A Design for Software to Assist in the Rehabilitation of Stroke Patients

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This paper describes the development of a prototype system to assist in the rehabilitation of patients who have suffered a stroke or cerebrovascular accident. Attention is paid to the use of the visual triggers to test and re-educate patients who develop problems with memory or spatial orientation of objects or other areas of the brain that can be helped by the use of visual cues.

These are the keywords. Stroke, cerebrovascular accident, software, rehabilitation, system, prototype, HCI

1. BACKGROUND

Strokes (cerebro-vascular accidents or CVA's) have a devastating effect on the lives of individuals afflicted by the disability that the CVA imposes. Strokes are one of the main causes of medical emergencies worldwide with between 22 million and 60 million strokes being estimated each year. Each year one in every 100 people over 70 years old in the UK will suffer a stroke. Increasing obesity in the population at large is also a cause of concern; atheromatous plaques have been found at autopsy in children as young as 10 years old. Strokes may arise from fragments of an atheromatous plaque becoming dislodged in the carotid artery, the fragment subsequently travelling to the brain causing a stroke, (Medicine, 2004). They may arise from blood clots that are formed around the plaque which subsequently block or restrict blood flow to the brain tissues. Even when the condition is not fatal, this can lead to short term mini-strokes or transient ischaemic attacks (TIAs); reduction in the visual field or amorosis fugax; or to long-term consequences such as partial paralysis. The cost to the economy is also vast. It is estimated that an average 54 day stay on a stoke unit in the UK costs some ~£12,000 per patient. The total financial cost to the health service in the USA alone per year is some $60 million.

The incidence of cardiovascular disease could be reduced by as much as 50% with lifestyle changes. (Sandercock, 2003). In addition, many medicines are available to alleviate symptoms of these diseases and prolong life (Sandercock, 2003). Mortality rates for women have been estimated to be 256 per 100,000 for Glasgow, UK (Tunstall-Pedoe, 1994). A later UK survey indicated that the annual rate for a first or recurrent coronary event was 273 per 100,000 men of the population aged less than 65 years, in 1994-95 (Volmink *et al*., 1998).

Strokes, otherwise known as cerebro-vascular accidents or CVAs are divided into a variety of types shown in figure 1. Generally speaking, 80% of stokes are thrombo-embolic and 20% are haemorrhagic. In some instances Transient Ischaemic Attacks (TIA's) or mini stokes may arise, from which the patient recovers within 24 hours. Hereditary and lifestyle factors may can determine the vunerability of a given individual to CVA. Risk factors include hypertension, smoking, heart disease (valvular, ischaemic, atrial fibrillation), previous TIA, clotting disorders and excess alcohol (Longmore et al 2004).

1.1.1 The effects of stroke

The exact effect and severity of a stroke depends on the extent of the brain tissue affected, its location and the structures influenced by the blood supply to the area involving the CVA. It is evident from figure 1 that by far the most common type of stroke is the type arising from a blood clot blocking an artery supplying an area of the brain. Figure 2B illustrates this effect. Clearly a variety of functions can be affected e.g. perceptual function (tested by asking a patient to point to a named part of the body), spatial ability (copying matchstick patterns), apraxia (tested by drawing an object), agnosia (picking out and naming objects easily). Any rehabilitation system so designed, must therefore take into account all of these possible areas of concern, and be flexible enough to be adapatable to the needs of individual patients.

1.1.2 Treatment

The exact effect of a stroke depends on the extent of the brain tissue affected, its location and the structures influenced by the blood supply to the area involving the CVA. It is evident from figure 1 that by far the most common type of stroke is the type arising from a blood clot blocking an artery supplying an area of the brain.
There have been advances in terms of some aspects of the treatment of thrombo-embolic CVAs. Total plasminogen activator (TPA) occurs naturally in the body but can be used in increased concentrations to dissolve blood clots. Another clot busting drug called streptokinase has been used extensively in clinical trials globally.with some success, but its use is not without problems in some patients. Post CVA, neuoroprotective agents have also been used in animal models to help prevent brain cell death. However, no such agents are yet approved for use in human subjects. For the present, the main method of treatment remains as rehabilitation, which combines working on physical and mental aspects of the patient. This type of rehabilitation includes asking the patient to point to named objects, spatial recognition of objects, and picking out named objects e.g. clock face, pen, picture of a relative. This type of physiotherapy may be time consuming especially in areas of staff shortages in the NHS, since it often requires a 1:1 ratio of staff to patients, especially in the recording of the progress of each individual stroke patient. Clearly there is a need for a system involving the rehabilitation of a stroke patient that can be tailored to the needs of individual patients and monitor the progress of each patient over time. The system must be easy to use by the non-specialist, adapatable to a given patient (e.g. use pictures that are familiar to the patient), be useable on any computer system, be easy to load onto a computer system, be readily available, be cost effective, and be able to record and monitor the progress of individual patients.

With these requirements in mind, we designed a prototype system for testing on stroke patients. Ethical approval is now being sought to test this system on patients.

2. METHODOLOGY

Dummy patient data was used when assessing the interfaces with fictitious information being used. The application was developed using a combination of rapid application development (RAD) and structured systems analysis and design methodology (SSADM). User requirements were established by discussion with the medically qualified member of the team. A relational database was required for this project to enable the use of a structured query language (SQL) to execute queries. The system was produced as a prototype to run under Microsoft Windows 2000.

