity

Orthographic similarity denotes words, or in the current case, drug names, that appear visually similar when written. The process of naming a drug is subject to market considerations related to branding, which can result in the development of orthographically similar drug names with very different chemical properties (Kenagy & Stein, 2001). Similarity between two drug names has been shown to adversely affect accurate drug name recognition in computer-based memory tasks (Filik, Purdy, Gale, & Gerrett, 2004, 2006; Lambert et al., 2001) and prospective incident studies (Ashcroft, Quinlan, & Blenkinsopp, 2005).

A word's *neighborhood* is commonly defined as the number of words that are the same length and differ by only one letter from a target word (Lambert, Chang, & Gupta, 2003). *Density* denotes the number of words within that neighborhood. High neighborhood density has been shown to adversely affect pharmacists' ability to recognize blurred drug names (Lambert et al., 2003).

A potential extrapolation of this research is the question of neighborhood density during simultaneous presentation of multiple medication products, such as on a pharmacy shelf or a computer screen. An examination of error rates attributable to the proximity of drug specifications on computer stock lists found that almost half (45%) of wrongly dispensed drugs were in close proximity to the prescribed drug (Anto, Barlow, Oborne, & Whittlesea, 2011). The authors suggest that most errors previously linked to the single factor of orthographic similarity are in fact attributable to a combination of orthographic and proximity error. Furthermore, proximity of similar products on a pharmacy shelf was recently reported as a contributing factor in medication error by the Food and Drug Administration (FDA; Kalvaitis, 2011).

Visual Search and Tall Man Lettering

Linked to the idea of proximity error in drug selection is the accuracy with which health care personnel can engage in a successful visual search resulting in the identification of a required drug within a certain location, such as a pharmacy shelf or from a ward medicine cart. A visual search of an area typically involves the perceptual encoding of a relatively large area, followed by fast eye movements, known as saccades, to direct the focus of attention toward potential target locations (Najemnik & Geisler, 2005; Wolfe, 1994). According to cognitive theories of visual search, increasing the similarity of nontargets to a target object, along with concurrent increases in similarity between nontargets within a visual field, significantly increases the level of search difficulty (Duncan & Humphreys, 1989; Farmer & Taylor, 1980; Treisman, 1982). In these conditions, visual search is improved through the cognitive enhancement of relevant stimulus properties (e.g., the initial letter in the target drug name) and the suppression of features not associated with the target, so-called feature-based processing (Maunsell & Treue, 2006).

Linked to the idea of feature-based processing is the ergonomic design of drug packaging to improve the accurate perception of drug names (Hellier et al., 2006). Previous research has focused on the use of color (Filik et al., 2006; Hellier, Tucker, Kenny, Rowntree, & Edworthy, 2010) and textual enhancements, such as Tall Man lettering (Darker, Gerrett, Filik, Purdy, & Gale, 2011; Filik et al., 2004; Gabriele, 2006; Schell, 2009) to improve perception. Tall Man lettering is used to highlight the differences between orthographically similar names by emphasizing the dissimilar areas (e.g., AmILORide and AmiSULPride; Darker et al., 2011; Schell, 2009). By highlighting the area where the drug names differ, the lettering draws the perceiver's attention to the relevant section of the drug name, increasing the perceptual salience of that area (Maunsell & Treue, 2006; Schell, 2009). According to the bottom-up approach to word perception (McClelland & Rumelhart, 1981), whereby words are perceived on a letter-by-letter basis, the use of capital letters provides an additional aspect of information (case) that should increase the accuracy of word perception (McClelland & Rummelheart, 1981; Schell, 2009). On this basis, Tall Man lettering has been recommended by the FDA (2001) as a method for reducing dispensing errors.

Previous research has shown a positive effect of Tall Man lettering on perception of drug names during a visual search task (Filik et al., 2004) and a memory task (Filik et al., 2006) with laypeople and the Reicher-Wheeler task with health care professionals (Darker et al., 2011). However, research involving a recognition task with both laypeople and health care professionals showed no effect of Tall Man lettering on accurate recognition of target drug names (Schell, 2009). Furthermore, to date, Tall Man lettering has been examined in relation to drug name *pairs*, without consideration of the potential influence of the presence of multiple similar drug names in the vicinity of a target.

Time Pressure

Modern theories of the underlying causes of adverse events in health care indicate that typically, a series of latent and error-producing conditions combine to produce errors (Reason, 2001). The dispensing process is subject to a variety of potentially error-producing conditions (Vincent, 2003), including high workload and noise (Flynn et al., 1996, 1999).

A typical manipulation for an error-producing condition, in terms of laboratory studies, is workload, often measured through the application of a time constraint (Reilly, Grasha, & Schafer, 2002; Schell & Grasha, 2000). Time pressure is manipulated by requiring participants to complete a task within a defined time period (Pontibriand, Allender, & Doyle, 2008). This use of a time constraint has been shown to have an adverse impact on cognitive task performance (Rastegary & Landy, 1993; Slobounov, Fukada, Simon, Rearick, & Ray, 2000). In health care, high workload has been linked to declines in pharmacist checking accuracy and a decrease in visual fixations on a task and checking procedures (Kataoka, Sasaki, & Kanda, 2011; Reilly et al., 2002).

Study Aims

In the current study, we aimed to examine the effect of proximity, Tall Man lettering, and time pressure on the perception of drug names in a visual search task. The main aim was to determine the relative influence of the close proximity of a single similarly named distractor or multiple distractors on the time taken to search and select a target drug accurately from a defined visual field.

A visual search paradigm similar to that used by Filik and colleagues (2004) was employed. A computer controlled the conditions in which the task was taken and monitored behavior across multiple matched trials. A priori, the expectation was that the presence of multiple similarly named and packaged drugs would have an adverse effect on the difficulty of visual search for a target, with measurable associated detriments in accuracy and reaction time.

Since drug name similarity can potentially affect patients and health care staff, we decided that both laypeople and health care professionals would be recruited to take part in this study. Although it is likely that the majority of the drug names used would be unfamiliar to the lay participants, the basis of the task, that is, visual search, word perception, and recall, meant that medical expertise was not required to complete the task successfully.

