Simulation to evaluate alternative approaches to blocking use errors

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Background

Unnoticed user slips may contribute to adverse events, but medical devices can be designed to help detect and block some slips, thus enabling the user to take corrective action. Obviously different designs achieve this with greater or lesser success [1]. This paper shows how comparison of alternative design features for a "5-key" user interface (figure 1) can help reduce number entry errors. 5-key interfaces are widely-used because they look intuitive and require very little physical space.

Method

We compare a typical commercial design, the 5-key hours/minutes user interface of the Zimed AD Ambulatory Syringe Driver, with alternatives that: (1) start with the cursor at the far left **or** far right; (2) make the ▲/▼ buttons change the value by ± 1 in the relevant number position **or** independently rotate the number dials without carry; (3) eliminate ◀/▶ wraparound **or** permit a single keystroke to move the cursor from the far left to the far right and vice versa; (4) block errors **or** ignore them.

User tasks cover setting any time from 000:01 (1 minute) to 999:59 (almost 1,000 hours), so for random times (u, v) we determine the optimal key press sequence to change the device from showing u to setting v as a new value. It makes little difference to results if (u, v) is restricted; for example the Zimed maximum time is 299:59.

We then simulate keying errors (substitution, repetition, omission, transposition) in achieving the tasks with the probability of a keystroke error p an independent variable. Hence design choices can be evaluated, and here we measure the proportion of tasks completed with out-by-ten errors (i.e., the display is ≥ 10 or ≤ 0.1 times the target number). It is easy to use other measures.

The method also serves as a randomised unit test, the use of which would be good development practice in any case (e.g., for $p = 0$ errors are zero). Also, randomisation tests all "foreseeable misuse," as required by legislation.

Results

Selected results are shown in figure 2. Data was based on 10^9 simulations, taking approximately 3 hours of computer time in Mathematica, a slow programming environment. (Noisy results can be obtained much faster of course, and initial testing need only take a few minutes.) Equivalent human experiments are infeasible (and with human experiments p is a dependent variable that has to be carefully controlled). In fact, as can be seen, relative

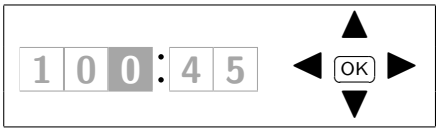

Figure 1. Typical 5-key number interface.

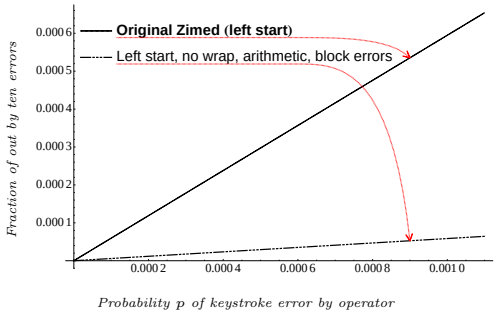

Figure 2. Impact of improving a user interface. Top line (solid) is original design. Lower line is 10.35 times better on this metric: cursor starts on left (as Zimed) but no wraparound, block errors & arithmetic dial.

improvements are essentially independent of the probability of user error, so human experiments with any particular p are not necessary.

Interpretation

Dependable user interfaces should be designed to eliminate design errors, but human evaluation cannot find all errors, and human experiments cannot be used as the only method for fault finding—they are better value-for-money to help refine "look and feel" issues. Formal techniques must be used to deepen the findings of human studies.

Healthcare needs to reduce preventable errors. If an error is not noticed, it cannot be avoided. This paper showed modifications to a standard number entry system can block certain errors—the user need not notice these errors if the system blocks them occurring—and the result is over 7 times reduction in the rate of out by ten errors caused by slips. Future work could embed the approach into a tool to systematically evaluate design alternatives.

Following the 1993/42/EEC directive, etc, and UK health and safety legislation, manufacturers should use such procedures to help reduce design-induced risks to be as low as reasonably practical (ALARP). Because the simulation evaluation is tool-based and so fast, it should be routine to include in iterative design processes. Since the method we have used is entirely computer based, it is easily converted into a tool (or made part of an existing tool or process) for any manufacturer to reuse for their own purposes.

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References

[1] Thimbleby, H. & Cairns, P. (2010). Reducing number entry errors: Solving a widespread, serious problem, *Journal of the Royal Society Interface*, **7**(51), pp1429–1439.