ORIGINAL ARTICLE

Retraining Visual Processing Skills To Improve Driving Ability After Stroke

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Objective: To evaluate the effectiveness of retraining using the Dynavision on driving performance of people with stroke.

Design: Randomized controlled trial.

Setting: Outpatient rehabilitation clinic in Australia.

Participants: People with stroke (N=26) referred for driving assessment.

Interventions: Eligible participants were randomized to either receive retraining with the Dynavision apparatus for 18 sessions or to receive no intervention and go onto a waitlist.

Main Outcome Measures: The primary outcome was an assessment of on-road ability. Secondary outcomes included measures of response speed, visual scanning, and self-efficacy. All assessments were conducted by assessors blinded to group assignment.

Results: No significant difference ($P=.223$) was found between the intervention and control groups in results of on-road assessment in terms of pass or fail; the primary outcome measure; or the results on the secondary outcome measures of response speed, visual scanning, and self-efficacy.

Conclusions: In this small trial, training underlying skills (such as executing a continuous wide scan, combining motor and visual processing into a motor response) using the Dynavision apparatus did not improve the outcomes of an on-road assessment for people after strokes. Larger trials are needed to evaluate devices that claim to retrain underlying skills related to driving.

Key Words: Automobile driving; Brain injuries; Cerebrovascular accident; Randomized clinical trial; Rehabilitation.

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S TROKE LEADS TO AN increased relative risk of crash while driving[1,2] and is a major cause of disability in the older population.[3] People with stroke have a range of deficits that may influence their driving ability including reduced visual scanning, attention, information processing speed, and visuo-spatial skills.[4-6] Increasing numbers of people with perceptual and cognitive impairments as a result of stroke wish to resume driving because of an increased survival rate and longevity.[7,8] These deficits translate into a reduction in on-road driving abilities including difficulty with observation and delayed planning of vehicle maneuvers.[5]

The loss of a license after a stroke is associated with a reduction in access to community and social activities.[9] Only 30% to 42% of people return to driving after stroke.[1,10,11] Factors that positively influence the likelihood of returning to driving include being younger,[10] having a lower level of disability,[10,11] having less attention deficits,[4] and being provided with advice and assessment related to driving.[11]

Although neurologic rehabilitation programs often offer assessment related to driving, little is provided in terms of driver retraining.[12] Two approaches to rehabilitation for driving after stroke are used by clinicians[13] including retraining the underlying skill deficits through retraining perceptual, cognitive, physical, or visual skills, otherwise known as a remedial approach, and a functional approach. The remedial approach takes a number of forms such as the use of paper and pencil tasks and devices such as specialized computer programs and other apparatuses designed for retraining of a specific skill set. This approach assumes that retraining cognitive and perceptual skills will transfer to functional performance in on-road driving skills. Simulators and on-road driving in the form of driving lessons are the common methods used in the functional approach to driving rehabilitation.

Controversy exists around the mechanisms that underlie the remedial approach in stroke rehabilitation, particularly in the area of vision.[14] There is debate over whether improvement resulting from remedial approaches is caused by plasticity of the brain and its capacity to reorganize after damage from stroke or compensatory abilities.[14]

Despite the importance of driving to stroke patients, there has been little research[13] evaluating potential rehabilitation approaches to assist patients return to driving. Approaches that have been evaluated include a simulator[15] aimed at improving functional driving skills and 2 devices, the Useful Field of View test,[12] and the Dynavision board,[16,a] which are remedial approaches to driving rehabilitation. A recent randomized controlled trial[15] evaluated the effects of a simulator on 83 patients by providing a 5-week 15-hour training program for the experimental group (n=42) and a control group who received cognitive tasks related to driving (n=41). Significant improvements in the outcomes of on-road assessments were found in the post-training experimental group. Additionally, there was a

List of Abbreviations

ADSES	Adelaide Driving Self-Efficacy Scale
GOSE	Extended Glasgow Outcome Scale
OARS-ADL	Older American Resource and Services Activities of Daily Living Questionnaire

significant difference in performance on a road sign recognition test between groups, with the experimental group achieving higher scores. This suggests that the functional approach, in this case the use of a simulator, does translate to improvements in driving ability for people with stroke. Unfortunately, simulators are not widely available in rehabilitation units, and the other form of functional retraining (ie, driving lessons) has not been evaluated because of the expense involved; lessons are usually provided by privately run driving instruction businesses.

