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Visual errors in the perception of written drug names can reflect orthographic similarity amongst certain names. Drug names are typically printed in lowercase text. ‘Tall Man’ lettering, the capitalisation of the portions that differ amongst orthographically similar drug names, is employed in the field of medication labelling and prescribing to reduce medication errors by highlighting the area most likely to prevent confusion. The influence of textual format on visual drug name perception was tested amongst healthcare professionals (n = 133) using the Reicher-Wheeler task. Relative to lowercase text, Tall Man lettering improved accuracy in drug name perception. However, an equivalent improvement in accuracy was obtained using entirely uppercase text. Thus, character size may be a key determinant of perceptual accuracy for Tall Man lettering. Specific considerations for the manner in which Tall Man lettering might be best formatted and implemented in practice to reduce medication errors are discussed.

Statement of Relevance: Tall Man lettering aims to prevent medication errors by reducing visual confusions amongst orthographically similar drug names. It was found that, compared to lowercase text, Tall Man lettering improved accuracy in drug name perception. Character size appeared to be a key determinant of perceptual accuracy for Tall Man lettering.

Keywords: drug name; medication error; reading; Tall Man lettering; visual perception

1. Introduction

Medical error is a leading cause of morbidity and mortality in the developed world, the most widespread form of which is medication error (Kohn et al. 2000). Medication error arises from drug therapy and can involve the wrong drug, wrong dosage, wrong route of administration, wrong therapeutic regimen or the omission of treatment. The application of ergonomic principles to the manner in which drug information is displayed has the potential to reduce medication error through, for example, improved medicine label design (e.g. Berman 2004, Buckle et al. 2006). Signal words, colours, shapes, symbols and textual formats can be used to draw attention to sources of medication error and make them more discriminable (see Hellier et al. 2006 for a review).

Of particular interest are ergonomic measures to prevent the unintentional substitution of an intended drug therapy for another with a similar name. In a review of medication errors across 50 pharmacies, drug name substitution errors have been observed to occur in 0.13% of prescriptions (Flynn et al. 2003). With 886.57 million items prescribed in the year ending March 2010 in the UK alone (NHS Business Services Authority 2010), even a small percentage is cause for concern. Such errors can reflect orthographic and phonological similarity amongst certain drug names: so-called ‘look-a-like’ and ‘sound-a-like’ errors (Lambert et al. 2001).

Ergonomically designed textual formats have the potential to prevent drug name substitution errors in any medium involving a written drug name, including medicine labels, prescriptions and e-prescribing software. A central aim of such textual formats is to highlight the differences between orthographically similar drug names. A number of typographic devices have been explored for this purpose, including the use of italics, bold type, different fonts and styles and rules such as underlines (e.g. Filik et al. 2006, Gabrielle 2006, Schell 2009). In particular, a textual format known as ‘Tall Man’ lettering (Cohen 1999) is recommended by the US Food and Drug Administration (2001) for the display of a set of drug names identified as highly confusable. Given a drug name printed in lowercase text, Tall Man lettering highlights the differences between orthographically
similar drug names by capitalising the dissimilar letters. In the present paper these letters are referred to as the ‘critical portion’. For instance, if ‘cefuroxime’ and ‘ceftazidime’ are likely to be confused for one another then the critical portions could be capitalised: cefUROXime, cefTAZIDime.

1.1. Research on the efficacy of Tall Man lettering

Current, empirical evidence regarding the efficacy of Tall Man lettering at reducing confusions amongst drug names is sparse and contradictory. Two studies of drug name recognition have found that Tall Man lettering confers an advantage (Filik et al. 2004, 2006), whilst a third study found that Tall Man lettering does not confer an advantage (Schell 2009). Various paradigms have been employed: a search task for drug packaging, by drug name (Filik et al. 2004); a recognition memory task (Filik et al. 2006 experiment 3); same–different judgement tasks (Filik et al. 2006 experiments 1 and 2, Schell 2009). These tasks address various processes from which drug name substitution errors might arise, including initial perception (e.g. Lambert et al. 2003) and recall from memory (e.g. Lambert et al. 2001).

The present study attempts to target the fundamental, perceptual process of visual word recognition; that is, the interplay of top-down and bottom-up processes that follow from viewing a word and that lead to the initial recognition of a word. In terms of the Interactive Activation Model (McClelland and Rumelhart 1981, Rumelhart and McClelland 1982), one of the most influential models of visual word recognition, this process would be the automatic analysis of sensory input that follows from viewing a word and which extracts letters and synthesises them into a word with the aid of feedback from an internal lexicon. The Reicher-Wheeler task (Reicher 1969, Wheeler 1970) is employed in the present study as it permits a focus upon the perceptual process of visual word recognition; that is, the interplay of top-down and bottom-up processes that follow from viewing a word and which extracts letters and synthesises them into a word with the aid of feedback from an internal lexicon. The Reicher-Wheeler task (Reicher 1969, Wheeler 1970) is employed in the present study as it permits a focus upon the perceptual process of visual word recognition by controlling the influences of higher-level, consciously employed and often task-specific word recognition strategies. Such strategies might include the use of sophisticated guesswork to fill in unseen letters on the basis of known letters and the use of context to help identify a word.

