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REHABILITATION OF VISUOMOTOR SKILLS IN POSTSTROKE PATIENTS USING THE DYNAVISION APPARATUS[1]

PETER KLAVORA AND MARY WARREN

School of Physical and Health Education
University of Toronto

Department of Ophthalmology
Eye Foundation of Kansas City

Summary.—The Dynavision is a new apparatus that may help address some of the limitations inherent in conventional approaches to rehabilitation of visual skills of persons suffering from neurological dysfunction. Here the basic features of the apparatus are described, an overview of preliminary experimental evidence for its effectiveness in rehabilitation presented and application in the training of compensatory scanning strategies for visual inattention and visual-field deficits and in the increasing of oculomotor control outlined.

Deficits in visual attention are common outcomes of brain injury and have long been considered prognostic of poor functional recovery (2). Deficient visual attention has been linked to persistent dependence in self-care, failure to resume driving, increased errors in reading and mathematics, an elevated rate of accidents, and the inability to learn to propel and navigate a wheel chair (3, 4, 8, 9, 23, 25). Visual attention is a function of two modes of visual processing within the central nervous system (18, 20). Focal or selective visual attention is responsible for the interpretation of discrete visual impressions (21). Information gained from focal processing is used for the identification and discrimination of objects, allowing the viewer to distinguish between a "b" and a "d," a tangerine and an orange, etc.

Ambient visual attention concerns the detection of events in the environment, their location in space and proximity to the viewer (10). This type of visual processing relies largely on input from the peripheral visual field. Visual input is integrated with other sensory information to provide an internal sensory map used for topographical orientation and to provide an early warning system that protects an individual from unexpected and harmful encounters (18).

Both aspects of visual attention are necessary for the performance of all daily tasks. Selective visual attention is required to complete activities that depend on high visual detail, such as reading, writing, and balancing a checkbook; peripheral visual attention is essential for safe ambulation within the environment and for mobility related to activities such as driving.

Challenged by clients with deficits in visual attention, clinicians have developed ways of assessing the extent and nature of the deficit and devel-

[1]Address enquiries to P. Klavora, School of Physical and Health Education, University of Toronto, 320 Huron Street, Toronto, Ontario, Canada M5S 1A1.

oping treatment strategies for remediation (1, 7, 25, 26). Both assessment and treatment, however, have largely focused on identifying and correcting deficits in focal rather than ambient visual attention, in part because focal attention relies on processing through the macula and central visual field and can thus be completed using eye movements alone. The typical environment of rehabilitation is severely limited; the scope of the activities is correspondingly restricted, often to no more than a sheet of paper or a computer screen. Although many assessment and treatment options are possible such tasks are usually marked by a slow, deliberate, item-by-item search strategy (10, 20); speed of scanning is not required for the successful completion of the task.

Peripheral visual attention, however, depends on a wide scanning strategy, and generally requires a combination of eye and head movements. Peripheral attention helps protect an individual from potential danger in the environment; speed in scanning is therefore critical, particularly in environments involving rapid changes in visual stimuli such as those encountered when driving a car. But evaluations and activities that stimulate the demands for peripheral attention, speed, and width of scanning are difficult to design and implement in a clinical setting. As a result, research on the correction of visual attention deficits has only been able to show improvement in those skills that depend on focal attention such as reading and the completion of mathematics problems (25). Other more demanding skills have proved far less amenable to improvement or rehabilitation.

The Dynavision apparatus, illustrated in Fig. 1, may provide therapists with a means to correct deficits in peripheral attention. The apparatus was originally designed to evaluate and train visuomotor speed and coordination, visual scanning, and visual attention. Over the past four years, approximately 40 hospitals and rehabilitation centres across North America have acquired the apparatus, and, on the basis of clinical work, several occupational therapists have indicated that Dynavision training may facilitate the recovery of impaired visual and attentional skills in persons who have sustained traumatic head injury or stroke.