Although both groups of participants in the present study were expected to complete the task successfully, it was uncertain as to whether the health care professionals might outperform the lay participant group. Past research indicates that orthographical similarity of drug names has an effect on both novice and expert participants (Lambert et al., 2001), yet the perception of drug names by experts is likely to be mediated by their experience, as indicated by the impact of prescription frequency on the perception of blurred drug names (Lambert et al., 2003). Recruiting both expert and novice participants made it possible within the current study to examine the potential impact of proximity, Tall Man lettering, and time constraint on the perception of drug names by both laypeople and health care professionals.

STUDY 1

Study 1 focused on the influence of close proximity of multiple similarly named medication packets and time pressure on target selection accuracy and reaction time in novice (nonpharmacist) participants.

Method

Design. The number of similar nontargets present within the defined perceptual array was either one or four. The number of similar distractors in proximity to the target was expected to have a direct bearing on task performance, with four nontargets associated with decreased accuracy and increased reaction times. We included the use of Tall Man lettering to determine the effectiveness of textual enhancements where more than one similar nontarget was present. Finally, the between-groups factor was time constraint, with a time limit of 12 min applied to half of the participants. The time limit of 12 min was selected because during the pilot stage of the study, this time was the fastest recorded for completion of the task, with the majority of participants completing the task in 15 min or more.

Participants. A total of 60 nonpharmacist participants were recruited (49 female, 11 male), ages between 18 and 45 years (mean age = 22). All of the participants were students or staff members from the University of Aberdeen. Students participated for course credit; staff members did not receive any compensation for their time. Half of the participants (30) completed the study with no time constraint (Group 1). The remainder (30) attempted to complete the study within 12 min (Group 2). All participants were randomly allocated to each group.

Stimuli. Target drug names (n = 50) were selected from the National Pharmacy Association (NPA; 2006) published list of confusable drug names. These names were combined with orthographically similar drug names to form 50 orthographically similar drug name pairs and 50 sets of five orthographically similar drug names. Similarity was confirmed with use of the bigram method, with one space inserted at the beginning and end of each word (Lambert et al., 2001). With this method, one essentially compares words on the number of matching letter pairs found within each word with use of the Dice coefficient ($2C/[B + A]$, whereby A = the number of bigrams in the first word, B = the number of bigrams in the second, and C = the number of bigrams in both), which is then used to compute a similarity score of between 1 and 0. Similarity levels for the drug names selected for use varied between 0.1 and 0.9, with 0.9 representing the highest level of similarity (see appendix).

Similar to the methodology described by Filik and colleagues (2004), images of identical 3-D boxes, designed to present some of the information commonly found on drug packs, were constructed to display on a computer screen. Each box featured the name of the drug (in 12-point Arial font) in lowercase or featuring Tall Man lettering, depending on the condition; an appropriate dosage level (with the caveat that the dosage level for the target matched that of the nontargets); and a red-and-yellow-colored strip across the center (Figure 1).

Each participant completed 100 trials, whereby each trial featured a perceptual array that consisted of 20 3-D boxes arranged as four rows, each row featuring five packs. Presentation of the trials was randomized across participants. The trials were split into two groups. In Condition A, 50 trials each featured 1 target, 4 nontargets that were orthographically similar to the target, and 15 nontargets that had been screened to ensure they were dissimilar to the target with the use of the bigram method (a similarity level of 0.1 or below was considered acceptable for inclusion in the array). The remaining 50 trials (Condition B) each featured 1 target, 1 orthographically similar nontarget, and 18 dissimilar nontargets. We balanced the sets by ensuring that the similarity levels recorded for the target drug names and their similar counterparts were equally spread between the two sets (see appendix). Presentation of the drug names and position of the target within the array were randomized between trials and across participants.

Finally, each set featured one final variable: alteration of the typeface with the use of Tall Man lettering. In each set, half of the trials (25) featured 20 drug packs all with lowercase text used for presentation of the medication names. The remaining 25 trials featured Tall Man lettering as a textual enhancement of drug names whereby the dissimilar section of the names was highlighted, for example, AmOXIcillin versus AmPICillin.

Procedure. Participants were seated within a quiet room, directly in front of a Toshiba Satellite Pro widescreen (15.6-in.) laptop. They were instructed that they would be presented with a series of target drug names, with each trial featuring a different drug name as a target. Their task was to view the target drug name, presented as text in the center of the screen; memorize it; and then locate it within the perceptual array. Presentation of the target was followed by a fixation point for 1.5 s before the perceptual array was shown. When participants located the target within the perceptual array, they clicked on the box containing the target and then proceeded to the next trial.

Group 2 was given additional instructions relating to time constraint. A digital clock was visible at the top of the laptop screen. The clock counted down from 12 min, flashing red when 30 s remained and becoming enclosed in a flashing red box when the participant exceeded the allotted time frame. Participants were instructed to attempt to complete the task within 12 min, but if they exceeded the allotted time,