We need to build on the research evaluating the remedial approaches to determine evidence on which practice can be based. However, evaluations of the effectiveness of devices aimed at retraining underlying skills related to driving (ie, remedial approaches) have not been conclusive. The training on the Useful Field of View has not been shown to improve driving performance.[12]

The Dynavision Light Training Board 2000[17] is another tool that aims to train skills relevant to driving including the ability to see all potential obstacles because training requires the continuous execution of a wide visual scan, moving from the central to peripheral and from the front to rear visual field; the combination of motor and visual processing because a motor response is required to visual input; and the speed of actions or response speed, making these actions automatic.[17] The Dynavision, which measures approximately $120cm^2$, consists of 64 small square buttons, each illuminated by a small light bulb and arranged in a pattern of 5 rings. Clients are required to locate an illuminated button and strike it with a hand as quickly as possible. The exercises performed are self-paced or apparatus paced.[17] The mechanisms that the Dynavision is influencing in people after stroke (ie, brain plasticity or compensatory strategies) are not specified.

A preliminary uncontrolled evaluation of the effectiveness of Dynavision training with 10 stroke patients showed improvements in driving ability and response times.[16] Unlike the other training methods, the Dynavision has not been evaluated in a randomized trial. The objective of this study was to evaluate the effectiveness of retraining when using the Dynavision on the driving performance of people with stroke as indicated by a pass or fail result on the on-road driving assessment. Additionally, the second objective was to determine the effects of Dynavision training on performance in terms of response time abilities, visual scanning abilities, and self-efficacy.

METHODS

Participants

Participants were recruited from 4 rehabilitation sites in Adelaide, Australia, between February 2002 and June 2003. Inclusion criteria were as follows: patients had to have a desire to return to driving, they had to meet the medical guidelines by being a minimum of 1 month since their stroke and have binocular vision of at least 6 of 12 with normal visual field on confrontation[18]; they had to have practical driving assessment recommended by treating medical practitioner; held a car class license; and they had to have driven before stroke. Exclusion criteria included less than 120° of peripheral vision[18]; unable to provide informed consent because of language abilities; and required the use of greater modifications than a spinner knob, such as a left foot accelerator, for completion of the on-road assessment. Written informed consent was obtained from all participants. Eligible subjects were included in the study if they were willing to participate and agreed to sign an informed consent form. Approval was obtained from ethics committees of the participating hospitals.

Procedure

All referrals to the study were evaluated for eligibility by a research occupational therapist. This included a liaison with the medical staff as to medical clearance to undertake an on-road assessment. If they were deemed eligible, a participant information sheet was provided and discussed, and they were asked to sign an informed consent form. All participants were informed that the result of the on-road assessment would be forwarded to the licensing authority who would make the final decision regarding license status.

Once baseline assessments were complete, participants were randomly allocated within 24 hours to the intervention or control group. A statistician external to the study generated the random sequence by using the random number generator in Microsoft Excel[b] and created sequentially numbered, opaque, sealed envelopes containing group allocation for participants. The research occupational therapist enrolled the participants, and a pharmacist, who managed the randomization allocation, assigned participants to the groups.

At baseline, demographic, medical history, and measures of functional status including GOSE[19] and OARS-ADL[20] were administered. Abilities in Response Time Measures,[21] visual field scanning using the Visual Scanning Analyzer,[22] and perceived confidence in driving using the ADSES[23] were measured. Subjects randomized to the experimental group received Dynavision training 3 sessions per week for 6 weeks as described in the Dynavision manual[17] discussed later. Participants in the control group were placed on a waitlist for the 6-week period.

