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HCI Challenges In Designing for Users with Disabilities

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ABSTRACT. Human-computer interaction (HCI) specialists propose methodologies for building interfaces to software applications. HCI emphasizes developing a deep understanding of user characteristics and tasks. As important as HCI is for designing programs used by the general public, it is even more important if the target audience is disabled. We designed software to be used in the Traumatic Brain Injury Program at a local hospital to assist the cognitive rehabilitation of patients with brain injuries. We gathered feedback from therapists and patients in the hospital environment to refine our product. The reactions of all users determined how successful we were at designing a program with such stringent requirements.

1. INTRODUCTION

The rehabilitation of Acquired Brain Injured patients at the Gorge Road Hospital (Victoria, B.C., Canada) has involved computer software as one component in the process. Original software was developed many years ago and contained the basic functionality for a set of ten activities, used either as part of the rehabilitation process or for assessment. No graphical interface was present and the software, while considered to be effective, presented itself no better than paper-based exercises. A new program, Indigo, was created, which incorporates all the activities and presents them in an effective manner, together with tools for scoring and feedback. Therapists need the system to evaluate, monitor, rehabilitate and for measurement purposes. The software needs to be repeatedly used and enjoyed both by the patients and by the therapists. The challenges to writing software to be used by such disparate groups are significant, particularly given the wide range of severity of the injuries suffered by the patients.

The activities were analyzed and restructured; they were significantly enhanced and new features added. The principles of HCI, the study of cognitive psychology, the characteristics of the patient population, and strict software engineering guidelines were all incorporated into the design process of Indigo. The therapists involved in the rehabilitation program were questioned to determine the results that were most important and represent the patients' abilities. Finally three sequential versions of the software were delivered and have been tested as extensively as possible. At the moment the software is ready to be distributed to other similar centers.

We report here on the process of developing Indigo from the point of view of the HCI issues as they relate to this special set of users: the disabled patients and the supporting therapists. While many items can be considered mainstream in the literature, their importance was enhanced by the special needs of the user group.

2. REQUIREMENTS

HCI is user-centered and accentuates the need for designing the visual representation of the program before focusing on the computing itself. A good interface design is extremely important for this group of disabled patients and their supporting therapists. This hospital unit is for Acquired Brain Injuries, which are all types of brain injuries acquired as the result of disease processes, ranging from MS (Multiple Sclerosis), strokes, and aneurysms, to traumatic brain injuries (typically as a result of motor vehicle accidents). As the software is part of a patient's therapy, they have no choice but to use it. Since the goal is to assess and retrain cognitive functions which worked normally before the brain injury, the patients are prone to suffer from very high frustration levels and poor concentration, so simplicity of use is critical and a primary objective is to spare the cognitive functions of the patients as much as possible by designing an easy system. Patients also suffer from a lowered threshold of indignation, which means that, if they do not enjoy using the program, they will quit early. On the other hand, the therapists are prescribing the program and

are responsible for setting it up and monitoring the patient's progress, thus they also have to feel comfortable. There are no alternative programs available, so we were compelled to develop an excellent product that could be used by other rehabilitation institutions as well as by patients working on their own.

These patients typically exhibit deficits in the following areas:

- Memory - specifically new learning is affected.
- Attention and concentration - sustaining attention during a task, shifting attention from one task to another and dividing attention.
- Executive functions - analyzing and synthesizing information, sequencing and goal directed activities.
- Perception - difficulties in auditory and visual functions, recognition of objects.
- Language abilities - quality and quantity of communication.

The rehabilitation of patients varies widely as each patient has different deficits and brings a wide range of previous skills and experiences to the process. In general, the rehabilitation process lasts from four to six months. A typical patient needs an assessment to determine the main problems and to chart the course of therapy. Therapy then includes a number of activities, of both remedial and learning types, to compensate for their deficits.

Issues that are common to almost all brain injuries are lessening of cognitive function, impaired accuracy of responses and a deterioration of the speed of responses. As well problems that are less universal, but occur frequently in the general population with disabilities, are loss of attention and concentration, learning and memory deficits, integrative thinking, planning and organizing, and lack of control over emotions and behaviour. This means that new information cannot be presented quickly, in a complex manner or in competition with other information. There are decreases in executive functions, reasoning and judgement. It is difficult for a brain-injured person to approach new situations. There are difficulties with sequencing and with operations that require multiple simultaneous decisions. Some patients are also severely challenged with physical effects. Reduced fine motor coordination and dexterity prevent some patients from using a mouse successfully so we have to allow a seamless combination of mouse and keyboard controls.