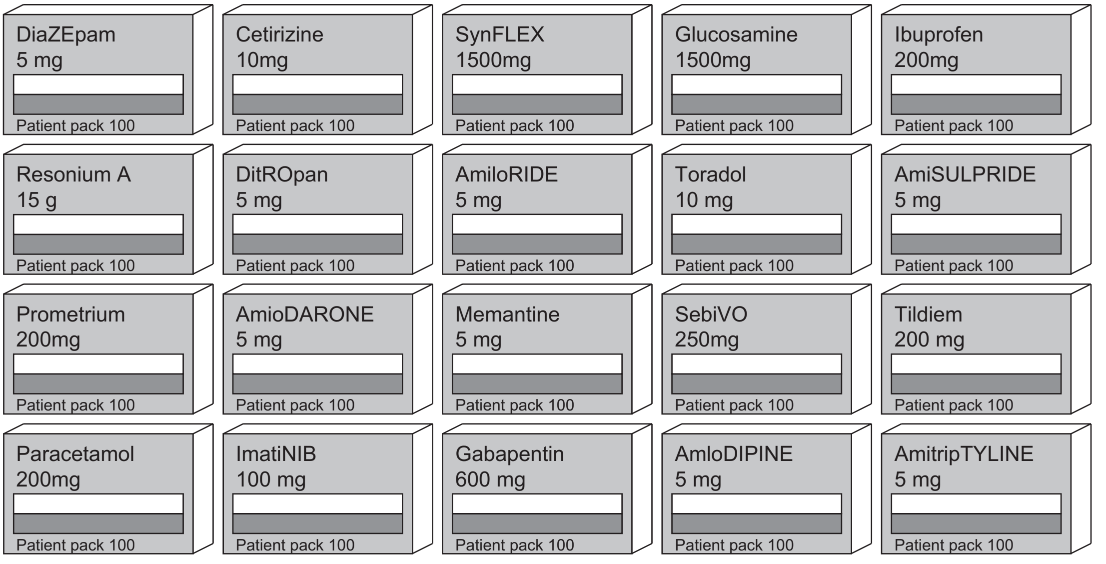

Figure 1. Example of perceptual array in which the target is Amiloride and the four nontargets are Amiodarone, Amisulpride, Amlodipine, and Amitriptyline.

they were instructed to continue to completion. This procedure ensured that data from 100 trials were collected for every participant.

Participants were allocated to each condition randomly.

Analysis framework. We conducted an analysis to determine the effect of the number of similar nontargets, Tall Man lettering, and time pressure on performance using measures of reaction time and accuracy. Accuracy represents the number of drug names correctly identified within each set (Condition A, four nontargets, or Condition B, one nontarget, present in array) of 50 trials. Reaction times were recorded in seconds for the time taken for each participant to select and click on his or her chosen mock drug packet from the visual array, with mean reaction times calculated for each condition (50 trials). Within each set of 50 trials, 25 trials featured Tall Man lettering.

We conducted the analysis using both MANOVA and univariate repeated-measures ANOVA. An initial MANOVA examined both accuracy and reaction time as dependent variables, time pressure as the between-subjects variable, and number of nontargets and Tall Man lettering as within-subjects variables. This analysis was followed by univariate analysis with two three-factor mixed-factorial ANOVAs with time pressure as the between-subjects factor and number of similar nontargets and Tall Man lettering as the within-subjects factors for each of the two dependent variables (reaction time and accuracy). We calculated partial eta squared (η_p^2) to measure effect size (.01, .06, and .14 indicating small, medium, and large effect sizes, respectively; Filik et al., 2006).

The results of this experiment are presented with $\alpha = .05$ for significance.

Results

Preliminary analysis suggested that the number of similar nontargets present in the array, together with time pressure, had an impact on both accuracy and reaction times (Table 1).

A repeated-measures MANOVA revealed a significant multivariate effect for time pressure, $F(2, 57) = 7.31$, $p = .001$, $\eta_p^2 = .20$, and number of nontargets, $F(2, 57) = 16.51$, $p = .001$, $\eta_p^2 = .37$. There was no multivariate effect for Tall Man lettering ($p = .48$), nor were there any significant interactions between the factors ($p > .05$).

A repeated-measures ANOVA revealed a significant univariate effect for the impact of number of nontargets on participant reaction time, whereby participants were significantly slower at making

TABLE 1: Mean Accuracy and Reaction Times by Presence or Absence of Tall Man Lettering, Number of Similar Nontargets Shown in Array, and Time Pressure for Nonpharmacist and Pharmacist Participants

Group	Tall Man Lettering	Lowercase Lettering	Four Similar Nontargets	One Similar Nontarget
Nonpharmacist participants (Study 1)				
Accuracy (number of items correctly selected)				
No time pressure	49.3 (1.1)	49.5 (0.9)	49.1 (1.6)	49.7 (0.6)
Time pressure	48.0 (2.4)	48.1 (2.7)	47.4 (3.8)	48.8 (1.3)
Both groups combined	48.7 (1.9)	48.8 (2.1)	48.2 (3.1)	49.2 (1.1)
Reaction time (seconds)				
No time pressure	9.4 (1.7)	9.1 (1.8)	9.7 (1.8)	8.8 (1.6)
Time pressure	8.6 (1.7)	8.6 (1.4)	8.9 (1.8)	8.2 (1.2)
Both groups combined	8.9 (1.7)	8.9 (1.6)	9.3 (1.9)	8.5 (1.5)
Pharmacist participants (Study 2)				
Accuracy (number of items correctly selected)				
No time pressure	49.7 (0.6)	49.6 (0.9)	49.6 (0.9)	49.7 (0.6)
Time pressure	49.6 (0.5)	49.3 (0.8)	49.2 (0.9)	49.7 (0.5)
Both groups combined	49.7 (0.6)	49.4 (0.9)	49.4 (0.9)	49.7 (0.5)
Reaction time (seconds)				
No time pressure	10.2 (3.3)	9.8 (2.9)	10.3 (3.1)	9.7 (3)
Time pressure	8.7 (1.7)	8.4 (1.8)	8.7 (1.7)	8.4 (1.7)
Both groups combined	9.4 (2.6)	9.1 (2.5)	9.5 (2.6)	9 (2.5)

Note. Standard deviations shown in parentheses.

their selection when multiple similar nontargets were present ($M = 8.9$ s) than when a single similar nontarget was present ($M = 8.2$ s), $F(1, 58) = 26.6$, $p = .001$, $\eta_p^2 = .31$. However, the mean reaction times did not differ according to time pressure ($p = .1$) or Tall Man lettering ($p = .5$). There were no significant interactions ($p > .05$).

In the second univariate ANOVA analysis, we considered the impact of time pressure, number of nontargets, and Tall Man lettering on accuracy. The results indicate that the number of nontargets present in the perceptual array had a significant effect on accuracy, whereby participants were significantly less accurate when multiple similar nontargets were present ($M = 48.2$) rather than a single similar nontarget ($M = 49.2$), $F(1, 58) = 11.97$, $p = .001$, $\eta_p^2 = .17$.

