Designing User Interfaces for Severely Handicapped Persons

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Abstract
This paper addresses the many factors involved in the design of user interfaces for persons with severe disabilities. Interface design must take into consideration new user requirements on top of the requirements of normal users and consider the wider range of user model parameters that must be accommodated to provide adaptation to the user. The paper stresses the wide variability of user needs and questions if and how such user needs can be satisfied.

An example from the ongoing INTERCOMUNICANDO project is presented. The results show the need for highly parameterised applications and the need for further research to design frameworks and tools to enable support of many different levels of users by applications.

Keywords
special user interfaces, interface design, user adaptation, disabled persons, elderly persons

1. INTRODUCTION

Much like elderly persons, severely handicapped persons have limited access to the benefits of the Information Society. The difference between elderly persons and severely handicapped persons lies in the degree of disability and the number and kind of simultaneous disabilities exhibited. Moreover, if we exclude accident originated disabilities, most deep disabilities occur either at birth or at an early age. This prevents such persons from developing adequate communication skills and, most important, from relating to the world and acquiring a normal education.The case of disabled persons whose disabilities are due to cerebral palsy may be viewed as the sum of many disabilities found on senior persons, but in a higher degree. Although such disabled persons are able to understand speech, think and express feelings within limits, they are unable to control the movement of most parts of their bodies. This means that their ability to perform manual activities is either minimal or inexistent. The same happens with speech control that is generally reduced to utterances.

Moreover, the ineptitude to speak and communicate leads these persons to a negative state of mind where frustration and the tendency to isolation settle in. This also happens with elderly persons but, again, in a lesser degree. This negative state of mind is exactly the opposite of what is required to make these persons relate to family relatives, friends and educators in order to find support, learn and progress.

For severely handicapped persons, the use of computers is a very promising therapeutic strategy yet to show its full potential and benefits. The basis for this is that computer mediated communication reduces or removes many usual inhibitions found in direct person-to-person communication. It is well known fact that persons engaged in discussion groups or chat rooms loose most of their inhibitions and divest themselves of most social conduct codes.

This happens with handicapped persons too, but is not the only factor in favour of computer use by disabled persons. The absence of the close presence of the person to whom they talk to removes an immediate source of disappointment, the negative body expressions shown by somebody who does not understand what the disabled person is trying to communicate.

Last, but not the least, most severely handicapped persons know what computers are. In fact, most disabled persons regard computers as toys and know that toys are meant to play. And, as everybody else, or more still, severely disabled persons are eager to play.

2. USER REQUIREMENTS

However, severely handicapped persons cannot use computers the way a normal person does. In the foregoing we will address some of the factors involved.

2.1 Limits to Input Device Use

First of all, the control severely handicapped persons have on their hands is very much limited. Persons with cerebral palsy who retain some hand control are in general unable to use their fingers and the number of hand movements they can perform is rather small. Moreover, these movements are spastic, i.e., movements are coarse and jerky. This means that they cannot point precisely to an icon on a screen and click on it. A parallel can be drawn with elderly persons with arthritis. Icons must therefore be large enough to allow (very) coarse pointing.

This is only part of the problem with point devices. Pointing to an icon is just the first part of the problem. Elderly persons suffering from arthritis may nevertheless be able to single or double click on an icon and even perform drag-and-drop operations with some effort.

However, once they press a clicking device, persons with cerebral palsy tend to keep on pressing it because, for them, the action is, in general, too complicated and so the time between button press and release may become very large. The outcome is often a drag-and-drop action instead of, say, a mere icon selection. It is well worth noting that the time to press and release a button is highly dependent on the person and his/hers disability degree and, therefore, timing must adapt to the user. The solution for this problem calls for user adapted filtering of clicking actions.

In preliminary tests we carried out in the scope of the INTERCOMUNICANDO project (details on this project will be presented later on) we attempted to make a person with cerebral palsy play the well know game of Solitaire on a PC, using a mouse as pointing device. Card games are a well-known strategy in the therapy of such persons and autistic persons.

