Rehabilitation of visual skills using the Dynavision: A single case experimental study

ABSTRACT

It has been argued that conventional approaches to visual skill training and evaluation have focussed excessively on higher level visual skill impairments, but often fail to target the basic skill impairments that may underlie them. A novel apparatus known as the Dynavision™ may be useful for remediating skills according to several key training guidelines that have been proposed. The Dynavision is specifically designed to train and test visuomotor response time and coordination, visual scanning, visual attention, and basic cognitive skills, within a broad visual training environment. This paper describes some of the general features of the apparatus, and reports preliminary but positive findings with one elderly person who has had a cerebrovascular accident.

RéSUMÉ

On a souvent reproché aux approches utilisées pour l’entraînement et l’évaluation des habiletés visuelles de porter essentiellement sur les atteintes visuelles de niveau supérieur, ne permettant pas d’évaluer les atteintes des habiletés de base qui peuvent leur être sous-jacentes. Un nouvel appareil appelé Dynavision™ peut s’avérer utile pour remédier à la déficience des habiletés suivant plusieurs directives clés d’entraînement qui ont été proposées. Le Dynavision est destiné de façon spécifique à l’entraînement et à l’évaluation du temps de réponse et de la coordination visuo-motrice, du balayage visuel, de l’attention visuelle et des habiletés cognitives de base à l’intérieur d’un vaste programme d’entraînement visuel. Cette étude décrit quelques unes des composantes générales de l’appareil et fait état de résultats positifs bien que préliminaires chez une personne âgée ayant subi un accident cérébro-vasculaire.

The Dynavision 2000™ is manufactured and trademarked by Performance Enterprises of Toronto.
Common visual deficits associated with stroke and head injury include impaired visual scanning and visual awareness in focal and ambient fields (Gianutsos & Matheson, 1987; Warren, 1990; Warren, 1993a). These skills and abilities are critical to a variety of everyday activities, ranging from reading to navigating in an environment while walking or operating a motor vehicle.

The rehabilitation of visual impairments in persons with acquired brain injuries has conventionally involved the use of paper-and-pencil, computer, and related tasks. Typically, clients might be required to determine a target letter or shape on a page covered with distractors, bisect lines, copy addresses, match objects, etc. (Carter, Caruso, Languirand, & Berard, 1980). The strength of conventional tasks lies in their simplicity, affordability, and demonstrable usefulness for retraining specific and often high-level visual skills, such as reading and writing.

Warren (1993a), however, has pointed out that the conventional treatment and evaluation of visual perceptual dysfunction places excessive emphasis on higher level visual skills. Warren contends that high level impairments are often the result of deficits in basic visual skills, such as oculomotor control, visual acuity, visual field integrity, attention and scanning. She conceptualizes these basic skills as forming the foundation of a visual skill hierarchy, in which lower skills levels support higher ones, and argues that such a model should be adopted to facilitate a more systematic and effective treatment and evaluation of persons with acquired brain injuries.

In accordance with her approach, Warren (1993b) outlines several broad guidelines for visual skill training. A central guideline is the remediation of basic skills. To illustrate basic training, she cites Weinberg et al.'s (1979) research, in which subjects with right cerebrovascular accident were trained to turn their heads to the left (their impaired side) and, using visual cues to anchor their attention and guide their eyes, scanned printed lines from left to right. As the training progressed and subjects became more skilled at scanning, visual cueing was systematically reduced and eliminated.

As Warren indicates, however, the training in the Weinberg et al. study improved academic skills (e.g., reading), but did not transfer to improved scanning performance over a broader visual space. As such, Warren's second training guideline specifies that training should take place within a visual training environment that is broad enough to require either head turning or the shifting of body position. Further, she stresses that treatment should integrate visual and sensorimotor activity and involve the inspection of detail (in particular in the impaired visual space).

Finally, she advises the practice of the skill in different contexts to facilitate the transfer of training (Warren, 1993b).

The purpose of this study was to explore the utility of an apparatus known as the Dynavision 2000 (Performance Enterprises, 1990) for visuomotor remediation. One rationale underlying the study of this apparatus was that the basic visual skill demands imposed by Dynavision tasks, the integrated visual/motor nature of these tasks, and also the size of the Dynavision training environment, may facilitate the training of basic visual skills in a manner congruent with many of Warren's (1993b) key guidelines.