Scientific investigation of the rehabilitative uses of the Dynavision has only recently begun. Preliminary work with elderly persons poststroke has shown that a 6-wk. training program on the apparatus can generate improvements in several psychomotor capacities, particularly those of the upper extremities, including reaction speed, motor movement speed, and peripheral visual attention (13, 14).

Recent studies at the University of Toronto and University of Missouri have indicated the efficacy of this apparatus for training of poststroke elderly drivers. These studies have shown that psychomotor abilities, such as improved information processing and allocation of attentional resources, can

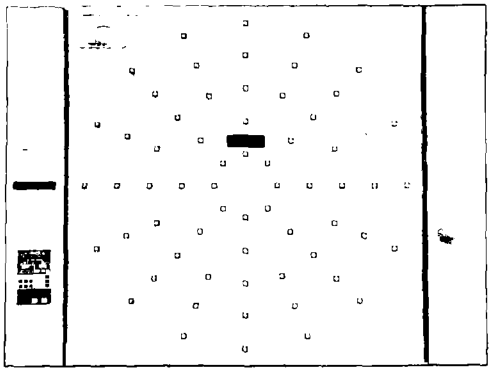

FIG. 1. The Dynavision board measures approximately 165 cm × 120 cm × 20 cm in height, width, and depth, respectively. The apparatus weighs 130 kg and must be wall-mounted.

be improved in elderly drivers who have suffered a stroke and would like to return to normal driving.

Klavora, *et al.* (14) examined the potential Dynavision training benefits to the motor, perceptual, and cognitive abilities of 10 elderly stroke-injured subjects. Apart from undergoing many of the natural physical and psychological consequences of aging, e.g., general behavioral slowing, most of the subjects also experienced various effects from their stroke injuries, such as motor deficiencies in one half of the body, reduced peripheral visual fields, loss of energy, weight gain, emotional lability, reduced attentional capacities, and other negative effects.

Training involved three 40-min. Dynavision training sessions per week for six weeks. The training schedules consisted of a number of Dynavision exercises which imposed various motor, perceptual, or cognitive demands. The results of the training were highly encouraging. Over the 6-wk. training, the speed at which the subjects visually registered and physically responded to single (simple RT) and four-choice (choice RT) stimuli increased significantly ($p < .0001$ and $p < .001$, respectively) as reflected in decreased visual reaction and motor reaction times. These improvements in response times also resulted in increased numbers of hits (on an apparatus-paced exercise) on the Dynavision board region represented by the three inner rings of lights, i.e., the 'focal' board ($p < .0001$) and on the board region represented by the two outer rings of lights, i.e., the 'peripheral' board ($p < .01$). Importantly, the significant increase in the number of hits on the peripheral board suggests that the general increases in visual and motor reaction times may reflect increases in the response speeds to moving stimuli in the peripheral visual field rather than simply to static stimuli within the focal field of vision. In general, the results suggest that a program of Dynavision training may significantly improve some basic psychomotor capacities in elderly subjects poststroke. With respect to driving the performance score on several Dynavision tasks differed significantly between persons rated 'safe' and those rated 'unsafe' in an on-road driving assessment.

In a second study at the University of Toronto (13) the researchers examined the efficacy of Dynavision training on a wide variety of psychomotor skills in one 71-year-old male poststroke driver whose license was suspended. This subject had limited mobility in his left arm and leg, and some peripheral visual impairment. Very intensive Dynavision training occurred over the course of 4 wk., with four sessions/week at approximately 60 minutes/session. A battery of four tests were all administered on each of six days before the treatment period and each of three days after the treatment period to establish reliable baselines for comparison. The four tests were also administered once each week during training to track change in test performance.

