The Influence of Emotion on Number Entry Errors

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ABSTRACT
Given the proliferation of devices like infusion pumps in hospitals, number entry and in particular number entry error is an emerging important concern in HCI. There are clearly design features that could greatly improve accuracy in entering numbers but the context of the task could also play an important role. In particular, the emotional state of a person is known to strongly influence their response to a difficult situation and hence the errors that they make. In this paper, we consider the impact of the emotional state of the user on the accuracy with which people enter numbers. Our experiment shows that participants who are in a more positive emotional state are more accurate. The effect is small but could be very important when considering the potentially highly-charged emotional contexts where many healthcare devices are used.

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Number entry; human error; affect; healthcare

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H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

General Terms
Human Factors; Performance.

NUMBER ENTRY ERROR

Number entry is a ubiquitous daily task for many people whether it is needed to use a PIN for a cash card or data entry as part of a job. Given human nature, errors are inevitable from time to time and in many situations, and they are usually little more than an inconvenience. But in the medical context, an incorrect number entered into a drug delivery device can have serious consequences, potentially the death of the patient. For example, a baby in intensive care died after a nurse mistakenly gave it 10 times the dose of calcium it needed. To add to the tragedy, the nurse also later took her own life despite this being the only serious medical mistake that she ever made [1]. Indeed, a large proportion of adverse drug events are believed to be due to numerical errors. [15].

Naturally, this has become an important topic for research into solutions, such as, in the interface design of the devices used [11], in the underlying software of the devices [14] and alterations to the task to include redundancy [18]. What has been harder to look at is the context in which the devices are used. There is evidence that how the devices are used varies enormously within the different medical domains [17]. However, capturing sufficiently many errors with the contextual richness of a functioning hospital environment remains elusive. Here, we therefore focus on aspects of the context that may be reliably manipulated in the more controlled setting of an experimental study. In particular, affective state has been shown to be an important factor in understanding how people react in safety-critical situations as discussed below but this has not been investigated at all, to the best of our knowledge, in the context of number entry error. Therefore, because healthcare can be a particularly emotive environment, we conducted an experiment manipulating the affective state of participants to investigate if, in principle, it may influence the rate at which people make number entry errors.

EMOTION AND ERROR

Emotion is an integral part of human rational behaviour [3]. It is aroused by external events, and reactions or responses are directed towards these events. From a psychologist's point of view, emotion points to a domain of phenomena of feelings, behaviours and bodily reactions [4]. Affect is most usually considered to be a two-dimensional construct [5] with the typical dimensions used being valence, that is whether the emotional state is positive or negative, and the degree of arousal associated with the emotion. So a highly aroused negative state corresponds to anger whereas a low aroused positive state would be something like contentment.

Emotional state is known to influence people's thinking. Common findings suggest that negative emotions make people avoid the task that produces negative emotions and impairs the processing efficiency in a cognitive task [3]. Similarly, Ashby et al. [2], reports that positive affect is associated with flexibility in reasoning, greater creativity in problem solving and seeking out variety. As a consequence, the affective state of people is able to influence their interactions with digital devices. For instance Aula and Surakka [3] showed that synthetic positive feedback improved the speed with which people completed simple arithmetic tasks over either neutral or negative feedback.

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Klein et al. [9] also showed that, in a game which provoked frustration, if the system gave the appearance of acknowledging the frustration, then participants were subsequently willing to play the game for longer.

When it comes to human error, it is recognized that how people make errors and respond to errors, particularly in safety critical environments, is substantially influenced by their affective state. For example, Causse et al. [6] demonstrated in a controlled study that negative emotional states can provoke plan continuation errors in pilots, meaning they are more likely to continue acting even when available evidence indicates they should stop. Similarly, Jeon et al. [7] demonstrated that there are behaviour changes when a driver is in different emotional states such as anger and fear, even when those states share the same emotional valence. It is also the case that negative emotions can have positive impacts, with Peters et al. [12] showing that a state of worry is a good predictor as to whether people will take precautions to avoid error. However, when it comes to the small-scale tasks, such as number entry, relatively little is known.