This proved to be true since the person in the experiment understood rather well the end of the game and how to play it. It was no surprise to find that, for this person, point-and-click and drag-and-drop were almost impossible. However, we found out that the person could perform these tasks if there were two devices and the user could point with one device using one of his hands and click on the other device with the other hand. Drag-and-drop using both hands was just within feasibility limits.

In general, however, disabled persons are not able to point-and-click. The most common alternative to point-and-click is the sweep-and-click approach. Icons on the screen are highlighted in turn and one at a time, and the user presses a switch, like the one figure 1 shows, to select the icon that is currently highlighted. Although sweep-and-click input is very slow, it can nevertheless be rather powerful since it can be used with virtual on-screen keyboards and text processing applications[1]. Figure 2 shows one of such virtual keyboards.

Switches can also be foot operated or head operated provided adequate switch mounts are used. Again the way these mounts are assembled depends on the user capability to control the movement of hands, feet, head or other parts of the body.

Some other solutions for pointing devices involve the use of head movement controlled pointing devices and head or eye tracking devices. Besides the problems related with pointing accuracy these devices provide, their use still depends heavily on user specific capabilities.

Figure 1 – A hand-operated switch.

[1] Next word suggesting software can further increase typing speed.

Figure 2 – Microsoft virtual keyboard showing a line of keys being swept (middle line).

2.2 Object Size, Colour and Animations

Icon size, colour and animations do matter. In fact, although it is difficult to detect, most severely handicapped persons have visual problems. Again, a parallel can be found with elderly persons whose sight is poor in general.

Some disabled persons are unable to distinguish foreground from background due to insufficient colour contrast. On the other hand, too much colour contrast involving bright colours may prevent some other persons from seeing what is shown on the screen because the eye is unable to simultaneously process areas with large differences in brightness. This is the case of the default white background colour used by most World Wide Web pages that prevent users from seeing page contents, even when large text characters are used.

Generally speaking, animations are not recommended. However there may be users with impaired sight that tolerate, or even require, animations. In tests that were carried out to determine optimal sizes of icons and screen pointers, we found cases where, besides the use of the largest screen pointers available, users showed actual preference for pointers with animations.

2.3 Coordination

Another problem found both with elderly persons and deeply handicapped persons relates to eye and hand coordination. This goes deeper than the usual well-known problem of coordinating pointing device movement with on-screen pointer displacement. In fact, most disabled persons must learn that there is a connection between what they do with their hands, feet and head with what happens on the screen.

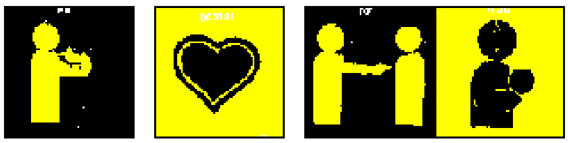
2.4 Reading and Writing

Lastly, one must always remember that reading and writing are not simple tasks, but rather complex tasks involving many functions of the brain. Although most elderly persons are able to read and write, some may have forgotten some words or may fail to recognise them. Visual acuity problems can be easily solved with the use of large characters or, in extreme cases, using speech output.

In the case of severely handicapped persons, especially with persons with cerebral palsy or persons who became handicapped very early in their lives, one cannot assume that they can read or write. In fact, most have never learn how to read and write. Speech from text generation solves only the reading part of the problem. Reading and writing call for communication solutions based on pictographic languages, like PCS (Picture Communication System, [JOHNSON]) and Makaton ([MAKATON]). Interfaces must be designed to use these languages instead of normal text.

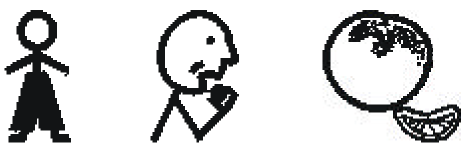
These languages enable disabled persons to read and write in a symbolic way using pictographic sentences. Figure 3 shows two examples of pictographic sentences that use PCS (above) and Makaton (below).

PCS



I love you mom

MAKATON



(the) man (is)eating (an) orange

Figure 3 - Two pictographic sentences in the PCS (above) and Makaton (below) languages.

