The role of perception in Medication Errors : Implications for Non-Technological Interventions

Wg Cdr Narinder Taneja*, Douglas A Wiegmann⁺

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Background

A medication error has been defined as “any preventable event that may cause or lead to inappropriate medication use or patient harm while the medication is in the control of the healthcare professional, patient or consumer”[1]. The inappropriate use of medications has been estimated to account for 19.4% of all iatrogenic injuries in the Medical Practice Study and is thus a cause for concern [2]. However, different methodologies adopted by researchers have made it difficult to estimate the true incidence of medication errors, which therefore remains controversial. Lesar found an error rate of 3.99 errors/1000 medication orders in a 631 bed tertiary care teaching hospital [3]. Bond et al [4] reported a medication error every 22.04 hours (every 19.13 admissions) in a UK hospital. The fact that approximately 50% of the 1.8 billion prescriptions are used incorrectly in the United States (US) reflects the possible potential for adverse outcomes [5]. Such medication errors are believed to be responsible for 7000 deaths per year [3]. The financial cost of drug related morbidity and mortality to the American healthcare system has been estimated to be between \$76.6 and \$136 billion annually [6].

Errors can potentially occur at any of the steps in the medication process, which comprises ‘prescribing, transcribing, dispensing, administering and monitoring’[7]. Steps of this process would differ to some extent between the inpatient and outpatient settings, as well as among different healthcare organizations depending on the use of technology and automation. Of these, the prescribing stage has been reported to be the most susceptible to errors, accounting for 49% of serious medication errors, followed by stages of administration (26%), dispensing (14%) and transcribing [7]. Factors associated with prescribing errors include calculations of drug dose [8-12], errors in decimal points [8-13], medications with similar names [13-15], medication dosage forms (controlled release vs. non controlled

release) [13-16], and use of abbreviations [17]. A recent study discusses the issue of medication errors in the Indian Armed Forces Medical Services and cites drawbacks in handwritten prescriptions [18].

Recommended intervention strategies are largely dependent upon technology or automation. These include Computerized Physician Order Entry (CPOE) and Computerized Decision Support at the prescribing stage [7]. The former measure has been reported to reduce serious medication errors by almost 55% [19]. Measures suggested to minimize errors in the dispensing stage include the use of robots, bar coding of medicines and automated dispensing devices [19]. Non-technological measures that have been implemented include the risk assessment of name confusion of new drugs with existing drug names. Adverse event reporting is another measure targeted at early identification of potential problems [20].

Purpose of Present Paper

While the introduction of above measures has undoubtedly generated hope that the incidence of medication errors could be reduced significantly, it is important to note that ‘electronic solutions’ are not a panacea by themselves [7]. A large part of healthcare around the world is still dependent on simple hand written prescriptions and manual dispensing and administration [18]. Introduction of widespread cost-intensive technological interventions in healthcare therefore is not always feasible. It is therefore, pertinent to understand medication errors from a perspective such that effective solutions that are not technology dependent are developed. The purpose of this report is to understand the perceptual mechanisms underlying medication errors and base interventions on sound knowledge of information processing characteristics.

Medication Errors as Errors of Perception

The majority of medication errors as discussed above that result from sound alike, look-alike drugs or the use of decimal point or abbreviations can be classed as errors

*Classified Specialist (Aviation Medicine), Institute of Aerospace Medicine, Indian Air Force, Bangalore. ⁺Associate Professor and Associate Head, Aviation Human Factors Division, Institute of Aviation, University of Illinois at Urbana-Champaign, USA.

of perception. Perceptual errors occur when the sensory input is either degraded or unusual [21]. Eliminating the human element from the process may be a possible solution. However, this may not be feasible under all circumstances or in all organizations. A different approach to perceptual errors involves understanding limitations of the information processing capabilities of the human being. We do not therefore discuss medication errors that can be categorized as skill based or decision errors. A brief discussion of the information-processing model would be essential to understand the genesis of such perceptual errors in medicine and the theoretical basis of suggested interventions.

General Information Processing Model

Information processing in humans occurs in various stages [22]. The first stage involves the sensation from various stimuli in the external environment. These sensations could be visual or auditory that are stored in a short-term sensory store from where they are then perceived. This stage of perception, termed pattern recognition, involves giving meaning to the multitude of sensory stimuli that are presented to us. Decision and response selection stages followed by response execution, constitute the next two stages within the information processing system.

Perception is affected by top-down and bottom-up processes influences [22]. Bottom-up processing implies lower level of stimulus processing moving up towards the higher brain centres involved with perception and understanding. Factors such as poor contrast and poor illumination affect bottom-up processing of visual stimuli. Any measure that improves the visibility, legibility, and discriminability of an object will enhance bottom-up processing. Top-down processing, on the other hand, is perception based on our knowledge or experience of what should be there. Based on our past experiences and knowledge, we develop a set of expectancies about how objects in the world should appear. Correct perception thus, results from interplay of top-down (what should be there) and bottom-up (what is there) influences. While generally these two work harmoniously, errors can occur when one of these influences is degraded and the other is erroneously applied. Fig. 1 provides a framework to explain the relation between top-down and bottom-up processing, medication errors and potential interventions.