EXPERIMENT

The aim of the experiment is to see whether the affective state of users is a possible influence in the number entry errors that they make. The specific hypothesis here is that people who are in a negative affective state will make more errors than those in a more positive affective state. The level of arousal is not considered here, partly because it is difficult to manipulate but also because there are ethical concerns with putting someone into a highly aroused negative state (ie making them very angry). In order to conduct error studies with a lab-based experiment, it is necessary to provoke an observable error rate and this has implications for the ecological validity of the work as will be discussed.

Design

This was a between-participants design to avoid learning effects and the possibility of the experimental manipulation having effects in more than one condition. The independent variable is the affective state of the participant. A standard way to influence affect is the use of the International Affective Picture System (IAPS) [10]. This is a database of images that have been validated for inducing different levels of affect in both the valence and arousal dimensions. Each image has a standardised score on each dimension between 1 and 9, with 5 indicating neither positive nor negative valence. The intention was to use positive valence images to induce positive affect and negative valence images to induce negative affect. However, the negative valence images are, not surprisingly, somewhat disturbing being images of mutilation, injuries and people in distress and some of the positive valence images have erotic content. Therefore, to avoid unduly stressing participants or making them feel awkward, images were selected first for content and the very negative valence images were avoided. This made the conditions asymmetric about the neutral rating: images in the negative valence condition were rated between 2 and 4, whereas in the positive condition they were rated above 7. One exception is an image of a member of the skinhead subculture which has a mean valence of 1.64 for women. The IAPS is separately scored for men and women but we deliberately chose images that had similar affective valences for both sexes and our analysis did not distinguish between men and women as this has not been previously observed as a potential factor in number entry errors.

The dependent variable is the number of errors made. Currently the extent and variety of number entry error is only just emerging, e.g. [16], so error here is treated simply as a person entering a number different from the number they were required to enter. They were able to correct errors they noticed in the course of entering a number using a backspace key. Also, to check the experimental manipulation, participants were asked to complete the Self-Assessment Manikin for affect [5]. This was converted to a number on the same scale as the IAPS measure of valence, from 1 to 9.

Participants

Twenty-eight participants, 14 in each condition, were recruited to the study by opportunity sample. All were students from The University of York at either Undergraduate or Masters level. The participants' ages ranged from 20 to 30 with a median age of 23. There were 20 women and 8 men.

Figure 1. The number pad interface used in the experiment (the arrow keys are not used in this study).

Materials

Two applications were used in the study. The first was a Microsoft PowerPoint presentation which was set up to display 24 images of either negative or positive valence depending on the experimental condition. In order to encourage participants to properly look at and consider the images, after seeing each image, participants were asked to rate how that image made them feel on a paper copy of the SAM affective valence scale.

The second application was Microsoft Excel which was used to randomly generate numbers and display them at

seven second intervals. Both PowerPoint and Excel were displayed on a 14.1 inch laptop.

Participants had to enter the displayed number into a tablet, a Google Nexus running Android 4.2, using a number pad touch interface to simulate using a keypad that might be found on a typical medical device, see figure 1. The 'C' key was used to confirm the number entered. Normally, 'C' indicates Clear the display and this was a potential source of confusion but after training, no such confusion was seen in the data.

The time limit of 7sec was used partly based on being a feasible time in which to enter a number of 6 or 7 digits as found in a pilot study but also to apply pressure to participants. Error rates in such studies can be very low [13] so some further manipulation, such as time pressure, is needed in order to make sure there are sufficiently many errors to allow a useful analysis.

Procedure

The participants were welcomed and told about the purposes of the experiment before signing the informed consent form. They were then briefed on the use of the SAM scale based on the briefing given in [10] and given a chance to try it on some example images. They were also shown how to use the number pad on the tablet.

When they were ready, participants were shown the 24 images for their particular experimental condition and asked to rate each one as they went along. After completing this, they moved on to the number entry task. They were instructed not to lift the tablet from the table and to use one finger to enter the number – this was to remove one potential source of variation between participants. They were given 51 randomly generated numbers to enter. Data was automatically collected through the number pad application.