Further impetus for research arose from the fact that the use of the Dynavision apparatus in clinical settings has already begun. Approximately 15 hospitals and rehabilitation centres in the United States and Canada have acquired a Dynavision (Performance Enterprises, personal communication, May 12, 1994), and are currently exploring it as a tool to improve impaired visual skills in persons post-stroke and persons with acquired brain injuries. Therapists have informally reported some success in the rehabilitation of visual scanning, attention, visuomotor coordination, and visual reaction time in persons with stroke and head-injury (K. Carr, Sarasota Memorial Rehabilitation Services, Florida, personal communication, Feb. 8, 1993; J.A. Spencer, Methodist Hospital, Minnesota, personal communication, Jan. 26, 1993).

Research confirming the true rehabilitative value of the apparatus, however, has only recently begun (e.g., Klavora et al., in press). The present, single subject study was undertaken to explore the extent of the benefits that can be realized by an intensive Dynavision training programme as applied to one elderly individual post-stroke.

**METHOD**

**Subject**

The study involved a 71-year-old male with a right cerebrovascular accident (CVA), 12 months post-stroke. His main visual impairments were left peripheral inattention and difficulties in scanning the left visual field smoothly and thoroughly. His major motor impairments included immobility of his left arm and a limited mobility of his left leg (he usually walked with the aid of a cane). A war injury left him with only one lung operational, resulting in somewhat laboured breathing. These characteristics were observed during assessments made at a local rehabilitation centre, and they also were evident in the subject's performance on the psychomotor tests used in our laboratory throughout our research. The research received ethical approval, and was conducted with the consent of the subject.
Apparatus

The Dynavision. According to the claims of the manufacturer (Performance Enterprises, 1990), the Dynavision apparatus was specifically designed to measure and train visual scanning, visual attention in focal and peripheral fields, visuomotor reactions and coordination, and basic cognitive skills. As noted, however, scientific support for the verity of these claims is currently lacking.

The Dynavision consists of a large wall-mounted board (120 cm x 165 cm) housing 64 small square buttons arranged in a pattern of five nested rings. Dynavision training tasks may be apparatus-paced or self-paced. In apparatus-paced tasks, target buttons illuminate, one at a time, at random locations across the board. A user, positioned in front of the apparatus, tries to strike each target button before it extinguishes, at which point another target illuminates. In the easier, self-paced versions of this task, targets illuminate at random points but do not extinguish until struck. Successful hits are signalled by a beep. Other, non-button striking tasks may involve visually following the targets (either directly or peripherally). The duration for which target buttons illuminate (for apparatus-paced tasks only), task duration, and the number of potential targets that may illuminate in a given task, may all be modified to accommodate the ability level or impairment of the user. The duration of tasks may be set at 30, 60, or 240 seconds. In addition, a liquid crystal display (LCD) near the centre of the board can also be preset to display up to seven random (computer chosen) digits for brief, preset exposure periods, every five seconds. Users can be instructed to call out digits, or to manipulate digits (e.g., add or multiply) during motor (button-striking) or visual tasks, thus increasing the demands placed on visual and cognitive information processing. Users may be seated or standing (see Figure 1). The apparatus also includes a reaction time test mode, which can be used to measure the speed of visual reaction and motor movement in simple (one choice) and complex (four or eight choice) response situations.

The collection of basic task data on the apparatus is straightforward. After each trial, the device issues a printout detailing the performance measures (e.g., the number of buttons successfully hit). Preliminary investigations have shown the Dynavision to have a moderate test-retest reliability ($r = .71$ and .73, for two major Dynavision tasks, respectively) (Klavora, Gaskovski, & Forsyth, 1994).