Time pressure was also found to have an effect, with participants in the time pressure condition ($M = 48.1$) significantly less accurate than participants who completed the task with no time pressure ($M = 49.4$), $F(1, 58) = 7.24$, $p = .09$, $\eta_p^2 = .11$. There was no effect of Tall Man lettering ($p = .4$). There were no significant interactions between factors ($p > .05$).

The total number of errors reported was 128 across all 60 participants (2.1% overall error rate). These errors were spread across multiple participants, with no single participant responsible for more than 6 errors. Of these events, 78% ($n = 100$) involved similar drug names and 22% ($n = 28$) involved nonsimilar drug names. When a nonsimilar drug name was selected, the majority (80%, $n = 22$) were selected within the time pressure condition.

Within the time pressure condition, the results indicate that 83% ($n = 25$) of the participants in that condition exceeded the time limit of 12 min. The majority (72%, n = 18) completed the task within 15 min; the remainder took between 16 and 22 min.

Discussion

These findings indicate that the presence of four nontargets in a defined visual field had an adverse effect on drug selection accuracy in nonpharmacist participants. The results also indicate an adverse impact of the proximity of four similar nontargets on reaction time, which serves as an indication of speed of processing (Jensen, 2006). Thus, as expected, processing efficiency, or the level of effort required to engage in a timely and successful visual search of a specified perceptual field, was greater when the number of similar nontargets within that field was increased. This finding concurs with previous research indicating the adverse effect of orthographic similarity (Filik et al., 2004) and proximity (Anto et al., 2011) on selection error. The adverse impact of time pressure on accuracy indicates that working with a time limit increased the likelihood of participant error. Finally, Tall Man lettering had no effect on error rate or reaction time, indicating that Tall Man lettering as a form of textual enhancement was insufficient to reduce the difficulty of a visual search in the current experiment.

STUDY 2

Study 2 focused on the influence of close proximity of multiple similarly named medication packets and time pressure on target selection accuracy and reaction time in pharmacists.

Method

Design. The aim of this study was to replicate the methods of Study 1 with health care professionals (pharmacy staff) to assess the impact of proximity, Tall Man lettering, and time pressure on accurate selection of drug names in those professionals.

Participants. A total of 26 pharmacists and 2 pharmacy technicians (26 female, 2 male), ages between 25 and 46 years (mean age = 30), were recruited. All participants were recruited from community pharmacies across a single Scottish health board through an e-mail recruitment letter, with a prize draw offered as an incentive for participation. Letters were sent to 120 participants, and 28 were recruited (23% recruitment rate). Of those participants, 14 were asked to complete the study with no time constraint (Group 1), and the remaining 14 were asked to complete the study within 12 min (Group 2).

Stimuli. The stimuli used in Study 2 were exactly as described for Study 1.

Procedure. The same procedure was used as for Study 1. However, the location in which the experiment was conducted differed, as in each case the researcher traveled to the pharmacy location of each participant.

Analysis framework. In an initial MANOVA, we examined both accuracy and reaction time as dependent variables, time pressure as the between-subjects variable, and number of nontargets and Tall Man lettering as within-subjects variables.

This analysis was followed by a three-factor mixed-factorial univariate ANOVA with reaction time as the dependent variable, time pressure as the between-subjects factor, and number of similar nontargets and Tall Man lettering as the within-subjects factors (see Filik et al., 2004, 2006, for a similar analysis).

We evaluated accuracy by comparing the number of drug names correctly selected across 50 trials in each of the conditions using a second mixed-factor univariate ANOVA with time pressure as the between-subjects factor and number of similar nontargets and Tall Man lettering as the within-subjects factors.

The results of this experiment are presented with $\alpha = .05$ for significance.

Results

A repeated-measures MANOVA revealed a significant multivariate effect for number of nontargets, $F(2, 25) = 4.82$, $p = .02$, $\eta_p^2 = .28$, and Tall Man lettering, $F(2, 25) = 3.62$, $p = .04$, $\eta_p^2 = .23$. There was no multivariate effect for time pressure ($p = .27$), nor were there any significant interactions between the factors ($p > .05$).

A repeated-measures ANOVA revealed a significant univariate effect for the impact of number of nontargets on reaction time, whereby participants were slower to select the target when four similar nontargets were present (M = 9.5 s) as opposed to only one similar nontarget present (M = 9 s), $F(1, 26) = 6.19$, $p = .02$, $\eta_p^2 = .19$. Tall Man lettering did not exert a significant effect (p = .07). Time pressure also had no effect on the results (p = .1). There was no significant interaction between the factors ($p > .05$).

In terms of accuracy, a repeated-measures ANOVA revealed a significant univariate effect for number of nontargets, whereby the mean level of accuracy shown when four similar nontargets were present (M = 49.4) was significantly lower than the level of accuracy achieved when only a single similar nontarget was present (M = 49.7), $F(1, 26) = 4.37$, $p = .05$, $\eta_p^2 = .14$. Tall Man lettering had no effect (p = .1). There was also no effect of time pressure (p = .5) and no significant interaction between the factors ($p > .05$).

In total, 25 errors were recorded for the 28 pharmacist participants (0.9% overall error rate). These errors were spread across multiple participants, with no single participant responsible for more than 4 errors. The majority of the errors reported (84%, n = 21) involved the inaccurate selection of a similar nontarget from within the array. In four cases (16%), nonsimilar nontargets were selected, two from within the time pressure condition.

Within the time pressure condition, the results indicate that 50% (n = 14) of the participants in that condition exceeded the time limit of 12 min. The majority (57%, n = 8) completed the task within 14 min; the remainder took between 16 and 20 min.

Discussion

The pharmacists showed a similar pattern of performance to the nonpharmacist participants, whereby four similar nontargets within the perceptual array were associated with an increase in reaction times and a decrease in accuracy. This finding provides validation that multiple similarly named drug packs in proximity to a target drug pack increases the difficulty of a visual search. The lack of an effect of time pressure indicates that working with a time constraint did not affect the selection of drug names from the computer screen by the pharmacy participants. Finally, multivariate analysis indicated a significant impact of Tall Man lettering on the results; however, separate univariate ANOVAs on the dependent variables indicated nonsignificant effects on reaction time and accuracy. Overall, this finding indicates that Tall Man lettering as a form of textual enhancement can affect perception of drug names in pharmacist participants but not simply in terms of measured reaction times or accuracy.

