A VIDEO AID TO REHABILITATION OF STANDING BALANCE IN HEMIPARESIS

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ABSTRACT

The reinstatement of adequate balance in standing following a trauma such as cerebrovascular accident (CVA or 'stroke') is an important step towards the restoration of normal activities of daily living.

A system of video 'games' has been devised to encourage patients with balance problems to achieve specific weight-bearing goals in a controlled and enjoyable manner. In general terms the video training system is as follows: The patient stands on a force plate and, by transference of weight both between the feet and from heel to forefoot, is able to control the position of a cross on a video monitor in front of him; the position of the cross represents the instantaneous centre of foot pressure. The therapist can select a task which involves the patient moving the cross to a specific target, these tasks are chosen to exercise various facets of balance. The tasks are scored automatically both to provide motivation for the subject and to monitor the progress.

The video games have been incorporated into a current research programme into the use of a Pedobarograph as an aid to the rehabilitation of standing balance in CVA patients.

The video games are not, however, dependent on the availability of a pedobarograph and can be operated from any force plate with slight modification to the technique.

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Introduction

In 1978, Chodera and Lord (1) reported to this conference the potential use of a device known as a Pedobarograph (PBG) as a training aid in the rehabilitation of standing balance. Using this system, a patient with problems of balance stands on a pressure-sensitive plate, and an image of his footprints appears on a video monitor placed in front of him, Figure 1. In this image, the various levels of pressure under the feet are represented by coloured zones, and a white cross indicates the overall centre of foot pressure (CFP). By reference to the patterns of pressure under the feet and the location of the CFP cross with respect to the feet, the patient can be instructed on correction of posture and acquisition of balance. For example, the therapist may wish the patient simply to attain an even balance position, as represented by similar colour patterns under the two feet with the cross centrally located, or may require the patient to move the cross in a controlled manner and effect a transfer of weight either laterally or anterioposteriorly. In early trials a transparent track had been laid down on the screen to indicate the desired CFP movement. This type of task was found to constitute a motivational 'game', and produced encouraging results for cerebrovascular patients (CVAs) in particular.

Since that time, the concept of directed video games involving the positioning of the CFP cross has been extended by the introduction of a microprocessor-based system. Particular advantages of the system are:

- that very specific weight-bearing objectives can be achieved by careful selection of the game targets
- that both maintenance of symmetrical stationary balance and active transference of weight can be encouraged
- that a scoring system can be introduced into the games to provide a monitor of progress for the therapist and knowledge of results for the patient
- that the video games raise the motivational level of the patient and encourage numerous repetitions of a task.

The system of PBG-based video games as described in this paper form the basis of standing-balance training in a full-scale trial of PBG therapy now in progress at Roehampton. Accordingly, the games have been selected as suitable for the type of patient on the trial, namely recent CVAs with resultant hemiparesis.

Although the video games are based on a PBG in the Roehampton system, it should be noted that the same system can be operated in conjunction with any force plate capable of driving the CFP cross, with slight modifications to the technique to be discussed later.

General Description of Equipment

The relative locations of patient, therapist, video monitor and keyboard control console are shown in Fig.1. The patient stands on a platform of 350mm x 350mm working area which has a load cell under each of the four corners to register vertical force (Fig.2). The platform comprises the top plate of a PBG and a video camera underneath the platform picks up a light intensity pattern corresponding to the foot pressure. Signals from the four load cells are processed by analogue methods to produce two voltages corresponding to the anterioposterior and lateral position of the centre of foot pressure (CFP) which, if the person is exactly stationary, is coincident with the vertical projection of the centre of gravity of the patient on to the plate. These two voltages are fed into a video circuit which generates the CFP cross, and used to position the cross appropriately in the video field. Video signals from the camera and cross generator are then mixed to superimpose the CFP cross on the foot pressure pattern, and displayed on the monitor in front of the patient. In addition a microprocessor, a NASCOM 2, is used to generate video targets which are also mixed into the monitor video input. The keys of the NASCOM typewriter console are specially labelled to indicate the particular function activated by each key, and once running, the physiotherapist merely hits an individual key to activate a particular task which then proceeds automatically. No computer jargon instructions are required.