The Reicher-Wheeler task proceeds by presenting a word stimulus to the participant, at a threshold of perception. In the present study the stimulus was a drug name, for example ‘vincristine’. The participant is then asked to indicate which drug name they have just seen using a two-alternatives forced choice (2AFC). For example, ‘vincristine’ and ‘vinblastine’ might be offered as the alternatives. The two alternatives are matched as closely as possible. In order to make the choice without resorting to guesswork, the participant must have seen at least a portion of the elements that differ between the two choices; in this case, the ‘cri’ of ‘vincristine’. Where guesswork is employed, context and reconstruction from other letters that were seen are of no use. Thus, the effectiveness of any consciously employed, sophisticated guessing strategy is minimised and only simple guesswork can be used with a 50% chance of success given two alternatives.

The level of difficulty of the task is tuned to the individual participant’s sensory and perceptual abilities. In the present study, this is accomplished with a training phase at the start of the experiment, in which the contrast at which the drug name is shown is adjusted gradually in order to work out each participant’s threshold of perception. If this is done successfully then mean accuracy across all the experimental conditions will be approximately 75%, halfway between simple guesswork and a ceiling of 100%. Thus, provided that the experimental manipulations are conducted within participants, then accuracy has the scope to vary above and below 75% for each experimental condition.

The use of accuracy as the measure of performance is also important in mitigating the potential influences of consciously employed, sophisticated guessing strategies. An alternative performance measure is reaction time. However, at a threshold of perception, accuracy more faithfully reflects perceptual processes than reaction time (Santee and Egeth 1982), which includes not only the amount of time taken to perceive the drug name, but also any time spent attempting to guess which alternative is the correct answer. Thus, a consciously employed, sophisticated guessing strategy will not improve performance on the Reicher-Wheeler task, both because the 2AFC limits the utility of guesswork to a simple 50–50 gamble and because any amount of time spent on guesswork will not be reflected in the accuracy-based measure of performance.

1.2. The need to assess drug name perception amongst healthcare professionals

A further issue with research on the efficacy of Tall Man lettering is that, with the exception of Schell (2009 experiment 2) and Gabrielle (2006), prior studies have concentrated on drug name recognition amongst lay people who would not necessarily be familiar with a large corpus of drug names (Filik et al. 2004, 2006, Schell 2009 experiment 1). Additionally, Schell (2009 experiment 2) examined the influence of Tall Man lettering on drug name recognition amongst only 11 healthcare professionals (practising pharmacists and pharmacy technicians); no significant effect was observed but this probably reflected a lack of statistical power. Similarly, Gabrielle (2006) sampled only 11 healthcare professionals (acute care nurses) in a
Drug name recognition might proceed differently amongst lay people and those who are familiar with drug names. Literate adults can read words automatically, without the need for conscious thought. This skill is thought to be facilitated by a perceptual process in which pre-stored knowledge of words, an internal lexicon, interacts with the pattern of activation caused by the sensory input from a word stimulus (Rumelhart 1977). Presumably, only people with extensive exposure to drug names possess a lexicon with a significant number of stored drug names. Indeed, the perceptual identification of drug names amongst pharmacists appears to reflect the presence of an internal drug name lexicon (Lambert et al. 2003). Consequently, the present experiment concentrates upon recruiting a statistically powerful sample of healthcare professionals.

1.3. Assessment of the mechanisms underlying any influence of Tall Man lettering

In addition to questions regarding the efficacy of Tall Man lettering at reducing confusions amongst drug names in healthcare professionals, there is also a need to address the mechanism by which Tall Man lettering might exert any effect. For instance, Filik et al. (2006, experiment 3) compared the effects of various combinations of Tall Man and coloured lettering to highlight the critical portion of the drug name against a baseline of lowercase lettering (this design was also adopted by Schell 2009). Tall Man lettering improved drug name recognition whilst coloured lettering did not. It was suggested that Tall Man lettering does not make drug names easier to read, intrinsically, nor does it make them less confusable in memory. Instead, Tall Man lettering might usefully increase attention to high risk drug names, thereby circumventing perceptual errors.

However, the origin of any Tall Man effect need not relate to an increase in attention or indeed to highlighting the critical portion of a drug name. For instance, capitalising the critical portion of a drug name inevitably makes those letters larger. This might confer a sensory and perceptual advantage that would not occur if highlighting were achieved using colour alone. The present experiment addresses this issue by considering drug names presented not only in lowercase and Tall Man lettering, but also drug names presented entirely in uppercase lettering. Compared to the critical portions of drug names with Tall Man formatting, within the constraints of the Reicher-Wheeler 2AFC the critical portions of drug names presented entirely in uppercase lettering will be of the same size and letter case, but will not be highlighted against a background of lowercase letters.