Results

The 28 participants entered 1428 numbers in total and made 240 errors, or approximately 16.8%. Thus participants made a mean number of 8.6 errors (SD = 2.64), ranging from 4 to 15. As hoped with the experimental manipulation, a Mann-Whitney showed significant difference between the SAM ratings for the positive valence images (M = 6.87, SD = 0.53) and the negative valence (M = 3.69, SD = 0.45) conditions, $W(14,14) = 196$, $p < 0.001$.

Participants in the positive valence condition made a mean number of 7.4 (SD = 1.65) errors, while for the negative valence stimuli the mean number of errors was 9.7 (SD = 3.00), see also Figure 2. A Mann-Whitney also showed this to be significant, $W(14,14) = 55$, $p = 0.046$.

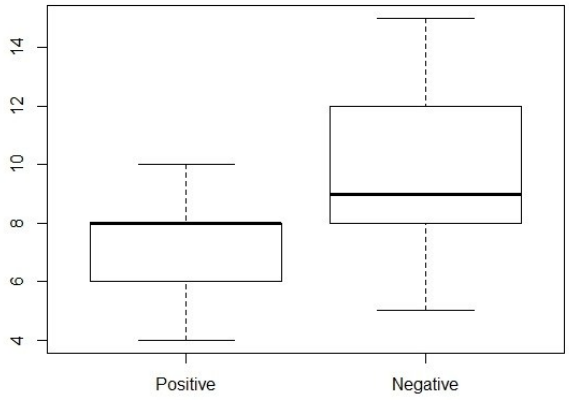

Figure 2. Boxplot of number of errors per participant against experimental condition.

DISCUSSION

As intended, the participants were able to appropriately attribute the expected valence to IAPS images. This suggests that the images were influencing the affective state of the participants and the experimental manipulation had worked. As a consequence, there was a significant effect of the affective state of the participants on the number of errors that they made.

The overall error rate is quite high. The error rate seen in number entry studies varies very much depending on the experimental tasks from between 2% [13] to 30% where the task is very challenging [16]. This suggests that the time pressure component made this into a somewhat challenging task, with an overall error rate of 16.8%, but this is not an unrealistic situation. In many health related situations, staff may find themselves trying to do tasks quickly either for the immediate well-being of the patient or because of the pressures of the job. What the limited time also does is prevent the possibility of a speed/accuracy trade-off. The participants in the positive valence condition cannot be more accurate because they took more time.

There are several issues of ecological validity which were compromises we felt necessary in order to be able to see if, in principle, affective state could influence number entry errors. Participants were required to enter many long numbers in quick succession. This is not how number entry is usually performed, at least not in the healthcare domain that motivates this work. However, without such techniques it is difficult to establish an appreciable error rate that could test the hypothesis. Number pads are also not the only style of interface seen in healthcare nor are they used exclusively with one-finger nor are they usual touchscreens. However, both the style of interface and style of typing are sources of variability in any such experiment and we chose to control rather than manipulate them in this early investigation. Touchscreens are a pragmatic tool for setting up experimental interfaces. It is hard to produce a physical replica of real devices suitable for experiments of this sort and, actually, with the proliferation of touch screen devices,

it may be that touchscreens do become more common in healthcare.

IAPS is also not a realistic reflection of how emotional state is induced in people. What the experimental manipulation does demonstrate though is that mere exposure to affective images is enough to influence performance on safety-critical tasks. In healthcare, not only do staff see distressing *real* situations, they may be actively involved in working with such situations. It may be important to manage staff's response to not only the most stressful situations resulting in PTSD [8], but also more generally emotive situations to reduce errors when treating patients.

Further work would of course be need to overcome the ecological limitations of the current work and see the effect across a range of number entry tasks on a variety of interfaces. We also have plans to work on number entry in a hospital setting and so have the opportunity to engage nurses as participants in our work and to better understand the richer context in which they work, particularly with regards to management of their affective state.

CONCLUSIONS

Motivated by the safety-critical nature of number-entry in the healthcare domain, this paper has described an experiment supporting that, in principle, users in a more negative affective state are more likely to make number entry errors. Though only in early stages, this work does provide evidence that the affective state of device users is an important consideration to address and manage when trying to reduce number-entry errors and could have important consequences for patient safety.

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