The Test Battery Five tests were used to assess the extent to which Dynavision training improved performance on a variety of perceptual and motor skills. These particular tests were selected for use because they likely assess many of the skills and abilities that are thought to be trainable using the Dynavision apparatus. In addition, many of these tests measure and demand the use of the same essential and basic visual skills described by Warren (1995a), such as scanning and visual attention. These tests were:

1. Simple response time. While holding down one telegraph key, the subject is required to strike another telegraph key, 30 cm away, when a signal light illuminates. The subject is given three practice trials and five test trials. The task imposes demands on integrated visual reaction time and movement time. The dependent variable is mean response time (in milliseconds) of the five test trials.

2. Choice response time. While holding down one telegraph key, the subject is required to strike one of four other telegraph keys, each of which was 30 cm away, when one of four corresponding signal lights illuminates. The subject is given three practice trials and five test trials. The task imposes demands on integrated visual reaction time and movement time, under a choice condition. The dependent variable is mean response time (in milliseconds) of the five test trials.

3. Visual scanning. This task is based on the Walter Reed Performance Assessment Battery (Thorne, Genser, Sing, & Hegge, 1985). In each of 20 trials, the subject sees two target letters, and is then required to determine whether or not both of the target letters are present in a string of 20 letters. The task imposes demands on lateral eye scanning. The dependent variable is total time (in seconds) to complete the task.

4. Pursuit rotor. The subject is instructed to hold the tip of a stylus on top of a small target (approximately 19 mm in diameter) located on the edge of a rotating
platform. The platform rotates at a rate of 30 rotations per minute for one minute. Visual and fine motor coordination are required to perform this task. The dependent variable is total time (in seconds) the stylus is kept on the target.

5. Ring replacement. The subject is required to move 20 rings from a set of five pegs to another, corresponding set of five pegs, located on the opposite side of a screen. The corresponding set and hand movement, however, can only be viewed through a mirror. This task involves visuomotor coordination and the ability to process visually reversed stimuli. The dependent variable is total time (in seconds) to replace the rings.

6. Dynavision task. In this task, the subject is required to strike target buttons while calling out three random digits that appear for one second on the LCD every five seconds. The task is 60 seconds in duration and apparatus-paced. In order to accommodate the subject's limited range of motion, the task was preset to incorporate only the inner four rings of the buttons. The task imposes demands on peripheral and focal visual awareness, visual and motor coordination and response time, concentration, visual recognition, and short term memory. The dependent variable is number of buttons struck.

Procedure
The study used a single case experimental design (Barlow & Hersen, 1984). In addition however, pre, post, and follow-up test scores were computed in order to facilitate a more straightforward analysis of performance changes over time (the details of the computation are described below). To establish the subject's pre-treatment baseline performance on the test battery, the battery was administered on each of six sessions, with each session separated by one to two days. Following this baseline period, the subject participated in 16 sessions of Dynavision training over a period of 4 weeks. During the treatment period, the test battery was also administered once every third or fourth day, in order to track treatment-related performance improvements. After the subject had completed the 16-session training programme, the test battery was administered on each of three sessions to determine his post-treatment performance level. A single follow-up test session occurred following an eight month interval, during which no training took place.

To familiarize the subject with the Dynavision apparatus, three Dynavision tasks emphasizing different abilities (such as visuomotor speed and endurance) were introduced during the baseline period. These tasks were run as a part of the test battery. Results on only one of the tests are shown however, because they are representative of those on the other two. Also note that it is unlikely that the Dynavision testing, which occurred only for a few minutes for each baseline day, had any training-related effect on performance on other tests.

The Dynavision Training
The 16-session training programme involved four sessions per week (for 4 weeks). Each session was 45 minutes in duration, and involved an average of 25 net minutes of training. Most tasks in the programme were one minute in duration, although four minute exercises were occasionally used to increase physical and mental endurance demands. An approximately 20 to 40 second pause occurred between exercises. This short period was used to provide the subject with feedback on his previous task performance, with instructions on upcoming tasks, and for rest.

The purpose of the training programme was to develop basic rather than high-level visual skills (i.e., scanning and attention rather than object recognition or reading), as defined by Warren (1993a, 1993b). As such, although the specific tasks used from day to day varied slightly (to accommodate several psychological variables, such as the motivational level of the subject), all tasks placed demands on a common set of basic, impaired capacities in the subject.

