FingerBall - A Suite of Video Games for Finger Training Following Hand Injury

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Abstract ÐThis paper describes FingerBall, a suite of video games for use as a training activity for patients recovering from hand injuries. FingerBall is based on the DataGlove[1] and a personal computer. Three months of clinical experience indicate that FingerBall provides a highly motivating training activity with good training attributes.

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[1] DataGlove is a trademark of VPL Research, Redwood City, CA., USA

INTRODUCTION

Hand surgery usually results in a period of finger immobilization followed by a program of training exercises to help the patient recover range, speed, accuracy, and strength of finger motion. The exercises are carried out under the supervision of an occupational therapist, typically during three half hour sessions each day for anywhere from one day to three weeks. An important factor for the effectiveness of this training is patient motivation. The objective of the work described in this paper is to develop highly motivating training activities. In cooperation with Norway's leading hand surgery clinic, Kronprinsesse Märthas Institute (KMI) in Oslo, we have designed and implemented FingerBall, a suite of video games based on the DataGlove and a personal computer. FingerBall provides a training exercise for improved tendon gliding which is experienced as fun by the patient. FingerBall has been used at KMI by hand injury patients for the three months January - March 1990. This clinical experience indicates that such video games can indeed be highly motivating and beneficial to the recovering patient.

DESCRIPTION AND OPERATION

Hardware Description

Figure 1 shows the FingerBall hardware. The patient's finger movements are monitored by a DataGlove, which measures finger joint angles in the first two joints (MCP and DIP) of each finger and the thumb[2]. The glove is made of light nylon, and has fiber optic sensors mounted on the outside. The sensors are connected via an interface box (provided with the DataGlove) to the serial port of an IBM-compatible personal computer equipped with an EGA graphics card. The DataGlove provides the ten finger angles with a resolution of 1 degree at 60 hz.

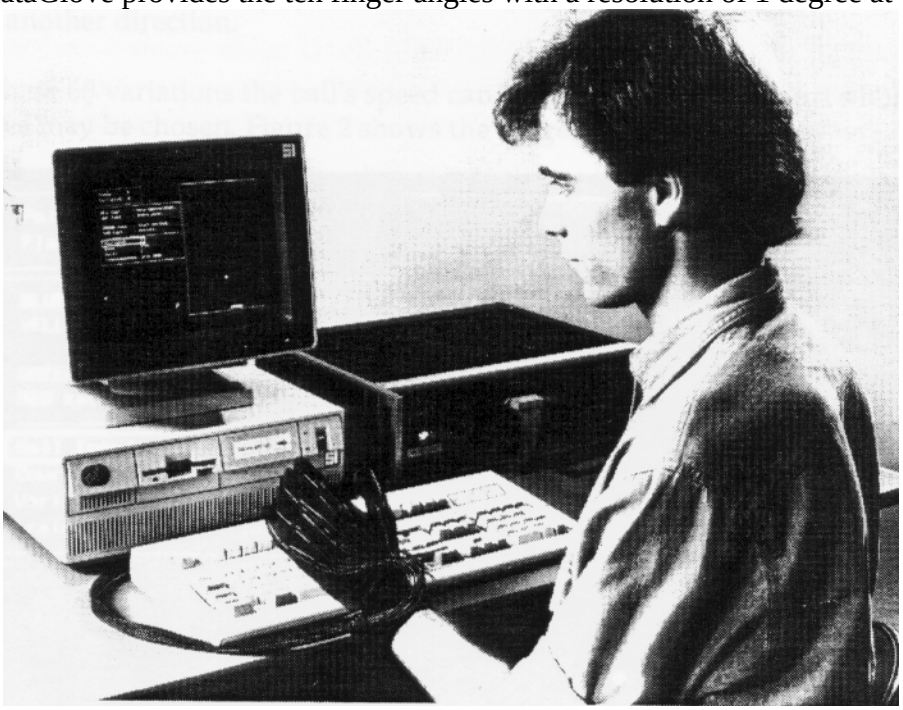

Figure 1: FingerBall hardware.

[2] Our DataGlove has ten sensors. However, additional sensors are available, including additional finger angle sensors and/or a Polhemus 3-Space Isotrack device (Polhemus Navigational Systems, Vt., USA), which provides a stream of hand position/orientation data.