Outcome Assessments

The primary outcome measure was the assessment of on-road ability,[24] which was performed at 6 weeks. Additionally, at 6 weeks, repeated assessment of the secondary outcome measures of the Abilities in Response Time Measures, Visual Scanning Analyzer, and ADSES occurred. These outcome assessments were chosen because the Dynavision is aimed at improving visual scanning and response times,[17] and driving self-efficacy has been found to be related to performance in an on-road test for people with stroke.[23] Furthermore, both the Visual Scanning Analyzer (a measure of scanning) and the Abilities in Response Time Measures (a measure of response speed) have been found to be associated with the outcome of an on-road assessment in stroke.[25] These data were collected by an assessor blinded to allocation group.

Outcome Measures

Standardized on-road driving assessment.[24] Driving performance was evaluated by using a standardized route and scoring protocol. The on-road assessment was conducted by a professional driving instructor and occupational therapist with a postgraduate qualification in driving assessment and rehabilitation in a dual-controlled vehicle. The same occupational therapist and driving instructor was used for all assessments to remove interexaminer variability. All assessments were performed in nonpeak times and were not conducted in adverse weather conditions.

Each assessment commenced at an off-road site. The first 10 minutes was a familiarization period, with the driving instructor providing standard information about the test vehicle. The ability of the participant to perform basic motor vehicle operational tasks and to follow instructions was assessed. Performance in this familiarization period was scored on a pass/fail basis, and, if the participant failed, the assessment did not proceed. The route took approximately 60 minutes including

business and residential areas. The route required the driver to negotiate multilaned and single-laned roads, controlled and uncontrolled intersections, speed humps, parking bays, merging roads, pedestrian crossings, straight and winding roads, and traffic signs and signals. The demands of the drive gradually increased in complexity as it proceeded. During the assessment, the instructor gave standard instructions on where to turn and ensured the safe passage of the vehicle. The occupational therapist recorded the driving performance by using the standard protocol. At the end of the assessment, the driving instructor and occupational therapist considered the performance of the participant and assigned a pass (which included those recommended lessons) or fail result. A passing result was given when a safe drive was performed. Lessons were recommended when errors occurred but improvement in performance was noted after instruction. A failing result was recommended when a critical error occurred defined by physical intervention, such as grabbing the steering wheel or applying the brake by the driving instructor required for safety. This standardized on-road assessment has been used in dementia research.[26] Driver assessors were blind to the results of the Visual Scanning Analyzer, Abilities in Response Time Measures, and ADSES.

Abilities in Response Time Measures. The Abilities in Response Time Measures[21] is a measure of response speed that breaks down the components of response into inspection time, responding time, reaction time, response initiation time, and checking and preparation time. It is delivered on a computer screen with a specially designed touch pad to record responses. Stimuli were 4 circles in the case of 2-choice tasks and 8 circles in the 4-choice tasks. Two were presented on the right of the screen and 2 on the left for the 2-choice tasks and 4 on the right and left in the 4-choice tasks. In each group of circles, one becomes solid in color first, and the participant is required to push the corresponding stimuli button on the touch pad. It evaluates these components in a 2-choice, 4-choice, and 2-choice incompatibility task in which participants use the right hand when the left stimulus presents first and vice versa. The inspection time is defined as the "shortest duration of a stimulus that can be responded to with near perfect accuracy on a simple detection task."[21(p183)] It is determined by the presentation of stimuli at graded shorter durations. The responding time is the shortest time required to respond with 80% accuracy to a task set at the individual's inspection time before the onset of the next stimulus. The reaction time is calculated by the addition of inspection time and the time taken to initiate the response after the correct identification of the stimulus. The response initiation time is calculated by subtracting the inspection time from the reaction time. The checking and preparation time is determined by the subtraction of the response initiation time from the responding time. The total processing time is calculated by the addition of the inspection time and the responding time. The lower scores relate to better performance.