3. SOFTWARE

Our prototype software was designed to assist in the mental rehabilitation of CVA patients. Since a CVA may affect different areas of the brain in different individuals, the software needed to be versatile so as to be used as a adjunct to stimulate particular functions of the brain. For example, Wernicke's area is involved in word formation; Broca's area is involved in speech; the occipital areas and pathways control those areas of the brain concerned with making sense of spatial information and input to the brain, such as the right parietal lobe. The software needed the ability to stimulate these different areas of the brain and be user friendly, easy to install and run on a wide range of systems. Bearing in mind these features we successfully designed such a system, which has been donated to a local hospital for testing on CVA patients.

The software makes use of the capability to incorporate specific familiar images for particular patients, i.e. tailor made to meet their needs, whilst maintaining the capacity to stimulate a wide range of areas of the brain (e.g. by using letter word quizzes, picture quizzes) if required. The software may also rotate the images in 3-D if that capacity is required in a particular individual patient.

Examples of screen saver shots from the software package are shown below in figures 4 to 6.

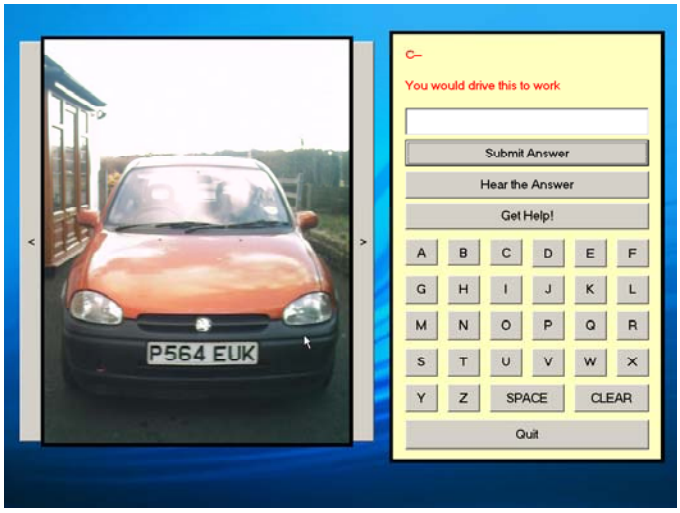

Figure 1. Identification of Objects Quiz

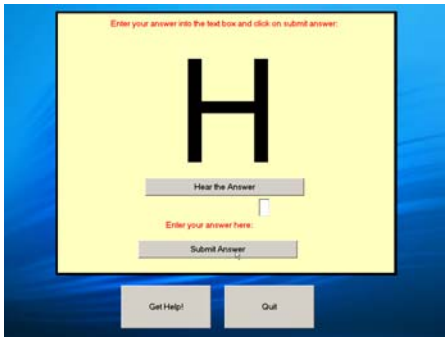

Figure 2. Memory Quiz

The screen may be adjusted for size of print, and at the end of each quiz, the software displays the number of correct and incorrect answers achieve by that patient. This enables a quick assessment to be undertaken of the progress of individual patients.
The package may be used by the patient alone or in conjunction with a nurse or health care worker.

3.1 Analysis of Requirements

The system requirements were established by discussion with the medical member of the team , Dr. Pearce. Clearly a security mechanism must be incorporated so that access was restricted by username and password; that the patient record system would hold details such as patient name, address, family and medical history. The system would ideally also be able to record and graphically plot the progress of a patient's rehabilitation, measured by their ability to perform the tasks provided by the software (e.g. spatial recognition test). The system must therefore store information in a database.

There are a number of proprietary relational database management systems (DBMS), for example Microsoft's *SQL Server* and Oracle. There are also Open Source DBMS, which are free of charge, normally under the GNU General Public License, such as Interbase and MySQL. In addition to this, there are PC based (desktop) relational DBMS and include Microsoft Access, Microsoft FoxPro and Borland dBase. Due to the limited resources available for the project the use of more expensive commercial database management systems (DBMS) were ruled out. For a small prototype application such as this one the ability to handle large quantities of data were not required. Another aim was to use software readily available within hospitals, and Access was deemed to be the most widely used. A relational database was required however, to facilitate the use of structured queries. Microsoft Access was selected as it was decided that its features, ubiquity and level of complexity would favour the successful completion of the prototype.

3.2 Systems Design

There are several functional areas in the main screen. These include: Patient Details; Medical Details, next of kin, and data concerning the progress of the patient in relation to the tasks presented. The screen designs are simple and relate to personal photographs for a given patient. The photographs can be scanned in for individual patients thereby making recognition tasks more personalized to assist in recovery from a CVA.

4. FUTURE DEVELOPMENTS

Next steps would include trialling of this prototype. Demonstrations have already taken place to hospital consultants. Interfaces to existing patient data systems would be necessary for use in the working situation, but as this would depend on what software is used in each specific hospital, this was not one of the aims of the project.

The database chosen for this prototype was Access, which is limited in its capacity and portability. Oracle would be a better choice for larger systems.

It appears that many hospital systems are being written as wireless personal computer developments, for example that described by Fortier *et al*., 2004, so the need for wireless web access could be investigated.

The system could prove to be a useful training tool for medical students and othe members of the medical profession.

5. CONCLUSION

Using appropriate methodologies and a range of software it proved possible to produce a prototype cardiovascular system offering the functionality required by the end user, with a pleasing colourful graphical interface. The functions included in the prototype were:

A graphical user interface
Rapid access of stored patient data
Easy input of new patient data.
Security of patient data

The robustness of the system - and how it would perform in a real situation - were not tested. This system could however be considered for development into a commercial product.

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