GENERAL DISCUSSION

Study Limitations

It should be noted that similarity between drug products includes, but is not limited to, drug name similarity. There may also be similarities in terms of packaging appearance, and similarly named drugs may also have similar strengths and indications (Filik et al., 2006). In addition to time pressure, other situational forces may influence the accuracy with which individuals select drug products, including lighting levels (Buchanan, Barker, Gibson, Jiang, & Pearson, 1991) and distractions (Flynn et al., 1996). In the current experiments, we aimed to assess the impact of the proximity of multiple similar drug names in controlled conditions, with Tall Man lettering and time pressure the only additional factors included in the analysis. It should be noted that factors other than those assessed in our experiments may function as contributory factors to error in situations outside these study conditions.

It is also possible that the frequency with which medications are dispensed may have affected the results for the pharmacy participants (Lambert et al., 2001). However, the study was not designed to take frequency into account, and so we could not scrutinize the data for such an effect. Finally, limited statistical power given the relatively modest sample size in the two studies (total N = 88) may have restricted the significance of some of the analysis conducted. A post hoc power analysis conducted with the use of G*Power revealed that on the basis of the within-group comparison effect size observed in Study 1 (0.3), a sample size of approximately 80 would be required to obtain the statistical power at the recommended .80 level (Cohen, 1988). On the basis of the within-group comparison effect size in Study 2 (0.2), a sample size of approximately

176 would be required to obtain the recommended power level.

Proximity Error

The current study extends the evidence for orthographic similarity effects (Filik et al. 2006; Lambert et al., 2001, 2003) with the finding that the number of orthographically similar nontargets in close proximity to a target drug name has an adverse effect on selection accuracy and reaction times in both nonpharmacists and pharmacists. This finding indicates that the task of selecting a target drug name from within a perceptual array increases in difficulty as the number of similarly named nontargets is increased within a specified visual field. This finding provides further empirical evidence for the suggestion that similarity between drug names, as a measure of edit distance (describing orthographic and dosage similarities), typically interacts with proximity effects to produce errors in the visual perception of drug names (Anto et al., 2011; Varadarajan, Barker, Flynn, & Thomas, 2008).

Interestingly, the issue of proximity-related error is not mediated by experience, as both the pharmacy professionals and the novice participants were adversely affected by the presence of four similar nontargets. This finding concurs with the prior findings of Lambert et al. (2001) whereby pharmacy participants were found to be generally more accurate at recalling drug names than were student participants, but both groups were adversely affected by drug name similarity.

Time Pressure

Previous behavioral research has shown that both real (Cella, Dymond, Cooper, & Turnbull, 2007) and perceived (DeDonno & Demaree, 2008) time pressure has an adverse effect on task performance. Within the current study, participants were made very aware of time pressure because of the visual cue of the countdown clock. The clock may have accentuated the effect of the time constraint on the nonpharmacists, perhaps contributing to the significant effect of time pressure, compared with the previously reported null effect (Schell & Grasha, 2000).

The impact of time pressure on performance appears to be mediated by experience, since in the current study the pharmacy staff were unaffected by the use of a time constraint. The reason for this null effect is outside the scope of the current article; however, it is possible that the experience of pharmacy staff with high workloads (Peterson, Wu, & Bergin, 1999) may have led to their developing coping strategies for time constraints. Alternatively, it is possible that the time constraint applied was insufficient to hurry the pharmacy participants and thus had no impact on accuracy or reaction time. In the future, researchers could use the NASA Task Load Index (Hart & Staveland, 1988) as a measure of perceived workload to ascertain the impact of time pressure.

Tall Man Lettering

The null univariate result for Tall Man lettering in the current study contradicts several studies that report a positive impact of Tall Man lettering on drug name perception (Darker et al., 2011; Filik et al., 2004, 2006). However, it should be noted that in much of the earlier research (Filik et al., 2004, 2006), the authors highlighted the purpose of the Tall Man lettering, potentially increasing its effect. Furthermore, the most recent study of Tall Man lettering (Darker et al., 2011) indicates that the perceptual advantage associated with Tall Man lettering was also apparent when the drug names were entirely capitalized (Darker et al., 2011). This finding indicates that it may not be the accentuation of the dissimilar areas of drug names that improves perception but rather that capital letters are easier to perceive than lowercase letters.

Research suggests that contrary to the proposal that Tall Man lettering improves word perception, "case mixing," whereby the case of lettering is mixed throughout a word, can actually disrupt perception (Mayall & Humphreys, 1996). This possibility has been found to be the case for word naming (Mayall & Humphreys, 1996) and lexical decision making (Besner & McCann, 1987), and it is generally considered that case mixing disrupts the visual codes that are used in word recognition (Mayall, 2002). Certainly, in the current study, the reaction times of the pharmacy participants (Study 2) indicate that the presence of Tall Man lettering slowed reaction times without any associated increase in accuracy (Table 1). It is important that guidelines for the appropriate use of Tall Man lettering be developed before applying textual enhancements to a wide range of medications (Emmerton & Rizk, 2012). Guideline development is particularly important when considering the positioning of the Tall Man lettering; at present, the use of Tall Man lettering is based on the orthographic similarity of drug names, with the dissimilar areas highlighted (Darker et al., 2011). However, research indicates that phonological similarity (how a word sounds) can influence the accurate recall of drug names (Lambert et al., 2001). It is possible that positioning Tall Man lettering to reflect phonetic rather than orthographic similarity may be more beneficial.

Finally, cognitive theory indicates that similarity between a target and a nontarget within a specified visual field increases the chance of selection error (Duncan & Humphreys, 1989; Farmer & Taylor, 1980). Tall Man lettering appears to be insufficient to reduce the level of difficulty associated with a visual search of an area containing multiple similarly named and packaged drug products.

