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Listen carefully: The risk of error in spoken medication orders

Bruce L. Lambert [a,*], Laura Walsh Dickey [b], William M. Fisher [c], Robert D. Gibbons [a], Swu-Jane Lin [a], Paul A. Luce [d], Conor T. McLennan [e], John W. Senders [f], Clement T. Yu [a]

[a] University of Illinois at Chicago, Chicago, IL, United States
[b] University of Pittsburgh, United States
[c] Independent Consultant, United States
[d] University at Buffalo, United States
[e] Cleveland State University, United States
[f] University of Toronto, Canada

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ABSTRACT

Clinicians and patients often confuse drug names that sound alike. We conducted auditory perception experiments in the United States to assess the impact of similarity, familiarity, background noise and other factors on clinicians' (physicians, family pharmacists, nurses) and laypersons' ability to identify spoken drug names. We found that accuracy increased significantly as the signal-to-noise (S/N) ratio increased, as subjective familiarity with the name increased and as the national prescribing frequency of the name increased. For clinicians only, similarity to other drug names reduced identification accuracy, especially when the neighboring names were frequently prescribed. When one name was substituted for another, the substituted name was almost always a more frequently prescribed drug. Objectively measurable properties of drug names can be used to predict confusability. The magnitude of the noise and familiarity effects suggests that they may be important targets for intervention. We conclude that the ability of clinicians and lay people to identify spoken drug names is influenced by signal-to-noise ratio, subjective familiarity, prescribing frequency, and the similarity neighborhoods of drug names.

Introduction

In clinical medicine, the risks of misinterpretation of telephone orders are widely recognized (Koczmara, Jelincic, & Perri, 2006; Pennsylvania Patient Safety Authority, 2006; The Joint Commission, 2008). The use of the telephone to communicate medication orders leads to error because of both ambient noise and the limited bandwidth of most telephones (Aronson, 2004; Hoffman & Proulx, 2003; Lambert, 2008; Rodman, 2003; Wiener, Liu, Nelson, & Hoffman, 2004). Telephones typically carry signals between 300 Hz and 3 kHz, a much narrower bandwidth than that of FM radio (30 Hz–15 kHz) or CD audio (20 Hz–20 kHz), whereas much of the important acoustic information that allows people to distinguish between similar consonant sounds lies above 3 kHz and is missing entirely from the telephone signal (Rodman, 2003). There are 3.8 billion prescriptions dispensed in outpatient pharmacies annually in the United States (IMS Health, 2008). Telephone orders account for 3–4% of retail prescription volume. This translates to 114 million telephone prescriptions annually, or 312,000 per day. One study of 813 telephone orders to two chain pharmacies found that the wrong medication name was transcribed in 1.4% of the orders (Camp, Hailemeskel, & Rogers, 2003). The 1.4% rate may not be a generalizable estimate, but given the number of opportunities, even a very low error rate would translate into a large number of errors.

Spoken orders were once common in inpatient settings also, although less so after accrediting agencies pressed for their elimination. One 346-bed hospital counted 4197 medication-related verbal orders in a seven day period (Wakefield et al., 2008). Hospital pharmacists reported 35 min of every 8 h shift were spent resolving problems with spoken orders (Allinson, Szeinbach, & Schneider, 2005). Respondents identified “people talking in the background” and “background noise” as the greatest barriers to the correct processing of spoken orders. Other factors included lack of familiarity with the patient's clinical condition or the medication, bad connections and excessively rapid speech (Allinson et al., 2005).

The use of cell phones and voicemail and the noisy environments in which orders are sent and received increase the risk of spoken prescription orders being misperceived. There are many

* Corresponding author. University of Illinois at Chicago, Department of Pharmacy Administration, 833 S. Wood Street (M/C 871), Chicago, IL 60612-7231, United States.
E-mail address: lambertb@uic.edu (B.L. Lambert).

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examples of auditory perception errors, some with fatal consequences (e.g., Liquibid vs. Lithobid, Cardene vs. codeine, Lopid vs. Slobid, erythromycin vs. azithromycin, Klonopin vs. clonidine, Viscerol vs. vistaril, Orgaran vs. argatroban) (Allinson et al., 2005; Dr. orders Liquibid–Lithobid dispensed – death results. Case on point: Clifford v. Geritom Med., Inc., 681 N.W.2d 680-MN (2004), 2004; Koczmara et al., 2006; Pennsylvania Patient Safety Authority, 2006; Vivian, 2004).