Study of the principles of cognitive psychology, HCI and software engineering helped to determine the overall principles of good program design for the general population. Those identified principles were then examined with respect to this specific patient population. There was an increased emphasis placed on ease of use over all other considerations, as it was determined that simplicity of design was of paramount importance.

The range of disabilities and deficits encountered by people with brain injuries were considered and taken into account during the design process. An assessment of the patients involved in the ward at that time was undertaken, the information collected included: age, time since injury, computer usage before injury, characteristics and education before the injury, cognitive problems, emotional and behavioral problems and physical problems.

3. DESIGN ISSUES

We tried to design software that had consistent and limited options. The limitations learned from the brain injured users gave us insights towards more general HCI paradigms for people with disabilities which overlap in some of the effects, whether they be psychological or physical.

Primary Design Issues That Were Identified:

- Use bigger graphic elements i.e. fonts, buttons, icons etc.
- Very few colours, clearly *distinct* from one another.
- Sound is used to reinforce the visual information, but used very sparingly.
- Minimize the quantity of information that must be remembered from one screen to the next.
- Use familiarity and imagery for things that must be remembered.
- Reduce the normally suggested number of maximum elements on a screen from 7 ± 2 to 4 ± 2; this was a crucial point.
- Direct users' attention by structuring and grouping elements.
- Avoid simultaneous tasks.

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- Avoid lengthy written information.
- Offer a narrow and shallow decision structure with few choices for options.
- Account for patients who cannot use the mouse or part of the keyboard due to motor impairments.
- Minimize the number of gross motor movements e.g. back and forth between mouse and keyboard.
- Minimize the number of transitions between gross and fine motor movements.
- Avoid situations in which the user feels 'trapped' in a screen which can trigger severe frustration.
- Keep things simple.

4. METHODOLOGY

Our program is composed of ten activities. The main new strategy was to use a game metaphor, with an accompanying game board as visualization, to present the activities and to make it easy for the user to understand and navigate the software. A short summary of the activities can be found in the Appendix.

4.1 Analysis of the existing software

The ten activities that were in use at the hospital were analyzed in depth: their functionality (to derive well defined software engineering specifications); their interface characteristics (to derive the HCI specifications); their cognitive psychology content (to make sure that only enhancements to the original rehabilitation goals would be introduced). The instruction screens, activities and scoring were all recorded. The original activities lacked a GUI and were entirely text based. For each activity observed, problems were noted, such as:

- the patient having to remember the name of a saved file,
- feedback not being displayed long enough,
- activities that can't be stopped before completion,
- meaning of options not explained,
- instructions not clear or inaccurate.

Fixing these problems as well as enhancing the activities was given emphasis during the design process and provided a starting point for the design.

4.2 Survey of Therapists

The therapists asked for meaningful scores for each exercise. The scores reflected both a short term use for the assessment of the progress of the patients and also a long term goal of being able, in the future, to collect valid statistical data on a large group of patients. It should be remembered that the software is used both for continuous rehabilitation on a daily basis - thus the obvious need for incremental scores with real time feedback and reinforcement - as well as for monthly assessment of some skills (e.g. memory) – requiring comparison tables of scores. For each activity, the most important information on the patient's performance was identified in consultation with the therapists. In general, the system should compute and save precise scores for all activities and then store the data in a form readily available for consultation. The patient should be able to choose how many times the exercise is to be executed. In addition, the therapists were given a questionnaire regarding new features and the activity of the icons and buttons.

4.3 Evolution of the program

Once a beta version of the program was completed, it was installed on two of the computers at the Gorge Road Hospital. The therapists were given a demonstration and were walked through each activity. The therapists went through one activity at a time becoming familiar with it, and they started a notebook for comments and questions on each activity. If they had any desired changes, there were discussed to clarify what exactly was wanted, and then the Indigo program was updated. After significant changes were completed, a new build was installed at the hospital. Once the therapists were comfortable with an activity they would introduce patients to it. The therapists were able to get initial feedback from their patients that had the most patience and highest functioning level. The characteristics of the patient population unfortunately made it impossible to administer a formal survey. Other patients made comments on their own, or the therapists made note of the areas that gave

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them difficulty, the functions they did not understand and the patients response to the program. Over time, all of the improvements and clarifications were incorporated into Indigo, and it was ready for more extensive testing.