Most of the training involved a combination of apparatus and self-paced button-striking tasks. In most exercises the subject was instructed, and repeatedly encouraged, to fix his eyes on the LCD and to call out flashing digits; simultaneously, he was required to use his peripheral vision to target illuminated buttons for striking with his (unimpaired) hand. These tasks were chosen to help the subject develop a capacity for allocating attentional resources to peripheral visual fields (one of his key impairments, as noted earlier), without compromising his attention to the focal visual field.

In highly demanding variations of the button-striking tasks, the subject was asked to strike targets, call digits, and also to perform a third response (for instance, to inhibit button striking to a pre-specified set of buttons, to call the word “now” whenever pre-specified buttons illuminated, etc.). The rationale for this multi-task approach was to stimulate maximally the subject's integrated use of his various visual-attentional and visuomotor response capacities.

In a fewer number of exercises, the subject was encouraged to shift his eyes and scan for target buttons in a systematic fashion, or to track targets buttons that illuminated from left to right or vice versa.

Computation of Pre, Post, and Follow-up Test Scores
Test scores were recorded as a mean of the two test trials administered in each test session. Baseline sessions one and two served as familiarization sessions. It
was initially intended that a pre-test mean for each dependent variable would be computed by averaging four baseline scores, namely sessions three to six. However, due to the subject's extreme fatigue on session five (as a result of a lack of sleep the previous night), most performance scores during session five were markedly poor. Therefore, in order to avoid an artificial inflation of the results the computation of the pre-test means was based on three baseline sessions only, namely sessions three, four, and six. The computation of the post-test means were based on the last three test sessions (23, 24, and 25). The follow-up test involved only one session of testing.

RESULTS

Table 1 presents pre and post-test performance comparisons and percent improvement on each dependent variable. After the treatment the subject showed enhanced performance on all tasks. Tests from the battery showed improvements ranging from 7.5 % (simple response time) to 280 % (Dynavision).

Table 1 also shows performance on the eight-month follow-up session (a mean score based on two trials for each variable). Dynavision test performance decreased by only 23.7% in comparison to the post-test score, and follow-up performance on the other dependent variables changed only marginally in comparison to post-test levels. These findings suggest strong training maintenance effects.

Any evaluation of performance results in a single case study requires that reasonable baseline measures are obtained on the dependent variables. Ideally, such a baseline shows minimal score variability and no marked improvement or deterioration trends that fail to level off by the end of the baseline period. In this way, a baseline serves as a standard against which changes in performance levels during the treatment period can be evaluated (Barlow & Hersen, 1984). In practice, an ideal baseline can be difficult to obtain. Figure 2 shows test scores across all test sessions. Initially, as expected, a large degree of variation is evident within the baseline period (sessions 1 to 6). In particular, scores on the Visual Scanning task show an improvement trend that does not level off by the end of the baseline but continues into the treatment period. Also, baseline scores on the Pursuit Rotor and Ring Replacement task show a high degree of variability (relative to the other tasks). Although it would have been preferable to extend baseline testing for these tasks until more stable performance levels were obtained, practical and ethical requirements necessitated the onset of treatment after only six sessions of baseline testing.

Dynavision performance scores for one task (described earlier) are also presented in Table 1 and Figure 2. Due to the relatively intense four week training programme on the apparatus, the performance improvement on this apparatus from its baseline levels was dramatic (i.e., 280%). Such improvements were also recorded for performance scores on several other Dynavision tasks that were regularly used for the purpose of providing appropriate feedback to subjects and monitoring rehabilitation progress.

DISCUSSION

The performance improvements recorded between the baseline and post-test period suggest that Dynavision training did generate some transfer of training effect on the various test measures. The minor changes in performance between the post and follow-up tests suggest substantial training maintenance effects. The progression and extent of the improvements and maintenance can be observed during the treatment (sessions 7 to 22), post-test period (sessions 23 to 25), and follow-up session (see Figure 2). Improvement appears to be strongest on the Pursuit Rotor and Ring Replacement Task, followed by the visual scanning task, and simple and choice response time. On the follow-up, only Dynavision performance decreased somewhat (although performance on the follow-up was still substantially higher than on the pre-test). This decline may be related to the likelihood that the Dynavision task demands (such as mental and physical endurance, dual-attention, and rapid eye-hand coordination) were relatively greater than those of the other dependent variables, and therefore more difficult to sustain.