Strategies to Reduce Error

Previous research indicates that the configuration of automated medication-dispensing drawers can have a direct impact on the likelihood that lookalike drugs will be confused. The reconfiguration of these drawers to ensure that no similar drugs were located in proximity to one another resulted in the prevention of similar drug errors across an observed 2-year period (Cooper, Barron, Gallagher, & Sciarra, 2007). Alternatively, methods to avoid the impact of proximity errors might include the use of a pharmacy robot for selection (Franklin, O'Grady, Voncina, Popoola, & Jacklin, 2008) or the use of bar code technology (Poon et al., 2006). However, further research with professional health care participants, such as pharmacists, is required to provide the necessary evidence for practical modifications to the workplace (Darker et al., 2011). The importance of involving professional participants is highlighted in past research in which the identification of drug names by pharmacists indicates the presence of an internal lexicon specific to medication (Darker et al., 2011; Lambert et al., 2003).

CONCLUSION

Similarity between drug names has previously been shown to increase the risk of drug selection error (Lambert et al., 2003). The studies reported in this article indicate that the proximity of several similarly named drug products has an adverse impact on selection error within a specified visual field (Wolfe, 1994). Unlike in previous research (Filik et al., 2006), Tall Man lettering was found to have no positive effect on the current results. Moreover, in the case of the professional participants, Tall Man lettering was found to have an adverse effect on reaction times, with no associated improvement in performance. This finding illustrates the requirement for further research on textual enhancement as an error-reducing strategy. Overall, pharmacy staff were generally more accurate in the task than were the nonpharmacist participants, indicating a mediating effect of experience on drug name perception.

APPENDIX

TABLE A1: Dice Coefficient Levels for Drug Names in Conditions A and B

Condition A (Four Similar Nontargets)			Condition B (One Similar Nontarget)		
Target	Similar Nontargets	Dice Coefficient	Target	Similar Nontarget	Dice Coefficient
QuiNIDine	QuiNINe	.9 (.6)	Burinex A	Burinex K	.9
Isotrex	Isotrexin	.9 (.5)	Escitalopram	Citalopram	.9
ProMAZine	ProMETHazine	.8 (.5)	FoLIC acid	FoliNIC acid	.9
Imipramine	Trimipramine	.8 (.5)	Rosiglitazone	Pioglitazone	.7
InDERal	InDOCid	.7 (.6)	CLotrimazole	CO-trimoxazole	.7
Lodine	Iodine	.7 (.4)	Ketoprofen	Ketoifen	.7
HydrALAzine	HydrOXYzine	.7 (.5)	LEVofloxacin	CIProfloxacin	.7
Amoxicillin	Ampicillin	.6 (.5)	Nicardipine	Nifedipine	.7
AmiTRIPtyline	AmiNOPHylline	.6 (.4)	CorDARone	CorTISone	.6
Lamictal	Lamisil	.6 (.4)	Cytacon	Cytamen	.6
CalcitoNIN	CalcitrIOL	.6 (.5)	APResoline	ISOprenaline	.6
Co-codamol	Co-proxamol	.6 (.4)	Desferal	Deseril	.6
CefOTAxime	CefUROxime	.6 (.4)	UrsoFALK	UrsoGAL	.6
Deseril	Desferal	.6 (.5)	Slow potassium	Slow sodium	.6
ErgoMETrine	ErgoTAMine	.6 (.5)	PerSANtin	PerIACtin	.6
Eldepryl	Enalapril	.6 (.6)	Irbesartan	Eprosartan	.6
LoraZEPam	LopraZOLam	.6 (.5)	MaxIDEx	MaxTREx	.6
Metronidazole	Mebendazole	.6 (.4)	Mebendazole	Metronidazole	.6
ModITen	ModUCren	.6 (.4)	CloBAzam	CloNAzepam	.6
Periactin	Persantin	.6 (.5)	Microgynon	Micronor	.6
PapavereTUM	PapaverINE	.6 (.5)	PRIadel	PARlodel	.5
Beclometasone	Betamethasone	.6 (.4)	Ritalin	Rifadin	.5
MydriaCYL	MydrilATE	.5 (.4)	DytAC	DytIDE	.5
Carbamazepine	Carbimazole	.5 (.4)	Viraferon	Interferon	.5
FemoDENE	FemoSTON	.5 (.3)	XATral	XYZal	.5
Lamivudine	Lamotrigine	.5 (.5)	Prochlorperazine	Procyclidine	.5
DoxaZOSin	DoxoRUBicin	.5 (.4)	BuPROpion	BuSPIrone	.5
Marcain	Marevan	.5 (.5)	Sertraline	Sertindole	.5
ProsCAR	ProstRAP	.5 (.4)	RapiFEN	RapiTIL	.5
Noristerat	Noritate	.5 (.4)	Glibenclamide	Glimepiride	.5
RifaDIN	RifiNAH	.5 (.3)	SineqUAN	SineMET	.5
Terbinafine	Tetrabenazine	.5 (.5)	Flurbiprofen	Fenoprofen	.5
CLOMipramine	CHLOrpromazine	.4 (.4)	WellDORm	WellVONe	.4
Kaletra	Keppra	.4 (.4)	Oxymycin	Oxynorm	.4
NeostigmINE	NeotigaSON	.4 (.3)	CIMetidine	AMAntadine	.4
Niacin	Minocin	.4 (.4)	Minocin	Mianserin	.4
FrANol	FrUMil	.4 (.4)	TraMAdol	TraZOdone	.4
Cardene	Codeine	.4 (.3)	Fluoxetine	Fluvastatin	.4

(continued)

APPENDIX (continued)