1.4. Rules for determining the implementation of Tall Man lettering

Tall Man lettering has been implemented in the USA since 2001 as part of the US Food and Drug Administration Name Differentiation Project (US Food and Drug Administration 2001) and its adoption is being considered in other countries including the UK. However, there is no definitive rule regarding which letters to capitalise in a given drug name. Consequently, the present experiment examined the efficacy of two derived rules for producing Tall Man formatted drug names. These rules are termed ‘Mid’ Tall Man and ‘CD3’ Tall Man (described in section 2.1). These two rules were compared against a third Tall Man format, termed ‘Wild’ Tall Man, which comprised existing examples of how Tall Man lettering has been implemented in drug names. It was not possible to discern a consistent ‘rule’ that would account for the Wild Tall Man format.

Thus, in the perception of drug names formatted with the Mid and CD3 rules could be compared with accuracy on the Wild Tall Man examples to determine if applying either of these rules would improve or reduce accuracy relative to current practice, where the application of a consistent rule could not be determined. Some overlap in the formats produced by the two rules and in existing Wild Tall Man drug names was noted.

2. Experiment

The experiment tested the accuracy of drug name recognition amongst healthcare professionals, across five different textual formats, in a repeated-measures design: Natural (lowercase except where the initial letter is capitalised for proprietary drug names), Uppercase, Wild Tall Man, Mid Tall Man and CD3 Tall Man. Two null hypotheses were tested:

(1) Adopting the Natural textual format as a baseline for performance, Tall Man textual formats do not improve accuracy in the recognition of drug names. This null hypothesis will be rejected if at least one of the Tall Man formats improves accuracy significantly above that observed for the Natural textual format.

(2) Relative to the Natural textual format, any increase in the accuracy of drug name recognition associated with Tall Man lettering does not reflect the use of uppercase letters to highlight the critical portion of the drug name
The experiment was automated

2.1.2.1. Apparatus.

2.1.2. Materials

...All participants gave informed consent. Psychological Society ethical guidelines were adhered to. Consequently, NHS research ethics approval was not required. Ethical approval was granted by the Loughborough University Ethics Committee, and British Psychological Society ethical guidelines were adhered to. All participants gave informed consent.

2.1. Method

2.1.1. Participants

A total of 144 healthcare professionals were approached to participate in the study. Of these, 133 completed the experiment: 52 medics, 36 pharmacists, and 45 pharmacy technicians, (age: mean 36, range 18–62 years). The participants were employees of the UK’s National Health Service (NHS). Consequently, advice from the National Research Ethics Service was first obtained. The documented decision was that the work should be viewed as service evaluation and, consequently, NHS research ethics approval was not required. Ethical approval was granted by the Loughborough University Ethics Committee, and British Psychological Society ethical guidelines were adhered to. All participants gave informed consent.

2.1.2. Materials

2.1.2.1. Apparatus. The experiment was automated on Toshiba Satellite Pro L300–19S laptop computers (Toshiba, Tokyo, Japan) (Pentium T3200 processor, 1024MB RAM, Windows XP operating system) using a computer program developed in-house with Visual Basic.net.

2.1.2.2. Stimuli. In total, 40 drug names, comprising 20 confusable drug name pairs (e.g. vincristine, vinblastine), were selected as the basis for experimental stimuli (see Appendix 1), in consultation with the National Patient Safety Agency and the NHS Connecting for Health Initiative. Seven of these drug names were proprietary brand names, the rest were generic names. The subtended visual angle of a drug name stimulus at a viewing distance of 45 cm: width, mean 3.28°, SD 0.73°, range 1.65–5.64°; height, mean 0.59°, SD 0.12°, range 0.51–0.76°. A further 18, different, confusable drug name pairs were selected for the training phase of the experiment.

2.1.2.3. Textual format. The Arial 12 point font was used to present all drug name stimuli. A review of e-prescribing software revealed that this font was most commonly used to display drug names. Each drug name was presented in five different textual formats over the course of the experiment: Natural; Wild Tall Man; Mid Tall Man; CD3 Tall Man; Uppercase. Drug names in the Natural textual format were presented in entirely lowercase text, except for proprietary (brand) names, where each initial letter was capitalised. The Wild Tall Man format used existing examples of how Tall Man lettering has been implemented. These were taken from the US Food and Drug Administration Name Differentiation Project (US Food and Drug Administration 2001), the Institute for Safe Medication Practices and the National Patient Safety Agency. The Mid and CD3 Tall Man formats were generated using the rules described below:

- The Mid Tall Man rule: collect drug names into groups of two or more names that are orthographically similar (these groupings were determined in consultation with experts at the National Patient Safety Agency and the NHS Connecting for Health Initiative); on a letter-by-letter basis, start from either end of each drug name in a confusable group and work towards the middle; capitalise the first letters encountered at either end that differ across at least two drug names in the group, along with all letters occurring between them. Essentially, the entire critical portion of the drug name is capitalised, for example, cefxime, cefotaxime, ceftazidime and cefuroxime would become cefIXime, cefOTAXime, cefTAZIDime and cefUROXime.
- The CD3 Tall Man rule: collect drug names into groups and define the critical portions in the same way as for the Mid Tall Man rule, but capitalise a maximum of only three letters per drug name. Where more than three letters are present in the critical portion of the drug name, capitalise the centre most three. Where this would result in letters that are common amongst all the drug names of the group in those positions being capitalised, then capitalise the next most peripheral letters that differ across at least two drug names. In order to prevent confusion with a lowercase letter ‘I’, the letter ‘i’ is not capitalised unless it is the initial letter of a proprietary drug...
name. Using the CD3 rule, cefixime, cefotaxime, ceftazidime and ceferoxime would become cefIXime and cefOTAxime, cefTAZidime and cefUROxime.

