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Residents' numeric inputting error in computerized physician order entry prescription

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ABSTRACT

Background: Computerized physician order entry (CPOE) system with embedded clinical decision support (CDS) can significantly reduce certain types of prescription error. However, prescription errors still occur. Various factors such as the numeric inputting methods in human computer interaction (HCI) produce different error rates and types, but has received relatively little attention.
Objective: This study aimed to examine the effects of numeric inputting methods and urgency levels on numeric inputting errors of prescription, as well as categorize the types of errors.
Methods: Thirty residents participated in four prescribing tasks in which two factors were manipulated: numeric inputting methods (numeric row in the main keyboard *vs.* numeric keypad) and urgency levels (urgent situation *vs.* non-urgent situation). Multiple aspects of participants' prescribing behavior were measured in sober prescribing situations.
Results: The results revealed that in urgent situations, participants were prone to make mistakes when using the numeric row in the main keyboard. With control of performance in the sober prescribing situation, the effects of the input methods disappeared, and urgency was found to play a significant role in the generalized linear model. Most errors were either omission or substitution types, but the proportion of transposition and intrusion error types were significantly higher than that of the previous research. Among numbers 3, 8, and 9, which were the less common digits used in prescription, the error rate was higher, which was a great risk to patient safety.
Conclusions: Urgency played a more important role in CPOE numeric typing error-making than typing skills and typing habits. It was recommended that inputting with the numeric keypad had lower error rates in urgent situation. An alternative design could consider increasing the sensitivity of the keys with lower frequency of occurrence and decimals. To improve the usability of CPOE, numeric keyboard design and error detection could benefit from spatial incidence of errors found in this study.

1. Introduction

Computerized physician order entry (CPOE) is a key health information technology in healthcare [1], in which clinicians directly enter medication and other orders into a computer system instead of using paper [2]. Although the implementation of CPOE has proven to be a significant improvement on medication safety by reducing prescribing errors [3–5], Nanji et al. [6] still found about one in ten computer-generated prescriptions included at least one error, of which a third had potential for harm. Most of these medication errors were associated with drug doses (68.5%) [7]. Fatal cases have been reported due to numeric entry errors in the popular drug delivery system used in hospital [8]. Health services organizations were seeking to implement computerized order sets to reduce unnecessary practice variation [9,10]. However, overall, the top 20% of order sets accounted for 90.1% of all usage [11]. The integration of Human Factors was still insufficient in the design and implementation phases of CPOE, which was a complex interactive system [12]. The physicians need to input many numbers frequently by keyboard, especially in chemotherapy departments, pediatrics and operation departments. Actually in the clinical settings, the orders are entered into the CPOE either by same or by different person

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who collected them during the visits in the ward. Junior doctors spent most of their after-hours prescribing time transcribing other doctors' orders [13].

Computers were the main equipment used in CPOE operations, including the desktop, laptop, tablet computer, and mobile phone. Despite the advances of computer system processor speed and memory capacity, improvements on input and output equipment were limited. Doctors conducted 93.6% of tasks using stationary PCs, most often within the doctors' office [14]. Touchscreen order system, tablet computer or mobile phone application software, which were still under CPOE supplier's research, have not been widely used in clinical settings. Other alternative data entry devices, such as automatic speech recognition, may be used to avoid manual typing, but they may not have any advantages in error rates and data entry speeds when compared with standard numeric keyboards for numeric data entry [15].

Numbers were often typed based on visual information within a prescription. Residents recorded orders in a ward round and routinely entered orders into CPOE, which assembled the process of transcription typing. In transcription typing, skilled typists can make use of permanent visual presentation to create a running buffer of encoded stimuli (preview) for parallel processing. Therefore, they can self-pace type without feeling much time pressure imposed by the feeding of information [16]. Previous studies in numeric typing have focused on single numbers in hear-and-type tasks [16] and the role of working memory in memorize-and-type tasks [17–19]. The physician would input the orders in another mechanism and have different error patterns. First, inputting order was a combined action of inputting letters, inputting numbers, mouse clicks, and drop-down menu selections, which was a much more complex interaction than the former experimental research that focused on only one typing mechanism. Secondly, the numbers in orders were meaningful to the physician. They were not only digit strings compromising numbers and decimals, but also the drug dosage familiar to the physician.