<table>
<thead>
<tr>
<th>Test and Dependent Variable</th>
<th>Pretest Mean</th>
<th>Posttest Mean</th>
<th>Improvement</th>
<th>Follow-up Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dynavision Task (number of hits)</td>
<td>10</td>
<td>38</td>
<td>280</td>
<td>29</td>
</tr>
<tr>
<td>Simple Response Time (millsec)</td>
<td>737</td>
<td>682</td>
<td>7.5</td>
<td>654</td>
</tr>
<tr>
<td>Choice Response Time (millsec)</td>
<td>964</td>
<td>827</td>
<td>14.2</td>
<td>78</td>
</tr>
<tr>
<td>Visual Scanning (sec)</td>
<td>11.4</td>
<td>9.4</td>
<td>17.5</td>
<td>8.8</td>
</tr>
<tr>
<td>Pursuit Rotor (sec)</td>
<td>34.7</td>
<td>44.6</td>
<td>28.5</td>
<td>42.2</td>
</tr>
<tr>
<td>Ring Replacement (sec)</td>
<td>110</td>
<td>86</td>
<td>21.8</td>
<td>85</td>
</tr>
</tbody>
</table>
The lack of a good baseline for most of the tests does call into question the source of the improvements observed during the treatment period. For instance, learning or familiarization effects that continued beyond the baseline period may have been responsible for the observed trends. Nonetheless, some evidence does suggest that training may have played a role in improving test performance. For most tests, marked trends toward improvement begin at or shortly following Session 9 (on the graphs), that is at least three training sessions after the baseline sessions ended. Given the consistency of this finding, it is possible that the training took some time to take effect, though once it did, the result was a steady trend toward improvement. Although learning effects may also have played some role in the improvement, such effects would likely be stronger in the earlier testing sessions (e.g., 1 to 9), rather than in the later ones.

It is arguable then, that Dynavision training may have resulted in at least some sustainable improvements in visuomotor response time in simple and choice situations, visuomotor coordination, visual...
attentional capacities and eye scanning. It is notable that performance improvements occurred more than one year following the subject's stroke. It is unlikely that these benefits were secondary to natural or spontaneous recovery rather than to training, given that natural recovery processes usually occur within six months post-stroke (Goldstein & Davis, 1990; Skilbeck, Wade, Hewer, & Wood, 1983). Still, spontaneous recovery cannot be ruled out (e.g., see Wall & Ashburn, 1979), and so improvements cannot be solely attributed to Dynavision training. Likewise, improvements may have been a placebo effect. This possibility however, is a limitation inherent to any single or case-study finding. Only future research, using more conventional designs (involving control groups), can determine the precise degree to which Dynavision training improves performance.

In spite of the importance of laboratory or experimental measures, another valuable and ultimately more significant criterion for evaluating the effects of Dynavision training relates to the extent to which it benefitted the functioning of the subject in everyday activities. During subject interviews conducted before, during, and after training, the subject in our study did report improvements in motor flexibility, physical energy, and attention. These improvements were noted by the subject during the performance of simple, everyday activities performed within the home. Though highly informal and subjective, these findings, along with the laboratory findings, do suggest that it would be useful to explore the rehabilitative potential of the Dynavision or similar multimodal training apparatus using more sophisticated methodologies and dependent variables that are more relevant to real world tasks. In future research, the assessment of daily functioning using personal diaries might provide valuable information on the transfer of training to everyday learning.

In summary, Dynavision training appeared to show some carryover effect to basic visual skills (as described by Warren, 1993a, 1993b) in an elderly individual who sustained a CVA. The results are tentative but suggest that the apparatus may be useful for improving some impaired visual and visuomotor functions, and may serve as a useful supplement to many traditional occupational therapy activities to provide a more complete and faster recovery. Ultimately, however, the true rehabilitative value of Dynavision training can only be established by further research into the extent to which it produces functional benefits outside of the clinic.

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REFERENCES