Rehabilitation of Handwriting Skills in Stroke Patients Using Interactive Games: A Pilot Study

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Abstract

This paper describes an interactive application which was developed to support the rehabilitation of handwriting skills following stroke. The purpose of the application is to make the rehabilitation of handwriting skills fun and engaging. Four platform-independent games were created, targeting varying skills and adjustable levels of difficulty. Other application features include: performance history, audio-visual feedback, and posture reminders. The application was evaluated by medical staff and patients from the Hoensbroeck Rehabilitation Centre in the Netherlands. Initial results indicated that the games are more motivating and fun than traditional pen and paper exercises. Feedback from therapists was supportive of the games as a useful addition to the rehabilitation of handwriting.

Keywords

Stroke rehabilitation, interactive game, user-centered design, handwriting

ACM Classification Keywords

H5.2. Information interfaces and presentation (e.g., HCI): User Interfaces. K4.2 Computers and society: Social Issues—Assistive technologies for persons with disabilities

Introduction

In all, about half of the population of stroke survivors will experience debilitating loss of arm and hand functioning to some degree [1,2,4]. Specifically, following stroke many individuals experience paralysis or weakening of the side of the body opposite the brain hemisphere in which the focus of a stroke occurred [9]. In order to regain function to the affected side of the body, the most facilitative course for rehabilitation involves intensive physical therapy.

Physical therapy during rehabilitation involves training of activities with a focus on regaining daily life skills. Timmermans et al. (2008) polled stroke survivors in order to understand the most important and regularly used skills that they would like to regain during rehabilitation [8]. Writing out text by hand was one of the skills that ended up in the top 10 list of most highly desired skills to recover.

Writing is a visual means of communication pervasive in society; writing personal reminders, posting letters, and the signing of one's own name on official documents are all examples of how writing is used in the day-to-day. However, although writing is an automatic and commonly used skill for most, the mechanics of handwriting can be deceptively complex. Given that it is a task that requires a high degree of fine motor control, handwriting can be one of the most difficult skills for stroke survivors to regain. Next to that, current exercises during therapy for handwriting recovery are generally rather tedious and repetitive, forcing patients to spend many hours practicing basic text-related shapes and letters.

Little prior work has been conducted with the aim of creating a specific tool for the rehabilitation of handwriting. To date, only one device, the Haptic Handwriting Aid has been developed with the explicit aim of rehabilitating this skill [6]. Using a Phantom Omni haptic device, it guides the user's hand through the proper motions required to form individual letters and sentences. However, the device was only tested with healthy adults. Another study tested the use of a force feedback joystick in the recovery of hand and grip function in stroke patients [7]. Although the researchers conjectured that the device might be beneficial to handwriting skills, this hypothesis was not directly tested. Thus, there remains a need to develop and test additional tools for the rehabilitation of handwriting following stroke or other injury.

The goal of this project was to use technology to create a game (or game system) that would engage stroke patients during their training in handwriting, in order to make the requisite exercises more fun. The project was carried out in cooperation with the Hoensbroeck Rehabilitation Centre, the Netherlands.

Users

For this project, two different user groups can be defined: patients and their therapists.

Regarding the patient user group, this project focused principally on patients that fit the following criteria, derived from pervious research at the center [8]:

• Currently recovering from at least one previous stroke
• Affected arm not completely paralyzed
• Native Dutch speakers

Patients with the following deficits were excluded:
severe hemineglect; severe spasticity; aphasia; apraxia; and, any additional impairments that might prohibit completion of the user evaluation.

The participating therapists comprised various specializations; ergo-, physio-, and occupational therapists—all of whom guide and assist patients throughout the rehabilitation process.

User Requirements

Patient needs

To assess patient needs, a focus group with five (one female) outpatients from the Hoensbroeck Rehabilitation Centre was held. The ability to write text out by hand was a major concern for all five participants. All participants' handwriting had changed markedly since having had a stroke; they reported shakiness, unreadable handwriting, physical and mental exhaustion, an inability to maintain uniform letter size, and difficulty gripping the pen. Interestingly, the ultimate goal of handwriting rehabilitation for them is not to objectively write well; rather, the end goal is to be satisfied with their own handwriting—be it readable by others or not. Standard handwriting therapy practices unanimously were considered tedious and dull—but critical to rehabilitation—and so compliance with completing the exercises was high.