Performance improvements began to occur after the start of the treatment. Following Dynavision training, the subject had improved on all four measures, namely, he showed a 40% increase in the number of hits on a 4-min. Dynavision task, a 6.95% decrease (faster) in simple reaction time, a 12.20% decrease (faster) in choice-reaction time, a 21% decrease (faster) in the amount of time required to scan a string of letters in a search for two target letters, and a 67% increase in the amount of time he could successfully perform a visuomotor coordination task. Even though the subject did not pass an on-the-road driving test, his posttraining on-the-road driving performance was evaluated as significantly improved from the baseline road performance test and recommendation was made that he receive 4 to 6 hours of additional behind-the-wheel training before attempting another on-the-road driving test.

Two further single-subject design studies at the University of Toronto (16) and at the University of Missouri (24) have supported these early studies that Dynavision treatment can have beneficial effects on the visual, perceptual, cognitive, and physical abilities of elderly subjects who have suffered cerebrovascular accidents. Furthermore, recent reliability studies have shown that the Dynavision has high test-retest reliability (11, 12).

To predict poststroke patients' fitness to drive an automobile a Dynavision Performance Assessment Battery (DPAB) of four tests was constructed based on a small sample of previously obtained data from poststroke patients who had passed or failed on-road testing (14). In this study (15) 56 stroke poststroke patients whose driving licenses were under suspension completed the battery and the Cognitive Behavioral Driver's Inventory in conjunction with the on-road driving test. The battery yielded results like those from the inventory, a much widely used and carefully developed test with high internal consistency (6) and high relationship to on-road driving performance (5). An analysis showed that each test yielded reasonable prediction of the on-road driving fitness of elderly poststroke drivers; however, when the scores on the two tests were combined, they explained a greater proportion of the variance in on-road testing than either task alone. Passing the inventory and the endurance task on the test battery could guarantee on-road success of the patients. These results suggested that the likelihood of passing the on-road tests can be predicted with relatively high accuracy and validity from more easily administered off-road simulation tests that measure the ability of individuals to perform the essential visuomotor skills and simple cognitive tasks related to driving.

The Dynavision

The Dynavision consists of a fairly large (165 cm × 120 cm × 20 cm), heavy-duty board that may be wall-mounted. Its training surface houses 64 small square buttons, arranged in a pattern of five nested rings. The apparatus can be adjusted to accommodate users of different heights as well as seated users, e.g., in wheelchairs. A light-emitting diode (LED) display is located just above the centre of the training surface. A computerized display panel and a printer are built into the side of the apparatus.

The Dynavision requires the subject to point sequentially to diverse locations in visual space according to a set of programs. Each of the four major programs represents a basic visual or visuomotor exercise, which forms the foundation for the development of more sophisticated exercises. In the *self-paced program* a target button lights up at a random location on the board. The client, positioned in front of the apparatus, must locate and strike it manually as quickly as possible. Once struck, the target button beeps and is extinguished, reappearing at another random location on the board. The client continues striking targets (and scoring 'hits') for the duration of the exercise. In the *apparatus-paced program* a target that is not struck within a preset period, e.g., 1 sec., extinguishes automatically, and a new target immediately appears elsewhere on the board. The *tracking program* requires the subject to track visually (directly or peripherally) target buttons as they are illuminated in a circular pattern along the outer ring of buttons, alternating between clockwise and counter-clockwise movement at factory-set intervals of 30 sec. The *flash program* displays random sets of one to seven digits, for preselected exposure periods. The client's task is to call out the digits as they appear, while simultaneously performing button-striking tasks.

The approximate visual angle available to subjects during self- and apparatus-paced tasks is 90°. For tracking tasks this angle can vary between 30° and 90° depending on the user's distance from the board.

Application of the Dynavision to Rehabilitation

The design of the Dynavision in terms of size, button configuration, and modes of operation make it useful in treating a variety of age groups and rehabilitation conditions. The simplicity of the response required (button-striking) facilitates use of the apparatus by both children and adults. The option to restrict the lights to various regions and to adjust the board height also allows therapists to accommodate the different needs of patients with restricted upper extremity range or in wheel chairs as well as children. Although precision is required in the striking response, the button can be struck with any part of the hand: the palm, fingers, back of the hand, or even a fist. As such, even patients with limited prehension due to conditions such as quadriplegia, hemiplegia, amputation, etc., can work the board with success. Presenting the Dynavision as a game of skill whose purpose is to strike as many target buttons as possible also challenges patients and increases their motivation.