Medication Errors due to possible erroneous Bottom-Up Processing

Wrong dose of a correct drug may be administered because of an error in reading and perceiving a decimal

Fig 1 : Framework of top-down and bottom-up processing

point, rate expression, unit of measure or calculation of dose. Errors in reading a decimal point have long been documented. A 10-fold dosing error resulted in death when Digoxin .09 mg was misread as 0.9 mg [1]. Levothyroxine sodium 5 mg has been administered instead of 0.05 mg [3]. On the other hand, placing a zero after a decimal point can also cause confusion. 1.0 mg written for 1 mg can be misread as 10 mg if the decimal point is not noticed [23]. Degraded bottom-up processing can explain such misperception under conditions of poor lighting or glare or inadequate contrast or discriminability among labels. While CPOE could solve this confusion, proper prescription writing would also likely mitigate this problem [18]. The prescriber/dispenser, however, needs to be aware of these potential lapses in perception.

Misperception and confusion between units of measure can occur when 2 tablespoons of a pediatric medicine is administered instead of 2 teaspoons. Such errors may be potentially dangerous when using medicines with low therapeutic safety margins. The abbreviation U or u, implying unit has occasionally been read as zero (0) or a four (4) causing a 10 fold overdose or even greater (4U seen as 40 or 4u seen as 44) [24].

Miscalculation of dosage of medications is also commonplace. In one incident, ampicillin 300 mg/kg every 6 h was administered instead of 300 mg/kg per day in 4 doses [3]. Such calculations of doses are especially likely in cancer chemotherapy [3], where protocols are often expressed as a cumulative dose that is divided and administered over a period of several days. An example in case is the fatal outcome when a patient received cisplatin 100 mg/m² of body surface area/day for four days, instead of a cumulative prescribed dose of 100 mg/m² of body surface area over a period of 4 days [1].

There can also be confusion in the frequency or route of administering medications. An elderly patient received methotrexate daily rather than the intended weekly dose for rheumatoid arthritis, resulting in patient death [3]. A medication prescribed q.o.d or QOD for every other day has been misinterpreted as q.d (daily) or q.i.d (four times daily) if the 'o' is poorly written [24]. Examples of wrong route administration include SC (subcutaneous) and SL (sublingual), IU (international unit) and IV (intravenous) and vice versa [24].

Confusion between similar packing for premixed intravenous solutions has also been reported. Heparin or lidocaine mistaken for hetastarch is an example of such confusion. Similar packaging between doxil (liposomal doxorubicin) and doxorubicin hydrochloride may have been responsible for a reported fatal medication error [1].

Medication Errors due to possible erroneous Top-Down Processing

Errors subsequent to top-down processing could occur when expectancies based on experience of the physician/care provider fill in gaps in the audiovisual sensory inputs they receive. When top-down processing and expectancies influence auditory stimuli, it would generally involve sound alike names. It is estimated that errors due to sound-alike names of drugs may account for almost one-fourth of all errors, especially in an outpatient setting [25]. Alupent (metoprolol sulfate) administered instead of atrovent (ipratropium bromide) or dicloxacillin instead of doxycycline, and losec instead of lasix because of similarity in auditory stimulus are some examples of sound-alike names [3].

Similarity between look-alike drugs could be influenced by top-down processing through visual stimuli. The written names of some drugs look very similar and can cause confusion such as hydroxyzine and hydralazine. Coumadin and cogentin have been confused resulting in fatal bleeding, when coumadin 5 mg was erroneously dispensed for cogentin 0.5 mg [1]. Stemmed names of drugs can also be a source of top-down confusion error e.g., nitro drip could imply nitroglycerin or sodium nitroprusside infusion, or norflox could imply norfloxacin or norflex [24].

Medication Errors due to both Top-Down and Bottom-Up Processing

It would be naive to say that all perceptual errors can be differentiated as occurring either because of top-down or bottom-up influences only. On occasions, both processes may influence perceptual processes resulting in medication errors. For example, consider a situation where both saline and potassium solution are available in the medication tray. Both of them have similar packaging features [26]. Expecting to find saline solution at the usual location (should be there) a nurse picks up the bag and administers to the patient (believing it to be saline). It is very likely that this solution was potassium and not saline. Both bottom-up (similar packaging, similar appearance) and top-down processes (should be there, always there) can result in a serious medication error.