For both rules, the initial letters of proprietary drug names were always capitalised. See Appendix for the experimental stimulus set, organised by textual format. Finally, Uppercase drug names were presented in entirely uppercase text.

2.1.3. Procedure

The experiment was delivered to healthcare professionals as part of a suite of three related studies on one of five identical laptop computers (see Gerrett et al. 2009, Filik et al. 2010). Before commencing the three studies, participants were informed of the purpose of Tall Man lettering: ‘to highlight the parts of drug names that are most likely to prevent confusion with another, similar drug name by rendering those parts in capital letters’. They then provided demographic information. Subsequently, when starting the Reicher-Wheeler experiment, participants were given on-screen instructions describing the task. The experiment then proceeded in two phases. First, a training phase enabled the estimation of the level of stimulus contrast required in order that the stimuli were presented at a threshold of perception. An experimental phase then collected the study data. The training phase led directly into the experimental phase and it was not obvious to the participant at which point the changeover occurred.

The experiment consisted of 180 training phase trials followed by 200 experimental phase trials. Each trial proceeded as follows. The participant was presented with a cross-hair in the centre of the screen. On pressing the space bar, the cross-hair was replaced with the stimulus drug name, which was presented in the centre of the screen for 50 ms. The stimulus was then replaced with the 2AFC, which comprised the stimulus drug name and the matched, confusable drug name to which the stimulus had been paired in the stimulus set. The alternatives were positioned one above the other with the position of the correct alternative randomised from one trial to the next. The participant was required to select which alternative matched the stimulus that was just previously presented by pressing the up or down arrow key for the upper or lower choice, respectively. On making a selection, the two alternatives were replaced with the cross-hair and the participant was able to initiate the next stimulus presentation by pressing the space bar.

During the training phase each participant saw each of the 36 drug names of the training set, once in each of the five textual formats. The drug names were presented in a pseudo-randomised order such that every 10 trials each participant saw each of the five textual formats twice, with the further proviso that the participant should not have been tested on a given drug name in a given textual format, previously. Initially, stimuli were shown at the maximum possible contrast (Michelson contrast: 0.98) as black text (luminance: 1.3 cd/m²) upon a white background (luminance: 165.8 cd/m²). After every cycle of 10 trials, mean response accuracy across those 10 trials was calculated and contrast was adjusted up or down using a staircase procedure in an attempt to bring average performance over the next 10 trials to approximately 75% correct. The stimulus luminance was adjusted in grey scale while the background remained white. At the end of the training phase, the contrast level that had supported an accuracy level closest to 75% was derived. This contrast level was used throughout the subsequent experimental phase and was not adjusted further (Michelson contrast: mean 0.14, SD 0.08; text luminance: mean 126.3 cd/m², SD 16.9; background luminance: 165.8 cd/m²). Performance during the training phase did not contribute to the experimental dataset.

During the experimental phase, every participant saw each of the 40 drug names of the experimental set, once in each of the five textual formats. Again, the drug names were presented in pseudo-randomised cycles of 10 trials, as described for the training phase. A different pseudo-randomised order was generated for each participant.

3. Results

The data were subjected to a one-way, repeated-measures ANOVA with five levels of textual format (Natural, Wild Tall Man, Mid Tall Man, CD3 Tall Man, Uppercase). Proportion of correct responses was the dependent variable. Each data point, in each textual format, for each participant, represented an average of proportion correct across 40 drug names.

The z level was set at 0.05. The data failed Mauchly’s Test of Sphericity, $\chi^2(9) = 21.52, p < 0.05$. Therefore, the degrees of freedom were corrected using the Greenhouse-Geisser estimates of sphericity ($\varepsilon = 0.92$). There was a significant main effect of textual format $F(3.68, 485.89) = 34.21$, mean squared error 0.003, $p < 0.001$, $\eta^2 = 0.206$. Pair-wise post-hoc tests were used to resolve the main effect of textual format and the Bonferroni correction was applied. Accuracy on the Natural textual format (mean 0.78, SD 0.12) was significantly lower than on the Wild Tall Man (mean 0.84, SD 0.11, $p < 0.001$), Mid Tall Man (mean 0.84, SD 0.11, $p < 0.001$), CD3 Tall Man (mean 0.82, SD 0.12, $p < 0.001$), and Uppercase (mean 0.84, SD 0.11, $p < 0.001$) textual formats. Additionally,
accuracy on the CD3 Tall Man textual format was significantly lower than on the Mid Tall Man \( (p < 0.05) \) and Uppercase \( (p < 0.01) \) textual formats. No other pair-wise comparisons revealed significant differences \( (all \ p > 0.2) \). See Figure 1 for a summary of these results.