3. CONSEQUENCES IN USER INTERFACE DESIGN

Designing interfaces for persons without disabilities is an already complex task. However, this has been the object of many studies for quite a long time and so design, implementation and evaluation of user interfaces for "normal" persons is a well-known and mastered process. There are established methodologies and abundant literature and textbooks on this subject ([MAYHEW], [PREECE], [NIELSEN], [SCHNEIDREMAN] and [DIX]).

Although there is no such thing as a “normal” or “standard” user, the variability degree found within any heterogeneous group of “normal” persons is rather small. This allows the design of user interfaces to apply simple user models that fit most needs of “normal” users. The majority of user models needs only take into consideration user expertise level and user motivation. Well-designed user interfaces that provide alternative ways to carry out user tasks (redundancy) and different types of dialogues (menu, forms and direct manipulation, to name a few) can support beginners and expert users alike, with or without the motivation to perform tasks.

For persons with disabilities, user interface design must address the problems listed above (and others, since the list only addresses the most recurrent problems) and provide solutions to:

- Support user variability ([EDUARDS]). Interfaces must provide the means to adapt to user specific requirements in terms of size, colour and number of items show on the screen.
- Support of a wide range of input devices, e.g., mice, joysticks, trackballs, switches, sweep techniques and voice command.
- Support a wide range of output modes, including graphics, and sound and speech output.
- Provide minimal user interface design that does not leave out that some users may require richer interfaces (e.g., animations).
- Means to promote interaction and retain user attention on the tasks.
- Provide strong feedback mechanisms that stress results and changes to the user interface, and, in many cases, provide rewarding schemes.

All items in the previous list are permeated by the assumption that interfaces provide the means to adapt to each user’s specific case. Given the very wide variability of user cases, the question that arises is:

Can a very high degree of user variability be supported by the interfaces?

This raises two further questions:

How can this be accomplished?

How can the user models this requires be built?

The following presents a (small) contribution to the above questions.

4. THE INTERCOMUNICANDO PROJECT

INTERCOMUNICANDO is a project with the objective of establishing a computer-mediated communication environment for persons with cerebral palsy ([BRISSON]).

INTERCOMUNICANDO is currently developing and testing prototypes for a communication tool (see figures 4 and 5) based on the PCS and Makaton languages, game based tools to learn these languages (see figures 6 and 7), games to get users acquainted with computer usage (figure 10) and tools to manage user profiles and monitor user progress.

All these tools will be integrated in a common framework to monitor and register user actions, and to provide a common look and feel.

INTERCOMUNICANDO has selected to use agent technology ([BRADSHAW]) to support and (partially) substitute therapists and educators. Agents will act as tutors of the end users and will externally express their state and “feelings” with body expressions supported on animations and speech.

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5. USER SUPPORT WITH AGENT TECHNOLOGY

INTERCOMUNICANDO developed and tested an agent prototype to assess the effectiveness of autonomous agents as (partial) substitutes for educators and as a test bed for user input solutions and the agent itself. The test had to be simple so that results could easily stand out and that the prototype could be modified on location. Therefore the prototype implemented a simple tic-tac-toe game that fits the general user profile (Pereira et al [PEREIRA]).

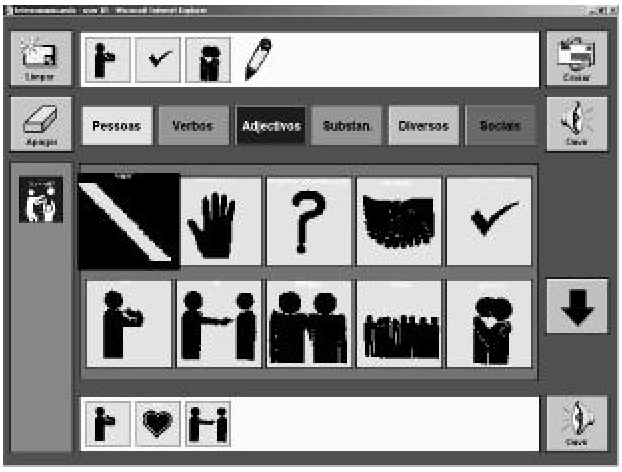

Figure 4 – User interface prototype (prototype A) for two-way computer-mediated communication using PCS and Makaton languages and providing speech output.