The programs allow patients to work with varying speeds of information processing. Self-paced program exercises can be used to rehabilitate visual scanning and localization in patients who have difficulty executing adequate scanning patterns, including individuals with oculomotor apraxia or dysmetria, injury of cranial nerves III, IV, and VI (which control extraocular muscles), damage to the frontal eye fields, severe visual inattention and neglect, or dense visual-field deficit. An apparatus-paced program combined with a digit flash option can be used to challenge a higher functioning patient who more often experiences the demands of rapid information processing and divided attention. Patients in this category are likely to resume city driving or engage in sports activities. Varying length of task (either 30, 60, or 240 sec.) allows the therapist to prevent fatigue for a patient who suffers from limited scanning ability or, alternatively, to challenge sustained attention of a patient who has difficulty remaining attentive. Various exercises can be used by patients with upper extremity limitations to increase their active range of motion and coordination.

Exercises of longer duration may be useful for placing demands on sustained attention and muscular endurance, while the shorter durations may be used for exercises that require performance of higher intensity, such as rapid visuomotor response. High functioning clients should be able to strike buttons or visually track target buttons within the 1.0- to 0.75-sec. range; clients of moderate functioning may be able to train at these speeds on smaller or restricted areas of the board (see below). Severely impaired clients may have to be restricted to self-paced exercises only as apparatus-paced exercises at their slowest speed (1.0 sec.) are still too challenging. This contributes an important limitation of the Dynavision apparatus.

Middle and inner boards are suited for patients with limited reach or with severe peripheral visual impairments. Very rapid apparatus-paced exercises which are sometimes difficult to perform on full boards are usually easier to perform on the smaller boards.

For exercises in which the patient is instructed to use peripheral vision to locate target buttons, the digit option can be used to ensure that a patient's eyes remain fixed on the LED, i.e., near the centre of the training surface. As such, the consistency and accuracy of the digit calling provides a general index of the extent to which the patient is looking away from the LED, i.e., 'cheating,' to search for the target. Also, the digits can be used to help patients reorient attention to the centre of the board after having completed a visual search during a scanning exercise. To increase task complexity further using the digit option, patients may be required to perform simple mathematical operations. For instance, on a task in which three digits flash, the patient may be instructed to multiply the first two digits, add the third, and call out the total.

Conclusion

Perhaps the greatest advantage involving the Dynavision for visuomotor rehabilitation is that it challenges the peripheral visual system, demanding that it responds in a way compatible with processing of peripheral visual input by the central nervous system. Tasks involving the illumination of target buttons in the outer rings automatically elicit the combination of head turning and eye movement, that is, the natural scanning strategy attending peripheral stimuli (17). In addition, all of the light buttons are identical, eliminating the need for discrete identification and making the person's response to the target button a more automatic one of visual localization which is compatible with the function of peripheral attention. Requiring the patient to locate and then physically strike the button integrates vision into the motor system, thereby providing more effective sensory coding of the visual stimuli and making the task more compatible with CNS functioning.

The application of the Dynavision can potentially be extended beyond visuomotor training. The capability of the apparatus to provide objective performance data in the form of number of hits within three standard time periods, i.e., 30, 60, or 240 sec., areas of visual neglect in the four quadrants or regions of the board, and range of motion and perception in five nested rings of buttons should provide researchers the opportunity to address methods for evaluating and improving peripheral attentional processing.

The importance of the present work lies in providing some evidence for the potential usefulness of the Dynavision apparatus in rehabilitation of visuomotor skills of poststroke patients. Our hope is that these findings will be validated by further research in rehabilitation settings using the same or similar equipment.

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