There were many factors affecting numeric inputting error, including numeric inputting keyboard layout. Many improvements on numeric keyboards have been made to reduce numeric inputting errors. Yan [20] arranged the numeric keys in the middle of the keyboard to provide numeric information and letter keys separated on both sides of the keyboard. Yang [21] used a counter keyboard according to ten colors of a color scale resistor, where each color presented a value for inputting color data. Although these improvements have promoted high inputting speed and have helped reduce inputting error, it was impossible for medical staff to spend a large amount of time to get familiar with these special keyboards. Currently, standard keyboards are widely used in wards. The physician inputs numbers either by number keypad in the small keyboard or by number row in the main keyboard when prescribing in CPOE.

Another important aspect to take into consideration in our experiment was the urgent situation in medical settings. It is generally acknowledged that health care workers have experienced the rescue of critical patients or other time pressure, such as overload or several clients waiting for treatment at the same time. Erroneous keystrokes were possibly caused by an operator's psychophysiological state such as a lack of attention, external distractions, and fatigue [22]. Zenziper et al. [3] found that a large volume of drug prescriptions was associated with a high rate of potential prescription errors, which are common in hospitalized patients and may lead to high significant morbidity, mortality and financial costs. Magrabi et al. [23] examine the effects of interruptions and task complexity on error rates when prescribing with computerized provider order entry (CPOE) systems, and found that complex tasks took significantly longer to complete. In addition, the study found that when execution was interrupted they required almost three times longer to resume compared to simple tasks. It was very difficult in the laboratory to imitate the emergency in the actual medical environment. A recent study in numeric typing succeeded in using different monetary rewards to manipulate levels of urgency realized by users [16].

The goal of this study was to address the following research questions through an experimentation in which confounding factors in speculation and practice effect were eliminated. First, do residents perform differently using the number keypad versus numeric row in main keyboard in the context of CPOE numeric typing? Second, does the daily prescription behavior lead to higher error rates and imply an inherent difficulty in using other typing strategies? Third, is urgency level an influential factor to consider when it comes to choosing a numeric input method?

2. Material and methods

2.1. Participants

Thirty residents (14 males and 16 females, ages 20–32, with an average age of 24.77 ± 2.60 years old) were recruited via a call for volunteers advertised on the hospital's notice boards. All the participants signed informed consent before the experiment. Each participant was paid for her/his participation.

2.2. Experimental variables

The experiment was comprised of four trials of prescribing tasks, which emulated daily prescription work in a ward. The numeric inputting method variable had two levels: (1) inputting with the numeric row in the main keyboard in which participants could only input numbers using the numeric row in the main keyboard, with a mask covering the numeric keypad portion of the keyboard, and (2) inputting with the numeric keypad in which participants could only input numbers using the numeric keypad, with a mask covering the numeric row portion in the main keyboard. Urgency was manipulated according to the same urgency manipulation method used in our published work in numerical typing area [16]. In that study, we have successfully manipulated urgency levels by two different compensation policies including a flat-rate payment and a performance based reward: in non-urgent situations, the participant received a flat-rate payment independent of her/his performance (15 dollars). In urgent situations, the participant's reward was contingent upon her/his performance for both accuracy and speed. Only correct rates over 90% within 300 s counted as 'passes'. Under urgent conditions, a successful participant could obtain twice the money (30 dollars) that she/he could get in non-urgent trials. To further assure that participants experienced urgency, a countdown counter of 300 s was in the right corner of the screen to emulate what physicians might experience in a clinic if they were stressed by the competitive work, such as a critical condition, operation or clients' complaint.

The dependent variable was mean error rate. When the physician order input in the CPOE did not match the corresponding order presented, or when parts of the physician order were omitted, an error had occurred.

2.3. Experimental task and procedure

Each participant was advised to complete a self-reported questionnaire, a pretest of performance, a sober prescribing exercise, and four trials of prescribing tasks in CPOE system.

2.3.1. Self-reported measures

All participants were asked to complete the following self-reported measures on-site before engaging in the CPOE prescribing task.