4. Discussion

The influence of Tall Man lettering on the perceptual confusability of drug names amongst healthcare professionals was tested. Accuracy in drug name perception was lower when the drug name was presented in the Natural textual format (which was principally lowercase, except when the initial letter was capitalised for a brand name) compared to when a critical portion of the drug name was presented in uppercase lettering, as in the Tall Man formats. Consequently, null hypothesis 1 is rejected. Compared to lowercase text, the use of Tall Man lettering does appear to be advantageous to drug name perception.

A key and somewhat unexpected finding was that accuracy in drug name perception was no higher with Tall Man lettering than with the Uppercase textual format. Consequently, null hypothesis 2 is accepted. It would appear that the perceptual advantage conferred by Tall Man lettering upon drug name perception may not relate specifically to the use of uppercase letters to highlight the critical portion of the drug name against a background of lowercase letters. Rather, the use of uppercase letters, themselves, is the critical factor in the perceptual advantage conferred by Tall Man lettering.

4.1. Conflicting findings amongst studies of the influence of Tall Man lettering on drug name recognition

The indication that Tall Man lettering confers an advantage in drug name recognition relative to lowercase text concurs with the prior findings of Filik et al. (2004, 2006) and with other work conducted alongside this study (Gerret et al. 2009, Filik et al. 2010), but contradicts the findings of Schell (2009). It is noted that Schell (2009) may have encountered a ceiling of performance, with mean error rates below 8% in experiment 1 and below 3% in experiment 2; if accuracy were measured at a ceiling of performance then differences in accuracy of recognition across the various tested drug name formats may have been masked.

The differences amongst the findings of prior studies of the influence of Tall Man lettering on drug name recognition might also reflect methodological differences amongst these studies. Unfortunately, the present experiment does not provide for a systematic appraisal of reasons for the apparent variability in the influence of Tall Man lettering. Numerous methodological differences exist amongst studies of the influence of Tall Man lettering on drug name recognition, including whether or not participants were informed of the purpose of Tall Man lettering, measures of performance, the tasks employed, the drug name corpus, font style, font size and statistical power.

As discussed in section 1 of this article, it is argued that the use of the Reicher-Wheeler task in the present study will have prevented the influence of many task-specific factors in order to focus upon the fundamental process of written drug name perception, whilst the relatively large sample size should offer statistically robust findings.

4.2. The mechanism by which Tall Man lettering influences drug name recognition

Why does Tall Man lettering confer an advantage in drug name recognition that is not related to the highlighting of the critical portion of the drug name? Uppercase letters are more legible than lowercase letters (Tinker 1963), a finding more recently replicated using modern computer displays and attributed to the greater size of uppercase letters compared to lowercase letters (Sheedy et al. 2005). This size advantage for uppercase letters applies to the Arial 12 point font used in the present experiment. Consequently, a sensory and subsequent perceptual advantage in drug name recognition might have arisen from the use of uppercase letters on the basis of character size.

This interpretation is supported by the pattern of performance across the Mid and CD3 Tall Man formats. In the Mid Tall Man format, all the letters in the critical portion of the drug name were capitalised, whilst in the CD3 Tall Man format fewer than all the letters in the critical portion were capitalised for 75% of the drug names. Accuracy on the CD3 Tall Man
format was significantly lower than on the Mid Tall Man format. Thus, it can be hypothesised that increasing the number of uppercase letters within the critical portion of the drug name improved accuracy. However, it is noted that increasing the number of uppercase letters outside of the critical portion, by stepping from the Mid Tall Man format to the entirely Uppercase format, did not increase accuracy further. This might reflect the fact that the contributions of letters outside of the critical portion of the drug name are limited in the 2AFC of the Reicher-Wheeler task.

Even so, it is possible that highlighting the critical portion of a drug name may have provided a perceptual benefit that was masked by the mixing of lowercase and uppercase letters in the Tall Man formats. Case-mixing has been found to disrupt word recognition, although the origins of this effect are uncertain (e.g., Mayall et al. 1997, Humphreys et al. 2003). Thus, the advantage conferred by Tall Man lettering might be further augmented if, in future work, it is possible to develop a method of highlighting the critical portion of a drug name that minimises any disruption to word perception.

In summary, Tall Man lettering improves accuracy in drug name perception when compared to the use of lowercase text. This improvement appeared to relate to the use of uppercase letters, rather than to the highlighting of the critical portion of the drug name. It was inferred that the larger size of uppercase letters compared to lowercase letters confers a sensory and subsequent perceptual advantage in drug name recognition.