4.4 Navigating through the program

At the opening of the application, the users type their name and, as with all subsequent screen, the focus can be changed using either the mouse or the space bar on the keyboard. Once the Indigo game board is loaded, the ten activities are depicted in a very simple fashion by a game board with squares surrounding a central panel (similar to a Monopoly board). This game metaphor proved to be a winning strategy, as it combined the ease of use, the simplicity and the effectiveness of functionality which were deemed critically necessary (see above), and enabled the interface issues to maintain a consistency throughout, eliminating a major source of frustration. Moreover, the game board itself provided a connection of personal familiarity for patients and reduced the computer anxiety.

When a user chooses an activity, a screen of instructions appears at first - unique for each activity, yet always completely consistent in their layouts. The option choices, clearly shown on the game board for each activity, can be different, as some games are so intensive that they allow only one repetition, while others can be customized, together with the therapist, for speed, repetitions, length, difficulty. The “Back”, “Help”, “Exit”, “Scores” buttons are always in the same locations on the board and directly accessible, and are integrated within the functionality. For example, if the Help button is pressed while an activity is running, the timing clock continues to count. This implies that the patient’s time score will be higher, a perfectly valid case. As the patient progresses in the rehabilitation, the Help button will be used less often, improving the score, and avoiding the patient’s attention from wandering during the pause in the activity.

4.5 Direct feedback

The therapists took extensive notes on the daily use of the system and some patients were also able to comment. The main changes made as a result of feedback were in the following categories:

- Color intensity – the contrast was fine, but the choices were changed slightly to less brighter shades.
- Fonts sizes and their ease of adjustment – extremely useful for vision problems.
- Range of difficulty levels – the ease of adjustment through the interface enables patients to make the changes as well as the therapists.
- Game metaphor – easily understood by all, even with the most varied background of users.
- Help and Instructions – their uniformity was enhanced even more.
- Scoring feedback – many changes were made here providing the easiest possible interface to both patients and therapists to check scores at any point in time, with a fine or coarse grain window, which was truly appreciated. For example, when an item was missed during a number search activity, the position as well as the item were emphasized in a non intrusive fashion, yet allowing the therapist to judge quickly whether patients were having trouble scanning from a particular side of their vision.

The main feedback notes were that patients actually had to be allowed, upon request, to continue activities beyond the allotted time, as they found the pleasant interface an enormous change from their regular expectation; most of all, many patients were able to use the software on their own after a few sessions, something never achieved before. It is hoped that this new level of enthusiasm will enhance their recovery process and make it rather less frustrating than formerly.

The program has been accepted with enthusiasm by both the therapists and patients. The program required alterations, but the design process was successful in creating a product that met the needs of the therapists and patients. The patients seem to enjoy using the program and are able to navigate through it easily for the most part. The figure in the Appendix shows 2 screen shots: the left one is of the main game board, while the right one is of the Number Search activity (they need color to look appropriate).

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5. CONCLUSION

In conclusion, the process for the creation of Indigo, while long and involved, was necessary and effective. The careful study of the HCI interface design issues relative to the needs of the special group of users is what made the product successful, beyond what the simple functionality could ever have provided. The therapists who have used the program have responded positively to it. Several comments have highlighted the constructive and beneficial aspects of the program for the patients. It has required a considerable amount of work on the therapists' behalf to complete this process, from the beginning consultation and lengthy questionnaire to the discussions during the beta-testing phase, and their total involvement in the development of the enhancements.

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7. APPENDIX: Indigo activities

1. **Logic Sequences:** pick the next logical step in a sequence.
2. **Circle Chase:** keep a smaller circle inside a bigger circle while the outside bigger circle moves.
3. **Mirror Image:** find objects on one side which are a rotation or reflection of objects on the other side.
4. **Vision Drill:** as two vertical bars move towards each from the outside towards the center of the screen, at different speeds, one must stop them at the precise moment when they meet.
5. **Count the Shapes:** in a grid with many shapes of different colors, one must count the objects of the same shape, or same color, or both.
6. **Missing Number:** numbers are scrolled in a set sequence with one missing which has to be identified.
7. **Number Search:** in 4 quadrants, numbers are scattered, and one must find and give the quadrant position of a given number.
8. **Reaction Time:** react as quickly as possible to an auditory or visual event by mouse or keyboard clicking.
9. **Towers of Hanoi:** the typical problem of moving some blocks of decreasing shapes from one peg to another, using only one extra temporary peg and maintaining the order of bigger shapes under smaller shapes.
10. **Memory Challenge:** letters or numbers are displayed on a grid, later covered; one is asked to remember where an item was located.