Game Description

FingerBall consists of 64 variations of a one-player squash-like game; the simplest of these will serve to illustrate the common elements of the variations: The game takes place inside a rectangular court. Opening and closing the hand in the DataGlove moves a racket back and forth along the bottom wall; opening the hand moves the racket right, closing the hand moves it left. At the players command (i.e. pressing a key on the computer keyboard) a ball is automatically served towards the bottom wall from midcourt. The player must hit the ball with the racket as it passes the horizontal line traversed by the racket or else the ball is out of play and must be served again. Upon successfully hitting the ball, the player receives one point and the ball travels around the court, bouncing off the other walls, finally returning to be hit again by the racket.

The 64 variations of this basic game include the following:

- The ball's return bounce angle off a wall or the racket may vary randomly.
- 1-4 rackets, each on a separate wall, are controlled simultaneously. There are various combinations of directions that the rackets moves in as the hand is opened and closed.
- 1-5 balls are simultaneously in play. The number of balls increases during play; a ball may suddenly split into 2 balls going slightly different directions.
- Upon hitting the ball, the racket's response to the DataGlove may be reversed; i.e. opening the hand moves the racket left, closing the hand moves it right.
- Upon hitting the ball, the racket may "hop" to the opposite wall.
- A ball hitting a wall or racket may disappear and instantaneously reappear at another wall, going another direction.

In addition to these 64 variations the ball's speed can be adjusted and the court's horizontal and vertical sizes may be chosen. Figure 2 shows the FingerBall screen.

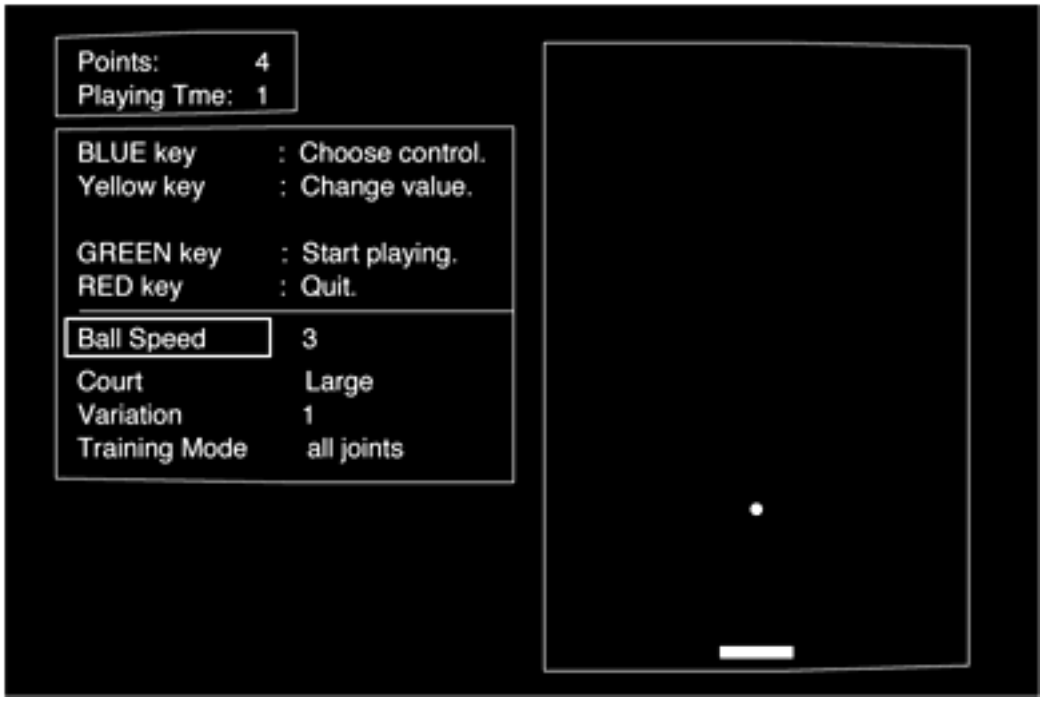

Figure 2: FingerBall screen.