The monitor display may be labelled with the patient's name, date etc. via the keyboard if documentary photos or video tapes are required. All information relating to the targets can be removed from the patient's monitor by activating a single key.

The Video Tasks, or 'Games'

1. To encourage symmetrical stationary balance:

   A small circular target is positioned between the patient's footprints, using keys to move the whole target left [←] right [→], up [↑] and down [↓], and two more keys to enlarge the target [bigger], or shrink the target [smaller]. All keys repeat if held down and a reference letter is displayed to mark the current size selected. The patient is instructed to position and maintain the cross within the circle.

   This target can be used to encourage even weight-bearing and maintenance of postural sway within normal limits. In order to monitor progress, a facility is provided to score the percentage of a fixed period of time during which the patient keeps the cross on target. When the patient is suitably stabilised, the physiotherapist activates the time trial key [score % target] and for the next 15 seconds, the microprocessor recognises when the cross maintains contact with the target symbol. At the end of this time the % score appears on the patient monitor, although this can be optionally hidden while the score is still visible to the physiotherapist on an LED display (Fig.3).

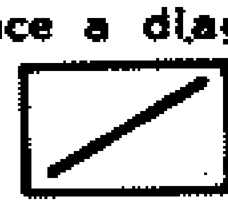
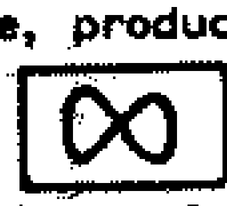
2. To encourage symmetrical balance during external disturbances:

In our set-up the force platform is mounted on a tilting table assembly which enables the patient to be tilted about a single central lateral axis using a variety of pre-programmed tilting cycles. The maximum angle of tilt used is $\pm$ 5° from horizontal, and the maximum tilt speed is approximately 10° per second.

The task described in 1 is repeated while the patient maintains balance during continuous tilting motion. This stimulates active balance mechanisms and reinforces 1.

To encourage controlled weight transference:

A variety of stationary target tracks can be produced on the screen along which the patient is required to move the CFP cross. Two straight line tracks are used first to encourage lateral  and anterioposterior  weight transfer; these must be suitably positioned with respect to the feet using the positioning and scaling keys, so that a realistic task is set for the patient. A circular track is used later.

The next stage is to produce a diagonal track from the left heel to right forefoot  , and vice versa, and finally a butterfly pattern is used which, if followed from heel to toe on each side, produces the pattern of transference required for walking.  (Fig.4).

4. To increase the speed of transference of weight:

The tracks described in 3 can be broken down into a series of equi-spaced dots 

. The dots appear one at a time in sequence, each one being deleted by touching the dot with the CFP cross. Hence the patient must chase the dots and is encouraged to do so as quickly as possible. The time to complete one cycle of the track may be displayed on the monitor at the end of each test, or again optionally hidden from the patient.

The Microprocessor System

The NASCOM 2 microprocessor is used in this equipment to generate targets (Fig.2), score performance and present alphanumeric patient data on the monitor screen. This microprocessor has a standard graphics option which gives a resolution of 96 horizontal by 48 vertical in the video field and generates a synchronisation pulse to enable a camera signal, for example, to be synchronised and mixed with the NASCOM graphics. Both camera and cross generator are synchronised to the NASCOM in our set-up.

Programming of the NASCOM is in a mixture of BASIC and Z80 assembly language, the latter being the language of the Zilog processor central to the NASCOM. The BASIC portion both calculates and presents the score results and also generates the targets as Lissajous figures, a device which eliminates storage of co-ordinate data and facilitates scaling. The assembly language portion handles timing, interrupts and 'bit' detection when cross and target overlap. For this purpose the onboard Z80 P10 (parallel input output chip) has a most useful interrupt facility and can be set up to cause interrupts whenever cross and target video are coincident. The entire programme is currently loaded from a cassette tape, simply by switching the equipment on and starting the cassette deck from the tape beginning. After the programme is read in, a cue is given to indicate that the special function keys are now operative (see General Description). Eventually the programme will be committed to EPROM for immediate start-up.