To get an impression of what kind of exercises the patients would like to do, we showed them some preliminary game concepts on paper. The feedback we got stressed that simple games with simple graphics were preferred because of lingering cognitive deficits. The inclusion of complex graphics is potentially distracting and novel games might require prohibitively difficult instructions. All said that they wanted to practice writing text. However, all were in agreement that they did not want to have to adhere to highly constrained templates for writing—in other words, they did not want to do any games which required them to trace the "correct" letter forms. For example, when shown an example of a letter template (in this case a "B") one man said that he didn't like the exercise because it "was not [his] 'B'." Multiplayer games were not liked by the participants, because it would be too distracting from the main goal; i.e., handwriting skill improvement. Rather, they preferred to compete against themselves by tracking their improvement individually from one session to the next.

Therapist needs

Because it is the goal of therapists to guide the stroke patients through their rehabilitation, three main needs have been identified by therapists. First, the therapist should be able to easily adjust the game difficulty levels and other specific aspects of the game system's controls in order to tailor game play to specific patients needs. Second, to get an overview of the progress of the patient the therapist should be able to track a patient's progress over time. Third, when a therapist is not direct guiding the patient, the system should act in the therapist's state. Therefore, the game should remind the patient for the correct posture and prevent overtraining. The progress overview is also very useful when the therapists is not observing the patient's performance.

Prototype

Based on the above requirements, four different games were prototyped (detailed below), and embedded within an interactive application. The games were chosen to address the varied handwriting abilities of individuals recovering from stroke. Moreover, the first three games were chosen to represent crucial movements in regaining fine motor skills, e.g. straight lines, curves, and connecting letters. The fourth exercise focuses on freehand writing to give patients the opportunity to write words and phrases. For the four games, three levels of difficulty were implemented ranging from a beginner level and increasing in difficulty across levels. Screenshots of all four games can be found in Figure 1.
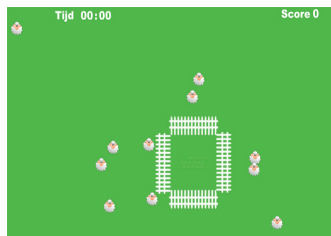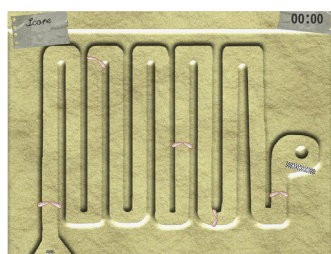
Figure 1A: Cathing sheep
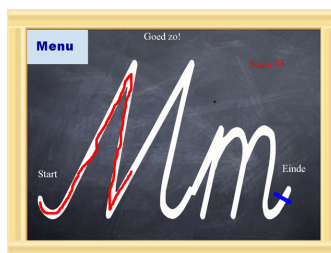

Figure 1B: Labyrinth

Figure 1C: Tracing over Letters

Figure 1D: Writing

Catching sheep (Fig. 1A): In this exercise the goal is to move all the sheep inside the fence by dragging with a digital pen. Therefore, this exercise trains making simple movements with a pen and targets coordination. The three different levels increase in difficulty by decreasing sheep size and increasing distance to the fence of the sheep.

Labyrinth (Fig. 1B): The goal of the labyrinth is to drag an object through a maze with the pen. In so doing accuracy is trained. Again three levels were created, ranging from small mazes with wide paths to large mazes with narrow paths.

Tracing over Letters (Fig. 1C): In this particular game, the focus is on tracing over letters, to emphasize the link to writing. The patient is given the option to trace over cursive and block letters, to match their own preference. Besides that, the level of difficulty increases by tracing over first letters, then words, and finally short sentences. Moreover, the letter size decreases as the level of difficulty increases.

Writing (Fig. 1D): In the Writing game, patients are presented with words, which they must copy. Therapists can choose these words, and in that way, adapt this exercise to needs and interests of patients. The patients themselves can choose to display the words in cursive or block handwriting. In this game, the level of difficulty increases also in the length of the words / sentences.

Each game contains the following elements:

▪ A consistent navigational structure across all screens which enables users to easily choose a game,

return to the main menu, or choose to play another round of the game.