4.3. How should drug names be formatted in order to reduce confusions amongst orthographically similar names?

It has been found that, compared to using lowercase letters, using uppercase letters throughout the entire critical portion of the drug name is most advantageous to perception, as in the Mid Tall Man format. Additionally, the Mid and Wild Tall Man formats supported equivalent levels of drug name recognition performance, indicating that the use of the Mid Tall Man rule would not be less desirable than current practice. In future research the Mid Tall Man rule, which takes into account only orthographic differences between similar drug names, might be improved upon. Drug names can be confused on the basis of similar phonology, as well as orthography, especially amongst healthcare professionals (Lambert et al. 2001). Thus, rules for implementing Tall Man lettering should at least consider phonology in addition to orthography and might also benefit from considering the morphemic structure of a drug name.

Compared to the Tall Man formats, capitalising the entire drug name offers no further advantage, but is not detrimental either. However, capitalising the entire drug name would not necessarily be desirable in practice. In the present study, uppercase letters were presented in isolation, but where drug names are presented in lists or in blocks of text, an entirely uppercase textual format may not be desirable.

Uppercase text has been found to take longer to read than lowercase text (e.g., Tinker 1963, Rudnicky and Kolers 1984), indicating a reduction in legibility for swaths of uppercase words. Additionally, it is important to note that the present study can only inform with regard to perceptual errors in drug name recognition. It is possible that Tall Man lettering may have further effects on drug name recognition outside of the perceptual process of recognition, which do relate to the highlighting of the critical portion of the drug name and which might not accrue from an entirely uppercase format. For instance, it has been suggested that Tall Man lettering may serve as an overt, conscious reminder to increase attention to drug names that carry a particular danger for confusion (e.g., Filik et al. 2006).

Thus, in attempting to determine how best to format a drug name in order to prevent visual confusions, it is necessary to consider the perceptual advantage associated with the size of uppercase letters, potential disadvantages associated with the exclusive use of uppercase letters in blocks of many drug names and any advantages associated with highlighting the critical portion of a drug name that might accrue in the wider context of drug name recognition beyond the boundaries of the perceptual process. These considerations would appear to point to the use of a Tall Man format that capitalises the entire critical portion of a drug name, with the remainder presented in lowercase lettering.

4.4. What does the perceptual advantage conferred by Tall Man lettering on drug name recognition mean for practice?

In the present experimental setting, Tall Man lettering reduces error in drug name recognition relative to lowercase lettering. However, the Reicher-Wheeler task does not represent an entire scenario in which a drug name might be read. Rather, the Reicher-Wheeler task concentrates upon the perceptual process of reading a drug name in isolation, from the point of sensory input and up to the point of initial recognition. It is important to consider how this finding might translate in real-life settings in which drug names are read, for example, the prescribing, dispensing or administration of medicines. Tall Man lettering may
improve drug name recognition at a fundamental level and so has the potential to reduce error rates wherever a drug name is read. However, in real-life settings, prior and subsequent processes, as well as other simultaneous tasks, might influence the efficacy of Tall Man lettering at reducing error in drug name recognition.

For instance, in the present experimental situation, accuracy in the reading of a drug name was probably reliant principally upon the quality of the sensory information received and thus might be considered a data-limited process (e.g. Norman and Bobrow 1975). Tall Man lettering could improve the quality of this sensory information by increasing letter size and so support a higher level of accuracy than lowercase lettering. However, in real-life situations, simultaneous tasks could influence the efficacy of Tall Man lettering at reducing error in drug name recognition by competing for resources. Under such conditions, the amounts of processing resources allocated to the drug name reading task could become a determinant of accuracy and the process might become resource-limited (e.g. Norman and Bobrow 1975). Even so, under resource-limited conditions Tall Man lettering retains the potential to improve accuracy in drug name recognition. For example, given that the presence of Tall Man lettering indicates the potential for dangerous drug name confusions, where attentional resources are limited Tall Man lettering might support higher levels of accuracy than lowercase lettering by causing an individual to prioritise attentional resources for drug name reading (e.g. Filik et al. 2006).

Further, there is the potential for subsequent processes, such as double-checking, the use of context and guesswork, to improve upon or detract from the accuracy of initial drug name recognition. In its capacity as a warning flag, Tall Man lettering may promote more double-checking and careful consideration of context, whilst suppressing the use of guesswork. Work conducted at the same time as this study (Gerrett et al. 2009, Filik et al. 2010) considers the influence of Tall Man lettering on the recognition of drug names in lists and in a mock e-prescribing task. These studies indicate that, even when the task is more complex, the advantage for the recognition of drug names with Tall Man lettering over those presented in entirely lowercase text remains. These various potential modes of action for Tall Man lettering need further investigation.

Another consideration in relating the present findings to practice involves the sample of healthcare professionals who took part in this study. A cross-section of healthcare professionals with responsibilities in prescribing was sampled. The inferential statistical analysis of the resultant dataset suggests that Tall Man lettering is effective at reducing drug name recognition error amongst the target population as a whole. However, it is possible that the influence of Tall Man lettering varies amongst individuals in this population depending upon, for instance, profession and experience. Unfortunately, between-participant comparisons are not possible with the present dataset because each participant’s overall error rate was tuned individually in an attempt to reach their threshold of perception. However, Tall Man lettering has been found to aid drug name recognition even amongst lay people (Filik et al. 2004, 2006), including both younger and older adults (Filik et al. 2010). Thus, it seems unlikely that the efficacy of Tall Man lettering will be entirely dependent upon profession and experience.