Operation

FingerBall's user interface was designed with two goals in mind: Ease of use by persons unfamiliar with computers; and flexible adjustment of game parameters in relation to each patient's needs and abilities.

Operation of the apparatus is extremely simple; turning on the DataGlove and PC causes the game software to be loaded and ready for use. Player-specific data is entered through a short sequence of screens. Only 4 keys on the computer keyboard are used; these have colored labels attached to them; accidentally striking other keys has no effect. Each screen has clear, concise instructions; no other documentation is needed.

Training Parameters

Each use of FingerBall starts with entry of patient data, including the following:

1. The patient's *active joints* are entered via a screen showing a diagram of a hand. A single keystroke moves the cursor from joint to joint; at each joint another keystroke is used to indicate whether or not that joint's motion will contribute to movement of the racket. Thus only the joints that need training are used.

2. The player is asked to first open and then close his/her hand as much as comfortably possible. This sets the range of hand motion that is needed to move the racket all the way across the court. Thus FingerBall is usable by patients having either large or small range of motion. Furthermore, as the patient's range of motion improves, FingerBall is constantly adjusted to fully utilize the patient's capabilities.

3. FingerBall has three *training modes*: (1) all joints, (2) MCP joints only, and (3) DIP joints only. Only the patient's active joints within the training mode are used to control the racket. This allows more selective training. The training mode can be changed at any time during training.

4. The *ball's speed* and the *choice of game* determine the difficulty of the training activity. Patients can change the speed and select any of the 64 games at any time during the training.

5. The *playing time* is set by the therapist; after the patient has played for this amount of time, FingerBall automatically stops.

CLINICAL EXPERIENCE

FingerBall has been used by 17 patients at Kronprinsesse Märthas Institute (KMI) in Oslo during the three month period January - March 1990. The occupational therapists used their individual judgement when selecting the patients; no uniform criteria was employed. In all cases the training goal was to increase the patient's hand's range of motion by improved tendon gliding [Wehbé]. The patients hands and bandages were such that they were able to wear the DataGlove in a normal manner.

FingerBall was used after the second or third day of training in conjunction with KMI's standard repertoire of training activities, which include the following:

- grasping (power grip) a foam rubber cylinder and placing it on a peg;
- grasping (pinch grip) small hard pegs and inserting them in holes;
- weaving;
- sanding wood with a sanding block having an upright cylindrical handle;
- working with a clay-like substance.

Figure 3 shows the total playing time (in minutes), number of sessions and average session time (in minutes) for 16 of the 17 patients. One patient has been dropped from these graphs because his data is off the scale in relation to the others; he played for a total of 345 minutes over 8 sessions.

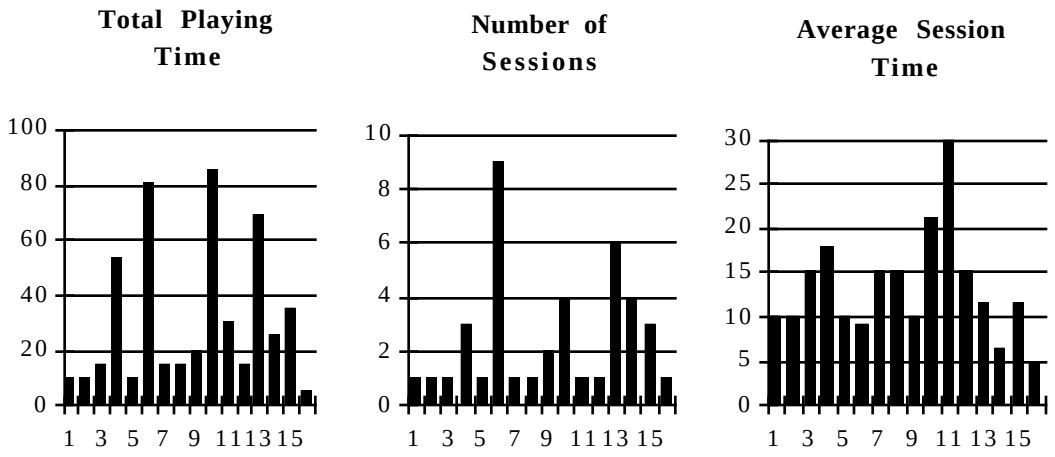

Figure 3: Data listed by patient. Patient numbers 1-16 along bottom axis.Times are in minutes.