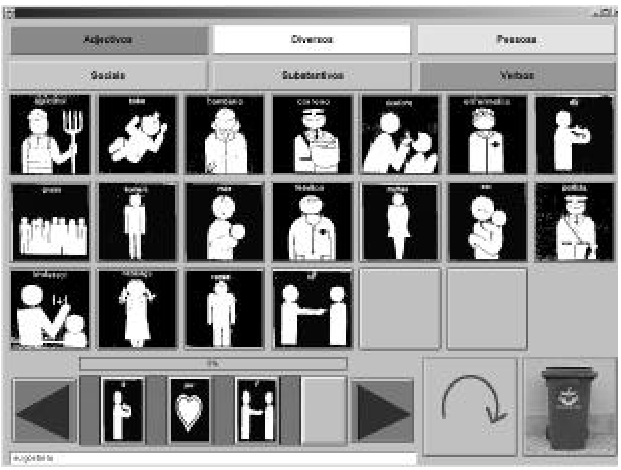

Figure 5 - User interface prototype (prototype B) for a computer-mediated communication tool that uses the PCS and Makaton languages

Figure 6 –User interface prototype (prototype C) for a matching words game intended for learning the PCS and Makaton languages that provides speech output.

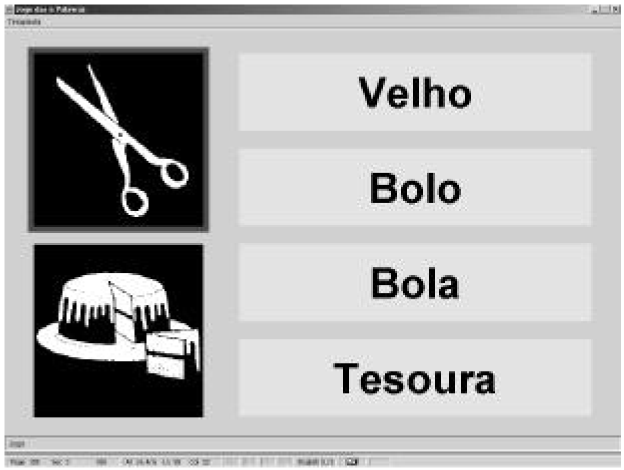

Figure 7 - User interface prototype (prototype D) for a matching words game intended for learning the PCS and Makaton languages.

At the core of the prototype is an agent that knows how to play tic-tac-toe, but not too well. A random factor was introduced to the game-playing agent so that it could make mistakes and play wrong moves.

The tutoring agent monitors the sequence of moves, knows a good move from a bad one and knows when a game ends and its result. It also keeps statistics on the games played so that it may define and update its emotional state. The agent uses MS Agent ([MICROSOFTa-b]) to externally express this state through animations and speech output. Speech output has four categories that depend on the game status: win, loss, draw and game in progress. Each category is in turn divided into 3 sections. Each section of a category represents a value of the agent's emotional state.

The external expression of the agent's emotions is also expressed through the "Happiness bar" (see figure 8). In a series of tic-tac-toes games, the agent becomes happier and the bar progresses to the right if the user wins. If the user looses, the agent becomes less happy and the bar goes to the left.

The prototype was developed in HTML and JavaScript and runs under Internet Explorer.

Figure 8 – Happiness bar expression of the agent's emotional state.

The prototype starts with the page shown on figure 9 that displays all the agent's characters available for the user to choose. Once the character is chosen, a new page with the game board and the "Happiness bar" is displayed (as figure 10 shows).

All objects shown on the page, including the agent's character itself, have been enlarged on purpose so that users could see them properly since most users exhibit visual acuity problems.

As figure 10 shows, almost all window tools were removed from the window where the game is played to maximize the area available for the game, to prevent the user from being distracted and to avoid any inadvertent resizing or destruction of the window.

At the beginning of the game, the tutoring agent shows up on the screen, explains the game and draws the attention of the user to the "Happiness bar" and that the user can increase it by winning several games in a row.