Finally, an attempt to translate the present research findings into practice needs to give thought to how Tall Man lettering is introduced to and received by healthcare professionals. For instance, it has been noted that knowledge of the purpose of Tall Man lettering might be important to its efficacy in reducing medication error (Filik et al. 2006). Additionally, an individual’s level of confidence in the ability of Tall Man lettering to reduce error in drug name recognition may be an important determinant of this textual format’s efficacy. Potentially, if confidence in Tall Man lettering is lacking then any advantage in drug name recognition that might accrue from Tall Man lettering acting as a warning flag could be lost. A survey by the Institute for Safe Medication Practices (2008) found that, of 457 respondents, 87% felt that the use of Tall Man lettering by the medical product industry helps to reduce drug selection errors. Thus, overall, confidence in Tall Man lettering may be high. However, this survey (Institute for Safe Medication Practices 2008) also indicates that confidence in Tall Man lettering may vary by application, whilst qualitative work has indicated that practitioners who view drug names with Tall Man lettering will not necessarily feel that this textual format is beneficial to drug name recognition (Gabrielle 2006). Confidence in Tall Man lettering may require a solid, empirical evidence base supporting the use of Tall Man lettering to reduce medication error across all of its applications and including the monitoring of its efficacy in practice. The successful transfer of the efficacy of Tall Man lettering observed in experimental situations to practice may further require the wide dissemination of information regarding its purpose and efficacy.

Thus, numerous factors that have the potential to influence the efficacy of Tall Man lettering in reducing drug name substitution errors in practice have been discussed, including the fundamental process of word perception, prior and subsequent error mitigation techniques, competing task demands, knowledge of the...
purpose of Tall Man lettering and confidence in its ability to achieve this purpose. Other factors that might influence the efficacy of Tall Man lettering in drug name reading in practice, not discussed here, might include the exact purpose for which the drug name is read, the level of familiarity with the drug name, the level of familiarity with Tall Man lettering and the context surrounding the drug name, such as information about dosage and formulation (see Gerret et al. 2009). Factors that may influence the efficacy of Tall Man lettering in practice need further investigation as it is important to understand the circumstances under which error mitigation techniques are effective and where they might fail.

4.5. Limitations of the present research findings

There are a number of caveats to the present research findings. The absolute error rates reported here cannot be taken as an indication of error rates in real-life situations as, for each participant, performance was tuned to approximately 75% correct overall. Additionally, as discussed above (see section 4.4), other factors present in real-life scenarios involving the reading of a drug name might influence the pattern of performance seen here. Even so, as this experiment focuses upon the fundamental, perceptual process of drug name recognition, the pattern of performance observed should describe the real-life baseline for the relative differences in accuracy of recognition amongst the textual formats tested.

The use of low contrast stimuli in the present experiment represents a further limitation in extrapolating the present findings to inform the origins of real-life performance. Typical Reicher-Wheeler experiments achieve performance at a threshold of perception with brief, tachistoscopic presentations of high contrast stimuli. This was not possible here as the experiment had to be delivered on portable, laptop computers, which did not support fine control over screen refresh rates and stimulus presentation durations. Reducing contrast in an image removes low spatial frequency information such as overall shape. However, it is not certain that word shape is used in word recognition (e.g. McClelland 1976, Paap et al. 1984). Further, if word shape does make a contribution to word recognition, it is only likely to be significant for common, higher frequency words (e.g. Allen et al. 1995). Even amongst those who are highly familiar with drug names, drug names may not have the same status in an internal lexicon as those common words that have been encountered frequently since childhood.

Additionally, the present study suggests that, at a perceptual level, Tall Man lettering reduces errors in drug name recognition as a result of increasing the sizes of letters in the critical portion of the drug name. However, this study does not delineate between the influences of letter size and letter case; future work should address this issue, perhaps comparing conventional Tall Man lettering with the use of relatively larger lowercase letters throughout the critical portion of a drug name. Indeed, the latter manipulation might confer an even greater advantage in drug name recognition as it has been suggested that lowercase letters are more physically distinctive than uppercase letters (Geyer 1977). A conscious decision was taken to present capitalisation as seen in prescribing and dispensing software, using the Arial 12 point font. In this font, there is a differential in character size between lowercase and uppercase letters.

5. Conclusion

To place the present work in context, the influence of Tall Man lettering on the substantive process of written drug name perception has been addressed. Tall Man lettering may act at a fundamental level with the potential to improve accuracy in drug name recognition wherever a drug name is read. In real-life scenarios where drug names are read, prior, subsequent and simultaneous, competing processes could improve upon or detract from the influence of Tall Man lettering on drug name perception. In order that Tall Man lettering might have the greatest possible effect in reducing drug name substitution error, there is a need to investigate factors that may influence the efficacy of Tall Man lettering in practice.