Training Protocol

When patients can stand for 60 seconds with minimal support from a handrail or the therapist, or with help from a knee brace, treatment can commence. Ten treatment sessions are given over a maximum of thirteen working days. Each session comprises approximately 3 ten minute periods of PBG therapy interspersed by rests, and is carried out at the Bioengineering Centre.

At the first training session, the various display elements are introduced and explained one at a time, with reinforcement before each subsequent session. The first aim is to achieve static standing balance. The task used is a small circle and this would be used each day until the patient could regularly keep the CFP cross in contact with it for 90% of the time.

Dynamic standing balance is encouraged using firstly the vertical and horizontal targets. The therapist varies the size of target to present a constant challenge and uses the dots chase as a check that the target extremities can be reached. Diagonal targets are used to encourage weight bearing under the affected heel.

A record of the targets presented and the resultant scores is automatically typed out on a teleprinter during the session. These records are kept in the patient's training file, and are helpful to the therapist in reviewing progress and choosing the next day's targets (see Table 1 for an example of this printout).

Discussion

Sixteen patients have been treated with this therapy so far, and eight of these have been assessed in considerable detail (by a series of sensory, motoric and psychological assessments coupled with technical assessments of balance and documentary pedobarograms and posture photographs) before and after the treatment as a pilot trial for the main trial now in progress. Although the results of the main trial are not yet available, the following comments can be made in the light of our current experience with the system.

As with all biofeedback techniques, the potential success of the training is due in no small way to the increase in motivation which can be inspired. It has been noted in previous publications (2) that the acquisition of motor skills requires many thousands of repetitions of actions for perfection, and the establishment of standing balance post-CVA can be regarded in the same light as skill acquisition. Because it is typical of cerebro-vascular damage to impair concentration, motivation and memory (3), the therapist may experience difficulty in persuading a CVA patient to make the necessary number of repetitions. In this context video games can be of assistance, not only to provide a direct motivation for the patient, but also to give the therapist a tangible, structured framework towards which the patient's attention can be directed. In a typical course of 10 training sessions as indicated in Figure 5, the patient completed 267 separate scored and recorded task; these would represent only a fraction of the times that the patient actually attempted the tasks.

For the patient whose results are plotted in Figure 5, the results of these 267 tasks were compressed to give a combined indicator of progress. (The % and time scores obtained are defined in the section 'Video tasts or games', parts 1 and 4). The results of a % score were weighted by multiplication with the target track length, irrespective of track shape, since larger tracks approach nearer to the limits of balance; time scores again depend on track length, and length divided by time gives in mm/s an average successful tracking speed. To obtain the averaged "Score" of Figure 5, averaged weighted % score was multiplied by averaged tracking speed for the session.

It is of interest to note that the average successful tracking speed for this patient stayed substantially constant at 23 mm/s during treatment. This reflects the therapist's consistent choice of difficulty of the task; as the patient improved his tracking ability, the target size would be increased to provide a greater challenge. This progressive increase in track length can be seen from the dashed curve in Figure 5.

The position of the feet relative to the CFP cross on the patient's monitor must be displayed in order to position and scale the target tracks. Our system uses a pedobarograph for this purpose. One could equally well use a force plate with a glass top and video camera below to outline the foot position. Alternatively the feet can be positioned in a standard location on the plate by a physical restraint such as the heel and lateral guides used by Hellebrandt (4) in studies of postural sway, and the triangular block used to position the feet in a 'V' on the 'stabilograph' (5) or by making an outline footprint which is transferred to the video monitor.