▪ Score tracking. The patient can see his/her score during the game play. When the patient is finished he/she sees his end score on a new screen. Patients can also see an overview of all their scores, as well as a high-score list if they go to the overview screen. For the "writing game" patients are able to view a screenshot of their own writing to self-evaluate their performance.

▪ Time keeping and tracking.

▪ Audio feedback for: correct actions (such as reaching an intermediary goal), incorrect actions (e.g., when tracing outside boundaries), and after successfully completing a level

▪ Encouraging text-based feedback for earning points and completing levels, e.g. "Well done!"

▪ Reminders to maintain the correct writing posture prior to each game.

Therapists are able to adjust various parameters of the games, such as difficulty level by way of a "back office". They can view the patient's progress in the overview page of all the scores—a feature which is also accessible to the patient.

All the games were implemented in Flash CS3 using ActionScript 3.0. The back office was created in HTML making use of a MySQL database. The application is meant to be platform independent. However, when choosing hardware we suggest the use of two technologies in particular, because each fit well with the writing metaphor: i.e., a graphic tablet and the tablet PC. We used a Wacom Cintiq 21UX Interactive Pen Dispay graphic display. This tablet allows the user to

receive direct feedback from writing onto the LCD screen with a digital pen.

Evaluation

Method

Now that a first prototype is ready, we would like to know how interactive handwriting training would be welcomed and utilized by both patients and therapists. However, during preliminary analysis it was only possible to form an initial indication of users' impressions of the system following short-term use. Therefore, the pilot user tests have revealed primarily qualitative data.

In total eight (three females) patients evaluated the prototype. Each participant was asked to play at least one or two levels of all four games, as well as navigate through various aspects of the menu structure. After finishing each game, the interviewer asked the participant what he or she liked and didn't like about the game and why. Finally, after completing all four games, each user participated in a semi-structured interview. The questions used were meant to target three aspects of game play: therapeutic benefit, usability, and enjoyment. The questions asked were modified from a pool of validated questionnaires [3, 5] and were presented in Dutch.

Therapists monitored the patients as they played the games during the evaluation. In addition, therapists also played the games during a demonstration market at the rehabilitation centre. Therapists gave verbal feedback during the demonstration and on paper through a small questionnaire.

Results

Not one of the patients accomplished the games without smiling once. Their enjoyment was also illustrated by some quotes: "This is more fun than on paper", "This is funny", "This is more modern". All patients agreed that doing the exercises while using the system offered more variability than when doing standard pen and paper exercises. However, they also all still wanted to use the pen and paper exercises as an ultimate goal, but saw the games as a valuable supplement to their training. Interestingly, the two persons who had the opportunity to play the games a second time were willing to do so, thus illustrating that they were positive about the system. Moreover, these people could play the games and navigate through the system without assistance. Writing with the tablet felt a bit different than with pen and paper for some. They felt less resistance from the pen on the screen than with paper, and the position of the screen was not the same as paper on a flat surface.

The therapists who saw and used the application were mainly very enthusiastic about it. It is the opinion of the therapists that the games could be therapeutically beneficial (of course, a longitudinal study would be required for confirmation). The direct feedback for the patients was mentioned as an important positive feature of the system.

Conclusion

Overall, patients and therapist received the discussed prototype positively. Using a user-centered design approach enabled the needs of both user groups to be targeted effectively. Due to the scope of this project, no conclusions can be made regarding possible therapeutic benefits. However, these preliminary evaluation results indicate that patients are motivated to use the system and therapists see it as a possible useful addition to the current rehabilitation methods.

Future Work

In this paper a first prototype is presented of an application to help patients regain handwritings skills after stroke. A pilot evaluation test was done to get an indication of the usefulness of the system to and feedback from both patients and therapists. For future work, a longitudinal study is required to test whether this system has any long-term therapeutic benefits. In addition, more systematic evaluation is required to research the opinions of both patients and therapist in using the system. To enhance practical use of the system, we suggest the implementation of more personally adaptable levels in each of the games. It is likely a higher variety within each level could motivate patients to continue using the system. Also the implementation of more games would be beneficial for this matter. Finally, it is desirable to investigate the proper set-up of the tablet position(in order to best facilitate appropriate writing posture), and the measurements of pen pressure and pen grip. However, such additions, might involve a total redesign of a new digital pen.

Acknowledgements

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