EVALUATION

During the three months of clinical use FingerBall has been informally evaluated by the occupational therapists at KMI with respect to two objectives, *patient motivation* and *training attributes*. A summary of their conclusions is that almost all patients find FingerBall to be *fun*, and that FingerBall has a number of *unique* and *positive* attributes in relation to other training exercises.

Patient Motivation

Patient motivation will in general depend on a variety of physical, psychological, and social factors; a rigorous study would need to take these factors into account in a controlled fashion. Such a study has not yet been carried out with respect to FingerBall; the current evaluation is based on the occupational therapists' observations and a short questionaire filled out by the therapist after each training session. The questionaire asks two multiple-choice questions relating to patient motivation:

1. What does the patient think about FingerBall?
   a. Fun and challenging
   b. Ok
   c. Not too exciting, but better than other forms of training
   d. Would rather train in other ways.

2. Does the patient find FingerBall simple to use?
   a. Simple
   b. Difficult
   c. Hard at the start, but got easier.

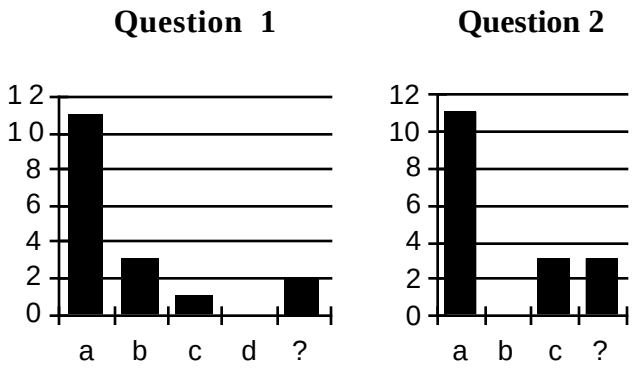

Figure 4: One answer to each question from each patient. "?" indicates no response.

The data clearly indicate that patients think FingerBall is fun and easy. A therapist's description of ease of use, for those who found it easy, is "Five minutes instruction the first time; no further instruction necessary". Patients who liked FingerBall continued to like it during repeated use; the *variety* of games may have contributed to this continued enjoyment.

Although no statistically significant data about the patients was collected, it was observed by the therapists that FingerBall was considered fun and easy by patients not having previous experience with computers or video games, including older patients. However one patient refused to try FingerBall, because she had an adverse attitude to computers.

Training Attributes

From the therapists' point of view FingerBall offered several advantages over other forms of training.

1. FingerBall requires that the patient *stretch* as well as close his/her hand, in equal amounts. This is important for training but is not a natural part of most other training activities, since they mainly involve grasping. In other activities this is compensated for by requiring that the patient carry out a stretching motion as an artificial part of the exercise; poor motivation often leads to "faking" this part of the exercise, i.e. not stretching sufficiently.

2. FingerBall is a *dynamic* activity; the patient's hand is in constant motion, making *effective* use of training time. A typical fifteen minute session may result in hundreds of open-close movements.

3. After initial training (typically five minutes) FingerBall is an *independent* activity. By playing the game the patient is guaranteed to be carrying out the training movements, thus freeing the therapist from observational activity required for other activities, where poor motivation or misunderstanding can lead to ineffective movements.

4. Some of the games in the FingerBall suite require the patient to hold his/her hand open or closed for one or more seconds. For example, this occurs when playing with two rackets on adjacent walls of the court such that the rackets converge in the corner when the hand is either open or closed. Often the ball will bounce off one racket and then the other; this requires holding them both in the corner. This attribute was not intentionally designed into FingerBall, but it was recognized as important and will be highlighted in future versions.

FUTURE RESEARCH

There are three main areas for future research and development based on FingerBall: new training applications based on other sensors; collection of patient movement data into a database; and physical considerations, including ergonomics, hygiene, and packaging.

The occupational therapists at KMI have suggested that FingerBall may be appropriate for training of the wrist, and for training movement accuracy of a prosthetic hook. Wrist movements could be monitored by the Polhemus position/orientation tracking device. Available as an optional part of the DataGlove system, the Polehemus tracker sends the hand's position and orientation in space to the computer along with the DataGlove's finger joint data. By placing the forearm firmly on a fixed surface these measurements would indicate wrist flexion.