Visual Scanning Analyzer. The Visual Scanning Analyzer is a validated instrument for the standardized assessment of the extent to which the participant scans or neglects his/her visual fields, and its outcomes have been shown to be related to driving performance in stroke.[26] It consists of a dome (diameter of 64cm) fitted with lights controlled by a portable computer that the participant positions his/her head inside. Lights are presented at fixed locations in the dome. The detection of a light is indicated by pressing a handheld switch. The computer records the number of lights correctly identified from the test sequences and the time taken to respond. In the tasks named "scan and field 5," the participant can turn his/her head, thus assessing scanning ability. The neglect task involves the person identifying the number of lights, 1, 2, or 3, which are presented simultaneously. In the fixate task, the head and eyes are fixed ahead, assessing peripheral vision. The higher scores on lights seen and the lower scores on time taken indicate better performance.

Adelaide Driving Self-Efficacy Scale.[23] The ADSES is a self-efficacy scale consisting of 12 driving behaviors and a Likert Scale from 0 (not confident) to 10 (completely confident), which allows participants to self-rate their confidence on each driving behavior. The ADSES has shown internal consistency and construct validity with the stroke and nonstroke population.[23]

Interventions

Experimental intervention. The intervention was provided by the research occupational therapist and consisted of training on the Dynavision device, which is described elsewhere,[16] with a standardized program of intervention,[17] which was devised at the University of Toronto for research purposes and tailored to individuals' clinical requirements. The program involves the grading in the complexity of tasks depending on skill level. This commences with self-paced to apparatus-paced tasks in which the time required for a response of finding the light and hitting is reduced as skill level increases. In all tasks, the size of the board used is expanded to increase the visual scanning required. The tasks are further graded by continuing to locate lights around the board while adding numbers coming up on a display in the center of the board with the participant required to call out the numbers or to perform an arithmetic task with the numbers. Every session includes a 240-second task to increase endurance. Treatment sessions most often involve tasks of 60-second duration because they allow sufficient time to adjust to the task and then improve performance. Participants in the retraining group participated in Dynavision training 3 times per week for 6 weeks involving approximately 40-minute sessions. This dosage was selected because of the precedence in another study[16] examining the effectiveness of the Dynavision in retraining driving skills.

Control group. Participants in the control group were placed on a waitlist for the 6-week period.

Sample size

The planned sample size was 26 participants providing 80% power (α level=0.05) to detect a 60% difference between control (20% pass rate) and intervention groups (80% pass rate) on the proportion who passed the standardized on-road driving assessment.