Condition A (Four Similar Nontargets)			Condition B (One Similar Nontarget)		
Target	Similar Nontargets	Dice Coefficient	Target	Similar Nontarget	Dice Coefficient
AmiloRIDE	AmioDARONE	.4 (.4)	RetROvir	RitoNAvir	.4
Alprostadil	Alprazolam	.4 (.4)	Amaryl	Reminyl	.3
SandoSTAtin	SanoMIGran	.4 (.3)	OTex	OVex	.3
Piriton	Ponstan	.3 (.3)	Amaryl	Amias	.3
ZolpiDEM	ZopiclONE	.3 (.3)	ISOprenaline	APResoline	.3
Baclofen	Buscopan	.3 (.3)	Ponstan	Paroven	.3
DipryiDAMOLe	DisopyRAMIDe	.3 (.3)	VeloSEF	VenoFER	.3
Stelazine	Stemetil	.3 (.4)	Diazepam	Ditropan	.3
CorDILOX	CorGUARD	.3 (.3)	REMinyl	AMAryl	.3
Tamoxifen	Temazepan	.2 (.2)	Resperidone	Prednisolone	.2
LasIX	LosEC	.2 (.2)	LOsec	LEscol	.2
Tagamet	Tegretol	.1 (.2)	Nitrazepam	Mirtazapine	.1

Note. For Condition A, the average Dice coefficient level for the remaining three drug names is indicated in parentheses.

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KEY POINTS

- In this study, we examined three factors that might influence accurate perception of drug names: proximity of multiple similarly named drug products, Tall Man lettering, and time pressure.
- Proximity, manipulated through control of the number of similar drug names present within the same visual field as a target drug name, was shown to have an adverse effect on both accuracy in the selection of a target drug name from a computer screen and reaction times in nonpharmacists and pharmacy staff.
- Time pressure was shown to have an adverse effect on drug name perception in nonpharmacists only.
- The results suggest that Tall Man lettering may not be effective as an error-reducing strategy, particularly when multiple similar drug names are in close proximity to a target, particularly in nonpharmacist participants. Further research is required to assess the usefulness of Tall Man lettering in health care.

REFERENCES

Akici, A., Kalaca, S., Umit Ugurlu, M., Toklu, H. Z., Iskender, E., & Oktay, S. (2004). Patient knowledge about drugs prescribed at primary care facilities. *Pharmacoepidemiology and Drug Safety, 13*, 871–876.

Anto, B., Barlow, D., Oborne, A. C., & Whittlesea, C. (2011). Incorrect drug selection at the point of dispensing: A study of potential predisposing factors. *International Journal of Pharmacy Practice, 19*, 51–60.

Aronson, J. K. (2009). Medication errors: Definitions and classification. *British Journal of Clinical Pharmacology, 67*, 599–604.

Ashcroft, D. M., Quinlan, P., & Blenkinsopp, A. (2005). Prospective study of the incidence, nature and causes of dispensing errors in community pharmacies. *Pharmacoepidemiology and Drug Safety, 14*, 327–332.

Besner, D., & McCann, R. S. (1987). Word frequency and pattern distortion in visual word identification and production: An examination of four classes of models. In M. Coltheart (Ed.), *Attention and performance XII* (pp. 201–219). Hove, UK: Lawrence Erlbaum.

Brass, E. P., & Weintrub, M. (2003). Label development and label comprehension study for over-the-counter drugs. *Clinical Pharmacology and Therapeutics, 74*, 406–412.

Buchanan, T. L., Barker, K. N., Gibson, J. T., Jiang, B. C., & Pearson, R. E. (1991). Illumination and errors in dispensing. *American Journal of Hospital Pharmacy, 48*, 2137–2145.

Cella, M., Dymond, S., Cooper, A., & Turnbull, O. (2007). Effects of decision-phase time constraints on emotion based learning in the Iowa Gambling Task. *Brain and Cognition, 64*, 164–169.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Lawrence Erlbaum.

Cooper, L., Barron, M., Gallagher, C., & Sciarra, J. (2007). Automated anaesthesia medication dispensing systems: Single-issue, limited-access drawers may reduce medication errors. *European Journal of Anaesthesiology, 24*, 190–191.

Darker, I. T., Gerret, D., Filik, R., Purdy, K. J., & Gale, A. G. (2011). The influence of "Tall Man" lettering on errors of visual perception in the recognition of written drug names. *Ergonomics, 54*, 21–33.

Davis, N. M. (1997). Drug names that look and sound alike. *Hospital Pharmacy, 32*, 1558–1570.

DeDonno, M. A., & Demaree, H. A. (2008). Perceived time pressure and the Iowa Gambling Task. *Judgement and Decision-Making, 3*, 636–640.

Duncan, J., & Humphreys, G. W. (1989). Visual search and stimulus similarity. *Psychological Review, 96*, 433–458.

Emmerton, L. M., & Rizk, M. F. S. (2012). Look-alike and sound-alike medicines: Risks and solutions. *International Journal of Clinical Pharmacy, 34*, 4–8.

Farmer, E. W., & Taylor, R. M. (1980). Visual search through colour displays: Effects of target-background similarity and background uniformity. *Attention, Perception and Psychophysics, 27*, 267–272.

Federal Drug Administration. (2001). *Name differentiation project*. Retrieved from http://www.fda.gov/Drugs/DrugSafety/MedicationErrors/ucm164587.htm

Filik, R., Purdy, K., Gale, A., & Gerrett, D. (2004). Drug name confusion: Evaluating the effectiveness of capital ("Tall Man") letters using eye movement data. *Social Science and Medicine, 59*, 2597–2601.

Filik, R., Purdy, K., Gale, A., & Gerrett, D. (2006). Labeling of medicines and patient safety: Evaluating methods of reducing drug name confusion. *Human Factors, 48*, 39–47.

Flynn, E. A., Barker, K. N., Gibson, J. T., Pearson, R. E., Smith, L. A., & Berger, B. A. (1996). Relationships between ambient sounds and the accuracy of pharmacists prescription-filling performance. *Human Factors, 38*, 614–622.

Flynn, E. A., Barker, K. N., Gibson, J. T., Pearson, R. E., Berger, B. A., & Smith, L. A. (1999). Impact of interruptions and distractions on dispensing errors in an ambulatory care pharmacy. *American Journal of Health-System Pharmacy, 56*, 1319–1325.

Franklin, B. D., O'Grady, K., Voncina, L., Popoola, J., & Jacklin, A. (2008) An evaluation of two automated dispensing machines in UK hospital pharmacy. *International Journal of Pharmacy Practice, 16*, 47–53.