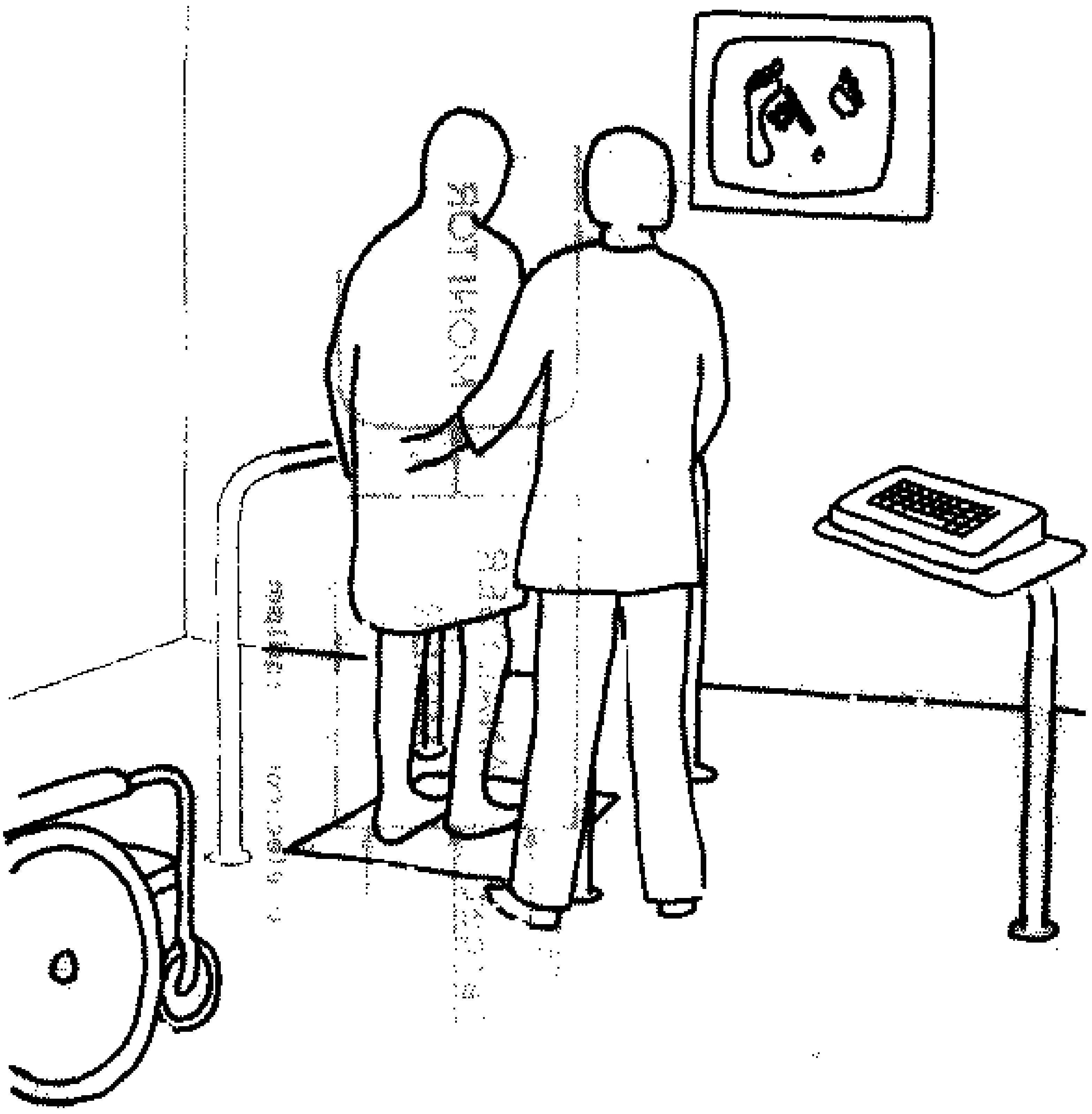


Figure 1. The physical layout of the treatment area. The physiotherapist can both assist the patients and operate the control console. One monitor is placed in front of the patient at eye-level; a second monitor can be used for photography, or for the therapist's reference when the subject is not permitted to view his footprints (e.g. at times of assessment).