Identifying the factors that influence accuracy in the perception of spoken drug names may facilitate interventions designed to make telephone orders safer. The U.S. Food and Drug Administration and the pharmaceutical industry have struggled to develop methods for evaluating the confusability of new drug names (U. S. Food and Drug Administration, 2008). Objective measures of similarity and prescribing frequency can reliably predict the probability that two names will be confused in visual perception and short term memory (Lambert, 1997; Lambert, Chang, & Gupta, 2003; Lambert, Chang, & Lin, 2001b; Lambert, Donderi, & Senders, 2002; Lambert, Lin, Gandhi, & Chang, 1999; Lambert, Yu, & Thirumalai, 2004), and processes have been described for designing safer drug names (Lambert, Lin, & Tan, 2005). One important part of that process is to use established experimental paradigms from psycholinguistics to evaluate the confusability of proposed drug names in relevant tasks (e.g., auditory perception, visual perception, and short term memory). An earlier study of noise and pharmacy dispensing errors found, counter-intuitively, that noise improved performance but recommended that more controlled experiments be done to clarify the relationship between noise and error rates (Flynn et al., 1996). In this study, we sought to demonstrate how this type of experimentation could shed light on the factors that influence auditory perception of drug names. Thus, one of the key challenges we addressed was to translate the basic science of auditory word perception into the applied domain of drug name confusion. The work was designed to determine how and to what extent characteristics of drug names, order takers, and practice environments affect a listener's ability to identify spoken drug names.

Auditory word perception

To explain auditory perceptual confusions, we used Luce's Neighborhood Activation Model (NAM) (Grossberg, 1986; Luce, Goldinger, Auer, & Vitevitch, 2000; Luce & Pisoni, 1998; Vitevitch & Luce, 1999). According to this model, stimulus input activates a set of similar sounding acoustic-phonetic patterns in memory. The activation levels of the acoustic-phonetic patterns are a function of their degree of match with the input. In turn, these patterns activate a set of word decision units tuned to the acoustic-phonetic patterns. The word decision units compute probabilities for each pattern based on the intelligibility and frequency of occurrence of the word to which the pattern corresponds and the activation levels and frequencies of occurrence of all other similar sounding words in the system. The word decision unit that computes the highest probability wins, and its word is what is heard. In short, word decision units compute probability values based on the acoustic-phonetic similarity of the word to the input, the frequency of the word, and the activation levels and frequencies of all other similar words activated in memory.

The NAM predicts that multiple activation has consequences: Spoken words with many similar-sounding, higher frequency (or more commonly occurring) neighbors will be processed more slowly and less accurately than words with few neighbors. These predictions have been confirmed in many studies: Words in densely populated, high frequency similarity neighborhoods are indeed processed less quickly and less accurately than words in low density, lower frequency neighborhoods, and words with higher frequency of occurrence are processed more rapidly and accurately than lower frequency words (Jusczyk & Luce, 2002; Lambert et al., 2003).

The NAM employs an explicit mathematical function that attempts to predict auditory perceptual errors based on the intelligibility of stimulus word, the frequency of occurrence of the stimulus word, and the similarity and frequency of neighboring words. This function is known as frequency-weighted neighborhood probability (FWNP, or neighborhood probability). Detailed mathematical descriptions of the function used to compute neighborhood probabilities for each name are given elsewhere (Jusczyk & Luce, 2002; Lambert, Lin, Toh et al., 2005). Other things being equal, neighborhood probabilities will increase as the number, similarity, and prescribing frequency of neighbors decrease. The Neighborhood Activation Model provided the framework for the development of several hypotheses about auditory perception: (1) Accuracy will increase as neighborhood probability increases; (2) Accuracy will increase as the signal-to-noise (S/N) ratio increases; (3) Accuracy will increase as objective prescribing frequency of the target name increases; and (4) Accuracy will increase as subjective familiarity with the target name increases.

Although frequency and neighborhood effects are well established in the study of ordinary words, we sought to extend this understanding in three ways. First, we planned to study proper names from a large, finite set of words, namely the closed-set lexicon of drug names, given that most previous work has been done with open-set word lists (Clopper, Pisoni, & Tierney, 2006; Sommers, Kirk, & Pisoni, 1997). Second, we wished to study multisyllabic words rather than the monosyllabic (often consonant-vowel-consonant) words that have typically been used in studies of neighborhood effects. That required us to develop measures of similarity and new measures of neighborhood probabilities for multisyllabic words (Lambert, Lin, Toh et al., 2005). Third, we wished to see whether the neighborhood effects would be present in both experts (clinicians) and novices (laypeople). We expected neighborhood effects in experts because, presumably, they would possess lexical representations (i.e., mental word lists) of large numbers of drug names, and these representations would compete in the manner described above. We thought neighborhood effects might be attenuated or absent in laypeople, who may lack representations for most drug names and hence would not experience the competition that causes neighborhood effects.

Even if we were not making any original contribution to the basic science of auditory perception, we believe that the model provides a powerful conceptual and experimental framework for understanding drug name confusion, one that could advance worldwide efforts to predict and prevent such errors. Thus, the present paper is offered as an example of translational research, where concepts well-known to one community are applied to problems in a different domain (Woolf, 2008).

We attempted to control for a large set of factors that might be associated with name confusion error rates. Among these was the type of name (brand or generic). One might expect brand names to be more confusing since they are typically shorter (Lambert, Chang, & Lin, 2001a), and shorter names tend to have more neighbors (Andrews, 1997; Luce & Pisoni, 1998; Storker, 2004). Conversely, generic names use a common system of stems (i.e., suffixes) which tends to increase their average similarity to one another, thereby increasing their confusability (Lambert et al., 2001a). Either way, the distinction between brand and generic names is an important one in practice, so we designed our experiments to take it into account.