Gabriele, S. (2006). The role of typography in differentiating look-alike/sound-alike drug names. *Healthcare Quarterly, 9*, 88–95.

Hart, S. G., & Staveland, L. E. (1988). Development of the NASA-TLX (Task Load Index): Results of empirical and theoretical research. In P. A. Hancock & N. Meshkati (Eds.), *Human mental workload* (pp. 139–184). Amsterdam, Netherlands: North Holland Press.

Hellier, E., Edworthy, J., Derbyshire, N., & Costello, A. (2006). Considering the impact of medicine label design on patient safety. *Ergonomics, 49*, 617–630.

Hellier, E., Tucker, M., Kenny, N., Rowntree, A., & Edworthy, J. (2010). Merits of using colour and shape differentiation to improve the speed and accuracy of drug strength identification on over-the-counter medications by laypeople. *Journal of Patient Safety, 6*, 158–164.

Jensen, A. R. (2006). *Clocking the mind: Mental chronometry and individual differences*. Amsterdam, Netherlands: Elsevier.

Kalvaitis, K. (2011). FDA warns of confusion in prescribing two dissimilar drugs. *Psychiatric Annals, 41*, 345.

Kataoka, J., Sasaki, M., & Kanda, K. (2011). Effects of mental workload on nurses' visual behaviors during infusion pump operating. *Japan Journal of Nursing Science, 8*, 47–56.

Kenagy, J. W., & Stein, G. C. (2001). Naming, labeling and packaging of pharmaceuticals. *American Journal of Health System Pharmacy, 58*, 3033–3041.

Lambert, B. L., Chang, K. Y., & Gupta, P. (2003). Effects of frequency and similarity neighborhoods on pharmacists' visual perception of drug names. *Social Science and Medicine, 57*, 1939–1955.

Lambert, B. L., Chang, K. Y., & Lin, S. J. (2001). Effect of orthographic and phonological similarity on false recognition of drug names. *Social Science and Medicine, 52*, 1843–1857.

Maunsell, J. H. R., & Treue, S. (2006). Feature-based attention in the visual cortex. *TRENDS in Neuroscience, 29*, 317–322.

Mayall, K. (2002). Case-mixing effects on children's word recognition: Lexical feedback and development. *Quarterly Journal of Experimental Psychology, 55A*, 525–542.

Mayall, K., & Humphreys, G. W. (1996). Case-mixing and the task-sensitive disruption of lexical processing. *Journal of Experimental Psychology: Learning, Memory and Cognition, 22*, 278–294.

McClelland, J. L., & Rumelhart, D. E. (1981). An interactive activation model of context effects in letter perception: Part I. An account of basic findings. *Journal of Experimental Psychology: General, 114*, 159–188.

Najemnik, J., & Geisler, W. S. (2005). Optimal eye movement strategies in visual search. *Nature, 434*, 387–391.

National Pharmacy Association. (2006). *Similar names*. Hertfordshire, UK: Author.

Orser, B. A., Chen, R. J. B., & Yee, D. A. (2001). Medication errors in anaesthetic practice: A survey of 687 practitioners. *Canadian Journal of Anaesthesia, 48*, 139–146.

Peterson, G. M., Wu, M. S. H., & Bergin, J. K. (1999). Pharmacists' attitudes towards dispensing errors: Their causes and prevention. *Journal of Clinical Pharmacy and Therapeutics, 24*, 57–71.

Pontibriand, R. J. D., Allender, L. E., & Doyle, F. J. (2008). Temporal regulation and temporal cognition: Biological and psychological aspects of time stress. In P. A. Hancock & J. L. Szalma (Eds.), *Performance under stress* (pp. 143–163). Hampshire, UK: Ashgate.

Poon, E. G., Cina, J. L., Churchill, W., Patel, N., Featherstone, E., Rothschild, J. M., Keohane, C. A., Whittemore, A. D., Bates, D. W., & Gandhi, T. K. (2006). Medication dispensing errors and potential adverse drug events before and after implementing bar code technology in pharmacy. *Annals of Internal Medicine, 145*, 426–434.

Rastegary, H., & Landy, J. F. (1993). The interactions among time urgency, uncertainty, and time pressure. In O. Svenson & J. A. Maule (Eds.), *Time pressure and stress in human judgment and decision making* (pp. 217–239). New York: Plenum.

Reason, J. T. (2001). Understanding adverse events: Human factors. In C. Vincent (Ed.), *Clinical risk management: Enhancing patient safety* (pp. 9–30). London, UK: BMJ.

Reilly, S., Grasha, A. F., & Schafer, J. (2002). Workload, error detection and experienced stress in a simulated pharmacy verification task. *Perceptual and Motor Skills, 95*, 27–46.

Schell, K. L. (2009). Using enhanced text to facilitate recognition of drug names: Evidence from two experimental studies. *Applied Ergonomics, 40*, 82–90.

Schell, K. L., & Grasha, A. F. (2000). State anxiety, performance accuracy and work pace in a simulated pharmacy dispensing task. *Perceptual and Motor Skills, 90*, 547–561.

Slobounov, S. M., Fukada, K., Simon, R., Rearick, M., & Ray, W. (2000). Neurophysiological and behavioral indices of time pressure effects on visuomotor task performance. *Cognitive Brain Research, 9*, 287–298.

Treisman, A. (1982). Perceptual grouping and attention in visual search for features and for objects. *Journal of Experimental Psychology: Human Perception and Performance, 8*, 194–214.

Varadarajan, R., Barker, K. N., Flynn, E. A., & Thomas, R. E. (2008). Comparison of two error detection methods in a mail service pharmacy serving health facilities. *Journal of the American Pharmacists Association, 48*, 371–378.

Vincent, C. (2003). Understanding and responding to adverse events. *New England Journal of Medicine, 348*, 1051–1056.

Wolfe, J. M. (1994). Guided search 2.0: A revised model of visual search. *Psychonomic Bulletin and Review, 1*, 202–238.

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