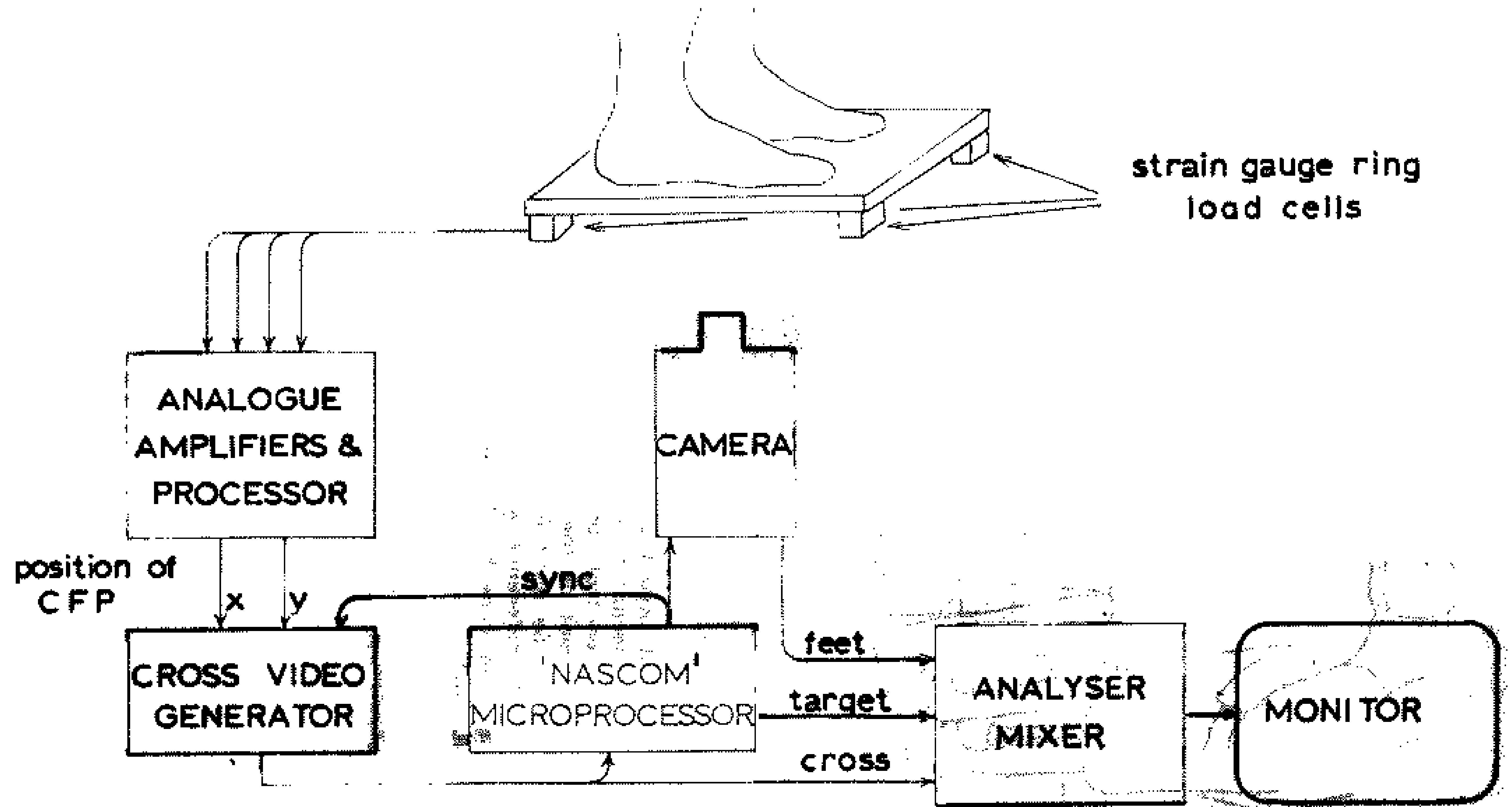


Figure 2. Signal flow in the electronic equipment.