Specifically, the present experiment investigated the influence of Tall Man lettering on the visual, perceptual confusability of drug names amongst a statistically powerful sample of healthcare professionals with responsibilities in prescribing. Adopting performance on lowercase text as a baseline, it was found that capitalising a critical, confusable portion of the drug name using Tall Man lettering increased accuracy in drug name perception. However, an unexpected finding was that capitalising the entire drug name conferred an advantage equivalent to that observed with Tall Man lettering. Thus, the perceptual advantage associated with the use of Tall Man lettering could relate to a size advantage conferred by the use of uppercase letters, rather than highlighting the critical portion of the drug name with uppercase letters. An explicit rule for implementing Tall Man lettering was found to be as effective as current practice for which no definitive rule has been identified. In future work, the rules and methods for implementing Tall Man lettering could be further developed to minimise disruption to
and, if possible, complement the perceptual processes underlying the visual recognition of written words.

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References


### Appendix: The stimulus set

Drug name pairs arranged by textual format.

**Natural**
- azathioprine
- azithromycin
- carbamazepine
- carbimazole
- cefaclor
- cefadroxil
- cefalexin
- ceftriazone
- cefixime
- cefotaxime
- ceftazidime
- cefuroxime
- clomifene
- clomipramine
- Depo-Medrone
- Depo-Provera
- dipyridamole
- disopyramide
- dopamine
- dobutamine
- folic acid
- folinic acid
- gliclazide
- glipizide
- mercaptamine
- mercaptopurine
- nicardipine
- nifedipine
- penicillamine
- penicillin
- pregabalin
- Pregaday
- Rifadin
- Rifinah

**Upper case**
- AZATHIOPRINE
- AZITHROMYCIN
- CARBAMAZEPINE
- CARBIMAZOLE
- CEFACLOR
- CEFADROXIL
- CEFALEXIN
- CEFTRIAZONE
- CEFIXIME
- CEFOTAXIME
- CEFTAZIDIME
- CEFUROXIME
- CLOMIFENE
- CLOMIPRAMINE
- DEPO-MEDRONE
- DEPO-PROVERA
- DIPYRIDAMOLE
- DISOPYRAMIDE
- DOPAMINE
- DOBUTAMINE
- FOLIC ACID
- FOLINIC ACID
- GLICLAZIDE
- GLIPIZIDE
- MERCAPTAMINE
- MERCAPTOPURINE
- NICARDIPINE
- NIFEDIPINE
- PENICILLAMINE
- PENICILLIN
- PREGABALIN
- PREGADAY
- RIFADIN
- RIFINAH
- VINBLASTINE
- VINCRIStINE
Mid Tall Man
azATHIOPRINE
azITHROMYCIN
carbAMAZEPiNe
carbIMAZOlE
cefACLOR
cefADROXIL
cefALEXIN
cefTRIAZONE
cefIXime
cefOTAXime
cefTAZiDime
cefUROXime
clomiFEne
clomiPRAMiNe
Depo-MEDRONE
Depo-PROVERA
diPYRiDAMOlE
diSOPYRAMiDe
doPamine
doBUTamine
folic acid
foliNic acid
gliCLAziDe
gliPIziDe
mercaptAMiNe
mercaptOPURiNe
niCARdipine
niFEdipine
penicillAMiNe
penicillIN
pregaBALiN
PregaDAY
RifaDiN
RifiNAH
vinBLASTiNe
vinCRiSTiNe
ZoFRAn
ZoTOn

CD3 Tall Man
azathioPrine
azithroMycin
carbAMAZePine
carbIMAZOLE
cefACLOR
cefADROXIL
cefALEXIN
cefTRIAZONE
cefIXime
cefOTAXime
cefTAZidime
cefUROXime
cloMiFEne
cloMiPRAMiNe
Depo-MEDRONE
Depo-PROVERA
diPYRiDAMolE
diSOPYRAMiDe
doPAMine
doBUTamine
folic acid
foliNic acid
gliCLAziDe
gliPIziDe
mercaptAMiNe
mercaptOPURiNe
niCARdipine
niFEdipine
penicillAMiNe
penicillIN
pregaBALiN
PregaDAY
RifaDiN
RifiNAH
vinBLASTiNe
vinCRiSTiNe
ZoFRAn
ZoTOn
zolpiDem
zopiCLone
Wild Tall Man
azaTHIOprine
aziTHROmycin
carBAMAZepine
carBIMazole
cefACLOR
cefADROXIL
cefALEXIN
cefTRIAZONE
cefIAXime
cefOTAXime
cefTAZIDime
cefUROXime
cloFene
clomipRAMINE
Depo-MEDRONE
Depo-PROVERA
diPYRIDAMOLE
diSOPYRAMIDE
DOPamine
DOBUTamine
foliC acid
foliNIC acid
gliCLAZide
glipiZIDE
mercaptAMINE
mercaptOPURINE
NICARdipine
NIFEdipine
peniciLLAMINE
peniciLLIN
PregABALIN
PregADAY
RifADIN
RifINAH
vinBLAStine
vinCRIStine
ZoFRAN
ZoTON
zoLPIDEM
zoPICLONE

Ergonomics