Afterwards, the tutoring agent comments every move on the game. Comments include sentences to keep the user focused on the game. The agent waits when the user stops playing and, after a time, starts prompting the user to continue playing.

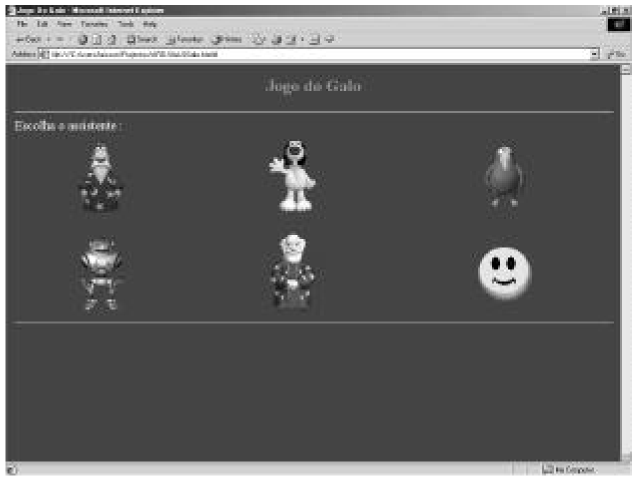

Figure 9 – Start page of the agent prototype.

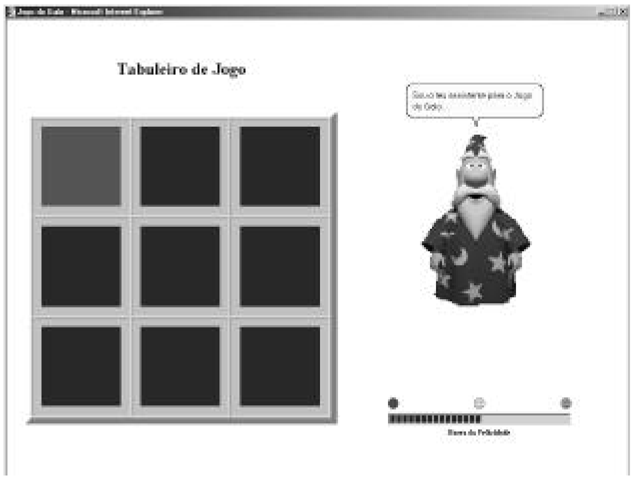

Figure 10 – Interface layout of the agent prototype to play tic-tac-toe.

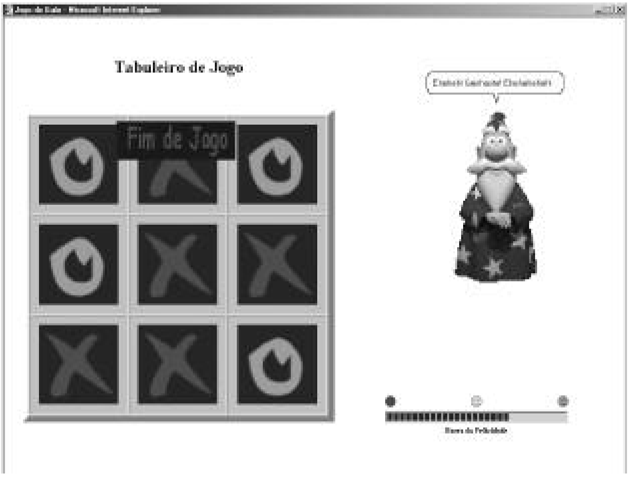

Figure 11 – The agent congratulating the user after the user wins a game.

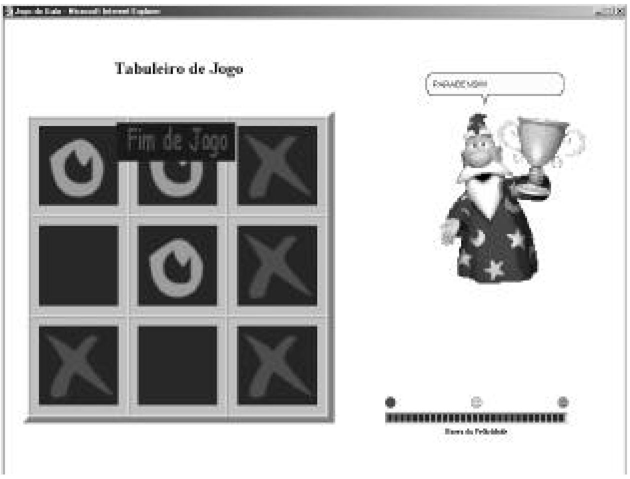

Figure 12 – The agent congratulating the user after the user wins a series of games.