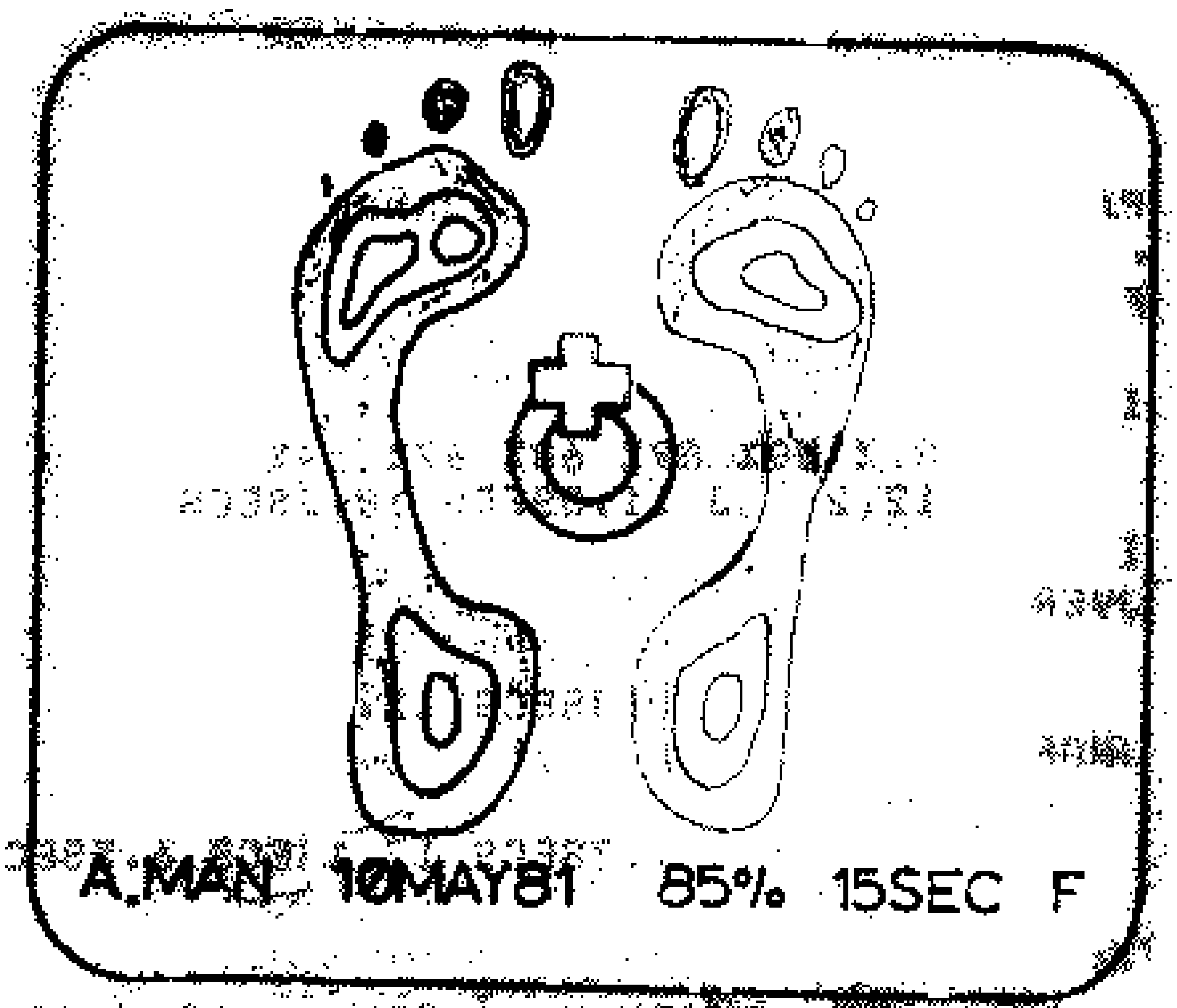


Figure 3. An example of a centring task. The subject maintained the cross in contact with the target circle for 85% of the previous trial period of 15 seconds. The code F designates target size.