The common prosthetic hook is opened and closed by direct mechanical coupling to the opposite shoulder; an upward movement pulls a cable against a spring, closing the hook. Training starts with picking up wooden blocks and ends with enough dexterity to manipulate an egg. A sensor measuring cable tension, hook opening, or contact pressure could interface the hook movement to FingerBall, providing a new training opportunity.

Another possibility is to interface FingerBall to devices measuring EMG [1] or grip force.

Collection, storage, statistical analysis, and presentation of patient movement data would allow therapists and doctors to review the patient's progress in a variety of graphical formats, and would make this data available in a digital form suitable for transmission over a computer network or telephone line. This concept embodies a number of significant research challenges. Raw movement data controls the FingerBall games, but it is not appropriate for storage and analysis. First, there is too much data, and second, it does not provide meaningful information about the patient's movements. A more appropriate unit of movement information might be an opening or closing of the hand; this could be measured in terms of angular degrees and speed. We remark that reliable automatic recognition of hand movements, and rejection of extraneous data, is non-trivial [2]. Another research problem is development of data selection and presentation methods appropriate for evaluation of patient progress.

The third area of future research concerns the system's physical aspects, including ergonomics, hygiene, and packaging. Ideally FingerBall would be packaged as a single processing and display unit connected to the DataGlove and a four-button keyboard. There are two problems related to the DataGlove itself: keeping it clean, and use on swollen bandaged hands. The first problem can be solved by using disposable plastic inserts. We have developed a solution to the second problem; the DataGlove can be fastened on the back of the patient's hand using straps affixed with velcro. This solution is illustrated in Figure 5 below; it has not yet been tested.

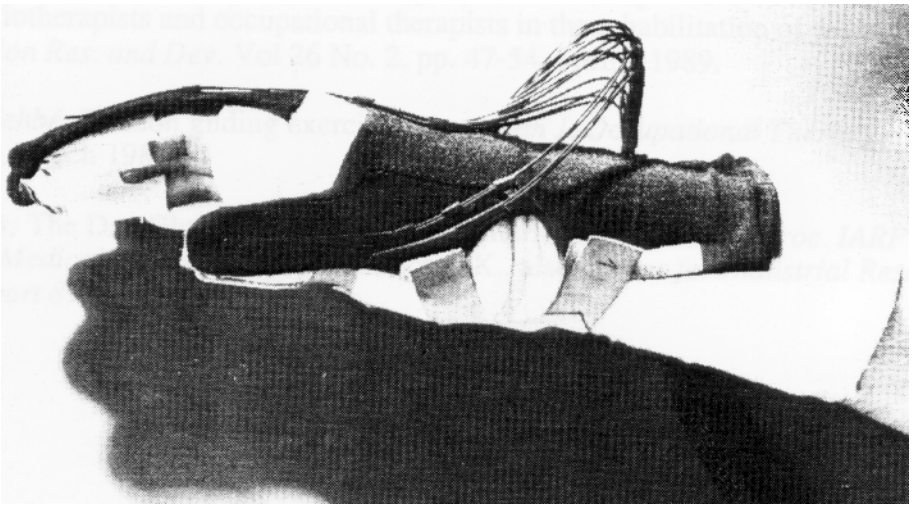

Figure 5: DataGlove modification for swollen or bandaged hand.

CONCLUSIONS

This paper has described FingerBall, a suite of video games controlled by the DataGlove for use in finger movement training after hand injuries. FingerBall has been tested for three months at KMI, Norway's leading hand treatment center. Clinical experience indicates that FingerBall is highly fun and easy for patients, and therefore provides excellent patient motivation. The clinical experience also demonstrated that FingerBall has positive training attributes: it requires equal amounts of grasping and stretching; it is an efficient use of training time; and it provides training that can be reliably carried out independently by the patient.

KMI treated over 500 hand injury patients in 1989; the occupational therapists working with FingerBall estimate that 200 of them could have benefitted from FingerBall.

ACKNOWLEDGEMENTS

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