If the user wins a game, the agent becomes happier and congratulates the user effusively (see figure 11). The agent expression goes overboard with congratulations after the user wins a series of games that make the agent's "Happiness bar" reach its maximum. Depending on the agent character chosen, the agent may even present the user with the winner's cup, as figure 12 shows.

The agent also comments when the user loses or draws but keeps on trying to motivate the user to keep playing and win.

6. FIELD TESTS OF THE AGENT PROTOTYPE

Field tests of the agent prototype were carried out to:

- Assess user acceptance of the agent and its effectiveness in providing adequate feedback and user motivation.
- Determine user requirements and problems of the user interface to enable better design of all applications and tools in the project.

The field tests were carried out with an heterogeneous sample of users that showed a split into two groups: users who understood the game and played it without help and users who required help.

User who did not require any help showed great motivation to play the game (tic-tac-toe) and paid attention to the game and the tutoring agent. The users understood the meaning of the "Happiness bar" and that its progress and the agent's happiness depended on them winning the game, so they engaged into playing until the "Happiness bar" reached its maximum. The ease of use shown by these users showed also that both the game and the agent might have been more elaborated for these users.

The users who required help had the common characteristic of carrying very deep disabilities, especially in terms of mobility and control of the hand and head. Although these users showed great willingness to play, they lacked concentration and showed little understanding and mastering of the tasks to perform when playing the game. The main constraints to their performance were the inability to use the input devices available and lack of coordination between on-screen pointer displacement and input device manipulation.

7. RECOMMENDATIONS FROM FIELD TEST RESULTS

The results obtained with the second group of users in the field tests of the agent's prototype provided invaluable data on user requirements and many suggestions for future improvements.

The first conclusion is that all applications must provide a range of different levels of difficulty and alternative ways to perform user tasks.

The second point is that applications should be highly configurable and adaptable to each user. Input tasks should be made simpler for users with greater handicaps. Applications must support a wide spectrum of input devices, ranging from mice and joysticks to the use of sweep techniques under switch control.

Another point is the need to make the tutoring agent even more active to stress out moves or actions of the user or the computer. Depending on the particular user, the agent should even be able to make suggestions. This is particularly true in the case of communication tools where mechanisms for word suggestion are used.

One other point is the need to filter input device generated events. The tests showed that users may inadvertently press buttons or switches twice in a row instead of just once or leave the same buttons or switches pressed for a long time, thus generating an unwanted sequence of events when there should have been only one event.

The main result arising from field tests is that all applications and tools must support a wide range of configuration parameters in order to be able to support the wide range of personal characteristics of the users. This support requires the development of additional tools to manage user profiles.

Another important result is the need for more functionality from the tutoring agent. This can be achieved with the adoption an agent framework like the APE framework for autonomous agents ([CABRAL]) that was originally developed to introduce complex behavior and expressiveness to pedagogical agents.

8. CONCLUDING REMARKS

This paper addressed the many aspects and problems that arise when user interfaces for persons with severe disabilities are designed and implemented and the wide range of user requirements that must be met on top of the requirements of normal users. The paper stresses the wide variability of user needs and questions if and how such user needs can be universally satisfied.

An example of an ongoing project, the INTERCOMUNICANDO project, was presented. The results so far achieve stress the need for highly parameterised applications. This means that, regardless of the specific solutions that may be applied, there is the definite need for further research to design frameworks and tools that will enable the support of many different levels of users by applications.

The task at hand is neither simple nor small. It requires more research programs in this area and adequate funding. Such programs should cover both elderly persons and disabled persons since the problems faced are similar.

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