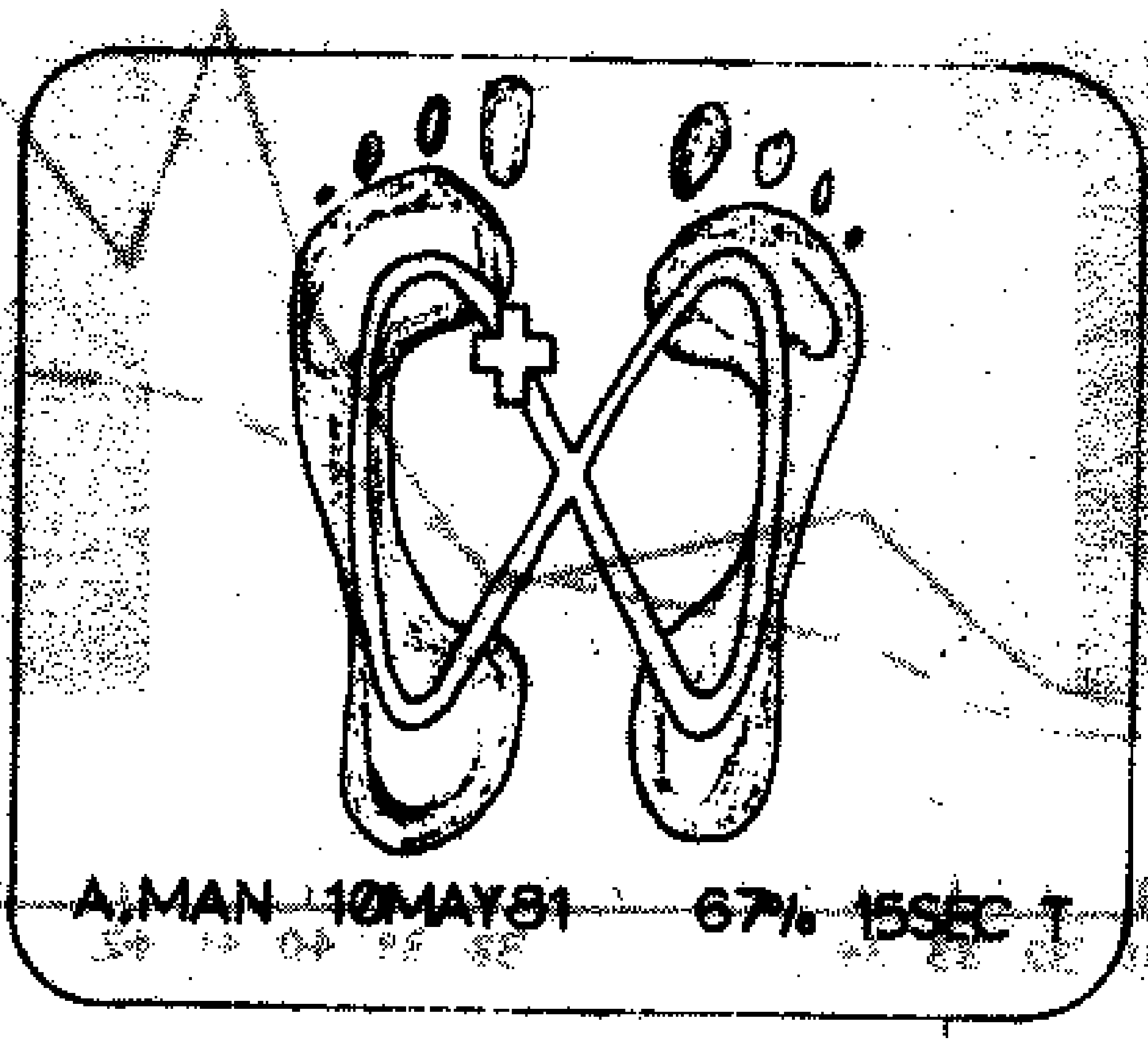


Figure 4. A Dynamic Balance Task with a 'Butterfly' Target Track.