Interventions

No concrete data exists on the magnitude of medication errors in different parts of the world, especially those that may not be so technologically advanced. It may however, be reasonable to consider that published data from one country would be a fair, if not an accurate representation of the problem across all healthcare organizations. Therefore, efforts to minimize such errors assume significance and priority. While appearing simplistic, non-technological interventions to

prevent medication errors due to erroneous perception involves a comprehensive and integrated approach. These interventions can be categorized into the following:

Training

The initial, recurrent and refresher training of physicians and healthcare professionals is crucial in any attempt to minimize such medication errors. Training junior doctors on how to determine the correct dose of a drug and its frequency and mode of administration will enable appropriate mental models and expectancies to be developed so that despite degraded bottom-up processing, appropriate top-down processing will prevent errors. This should be imparted during the initial training years at medical school reinforced during the clinical rounds so that correct practices are imbibed and developed.

It has also been observed that physicians do not ascribe due significance to the task of prescribing drugs [27]. It is common practice during ward rounds that the consultant instructs the patient to be placed on a certain drug without actually communicating the dose, route, form or duration etc. The junior physician has to fill in all these details based on his/her limited experience. This can lead to erroneous top-down processes in medication errors. There may be a case for introducing a module in human factors in team communication and coordination in the training curriculum of medical students.

Awareness of the Problem

Increasing awareness among healthcare professionals of the nature and mechanisms of such medication errors can possibly lead to early detection of potential errors. Dean et al [27] reported that physicians were often not aware of their prescribing errors, which is surprising given the high incidence of errors detected in medication orders. It is unlikely that these professionals would develop an appreciation for the possibilities and enormity of such errors during their training. Integrating such knowledge in their training would certainly minimize opportunities for committing error and maximize those of error detection. This can be achieved by introducing some component of human factors education during the medical school curriculum. Pending such integration, this awareness could be brought about during education of relevant pharmacological principles.

Standardization and use of Terminology/Abbreviations

While the best intervention strategy is to avoid altogether the use of any sort of abbreviation in the medication process, such a suggestion may not find universal acceptance. The suggested measures therefore

aim at ensuring that uniform standardized terminologies are adhered to during prescribing, dispensing and administration. The Armed Forces Medical Services could show the way by developing guidelines for use of standardized abbreviations by all medical officers. For example, it is recommended to place a zero before the decimal point for doses of less than one unit, and not to use terminal zero for doses expressed in whole numbers [24].

Regulatory Role

The potential for two drugs to be confused because they sound alike or look alike can be minimized if a regulatory body can conduct such risk assessments. The pharmaceutical industry in the US voluntarily submits names of new drugs to the Institute of Safe Medication Practices (ISMP) that assesses the potential for confusion [7]. Similar practices should be developed in healthcare organizations that are not so technology intensive. A possible step could be awareness and risk assessment at the time of procurement of medical drugs in the Armed Forces. Incident reporting is another means to capture errors that may have not been foreseen. Some form of adverse event reporting systems or incident reporting can provide timely and crucial information in preventing future recurrences. Current issues and future directions in medical incident reporting have been discussed in detail elsewhere [20].

Human Factors input to System Process

Human factors is the science of integrating humans and technology. Literature has abundant basic research knowledge that can be applied to healthcare, particularly the pharmaceutical industry. Unfortunately, medical systems till now have developed piecemeal and never had any human factors input in their design [28]. It is imperative that if error in medicine has to be minimized, adequate human factors input is critical at every stage of each of its processes. Such input will certainly improve the bottom-up processing and minimize errors related to degraded sensory input.

One human factor principle to minimize medication error is for the physician to ensure that the prescription is 'user-centred'. The prescription as a mode of communication should be explicit such that the patient should understand each and every component of the prescription. Physicians should realize that everyone involved in the medication process might not understand technical abbreviations employed by the medical community. Other suggested measures include the use of magnifying lens or copyholders by dispensers under all levels of lighting conditions [29]. Good ergonomics to ensure that reading is always at the eye level is also essential if perceptual errors during transcribing and

dispensing are to be minimized.

Visual stimuli to differentiate names of similar looking products can be effected in various ways. Changing the appearance of look alike names by highlighting, bold or different fonts, and use of colour are few of the suggested methods to enhance discriminability. Altering parts of names that are different (e.g. hydroxyzine and hydralazine) can also minimize confusion between look alike names [29]. Using name alert labels when storing look alike/sound alike products has been shown to minimize dispensing errors [29].

Error during telephonic orders or messages for medications can be minimized by a process called "read back" and widely employed in aviation [7]. Such a read back requires the recipient to report back the entire message and has been documented to reduce communication errors in aviation. Its potential to minimize perceptual errors in medication has yet to be explored.

Conclusion

Medication errors constitute a significant burden to the society in terms of individual morbidity and mortality. They also have tremendous financial implications and may thus influence the eventual cost of healthcare. But, while cost intensive technological interventions are possible in healthcare organizations where financial resources may not be a consideration, they may have limited applications in organizations where such financial resources are not available. Non-technological interventions based on an understanding of how the human brain perceives and processes information have the potential of addressing a category of medication errors that we have labelled as perceptual errors. Constant endeavours to evaluate such interventions may provide cost-effective solutions in the non-technology enriched environment.

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