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PATIENT NAME  L.CVA  21JAN81
F CIRC
F CIRC
        39% 75% 55%
I VERT
        81% 80% 89% 68% 67% 64%
        12.2SECS 11.5SECS 18.2SECS
IVERT
JVERT
        87% 80%
        13.6SECS 8.8SECS 12.2SECS
JHORIZ
        38% 61% 56%
        18.7SECS 6.7SECS 17.1SECS 6.5SECS
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Table 1: Typical session print out:
Size reference, Target Shape, Score

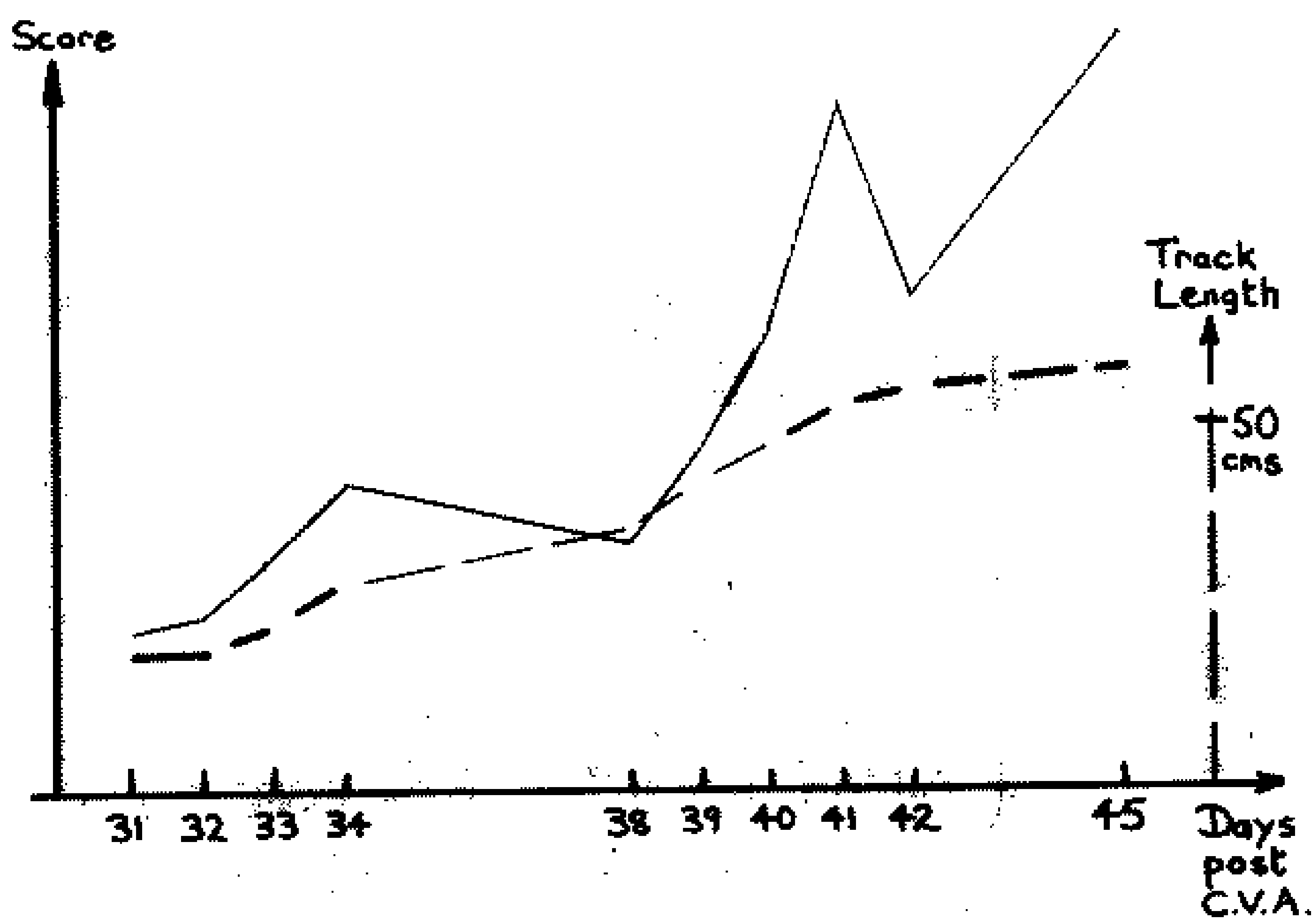

Figure 5. Progress during 10 treatments for one patient. "Score" reflects stability, speed and range of controlled movement.

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