Data analysis

Data were analyzed on an intention-to-treat basis by using the SPSS, version 12.0.[c] All results are reported as a mean ± SD except for the on-road result. Differences between groups on continuous variables and the change between initial and final outcome scores were analyzed by using analysis of covariance, adjusting for the effects of diagnosis, age, and driving experience in the comparison of the allocated groups. The analyses of the outcome scores were adjusted for the corresponding initial score and were also analyzed with the analyses of covariance. The relationship between the result of the on-road assessment and the allocated group was tested by using the chi-square test. For the purposes of analysis, those who were recommended lessons were combined with the pass group because our experience in our driving clinic is that the majority of people who are recommended lessons after stroke proceed to pass in future on-road assessments. All comparisons were 2
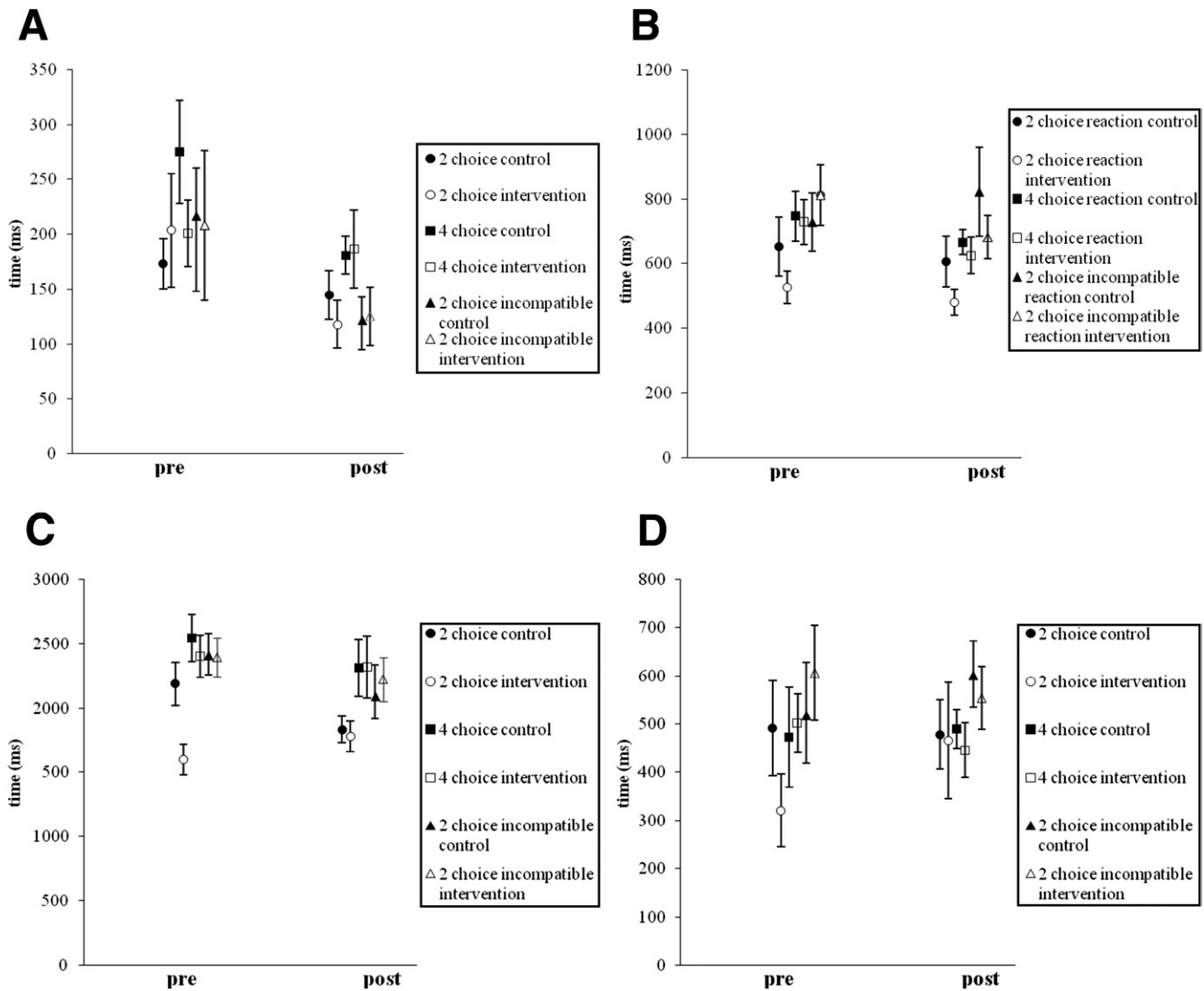
Fig 1. A summary of pre- and postoutcomes. Covariate-adjusted means and standard error of means are shown (adjusted for diagnosis, age, and driving experience covariates). (A) Inspection time, (B) reaction time, (C) response time, (D) response initiation time.

tailed, and significance was set at P less than .01 because of the number of statistical tests that were conducted.

RESULTS

A total of 37 potential participants were reviewed for eligibility; of the 11 excluded, the reasons were not meeting inclusion criteria (n=9) and refused to participate (n=2). Participants who consented to participate were randomized to either the retraining (n=13) or control group (n=13). Of those randomized to the intervention group, (n=13), 10 received the allocated intervention of 18 sessions. Of the 3 who did not, 1 died after 1 session from unrelated causes, 1 refused after 6 sessions, and the other refused the intervention completely. Two in each group were lost to follow-up.

Of the 26 participants (24 men, 92.3%) recruited to the study, the diagnoses included right-hemisphere stroke (n=15, 57.7%), left-hemisphere stroke (n=7, 26.9%), and other stroke (n=4, 15.4%). At baseline, the mean age of all participants was 65.6±13.1, the median days since injury was 83.5 (range, 29–816), the mean years of driving experience was 46.3±

13.4, and the median days since the patient last drove was 83.5 (range, 11–816). The mean GOSE was 5.7±1.4, and the mean OARS-ADL score was 12.4±1.9, indicating a high level of functional independence. At baseline, there were no significant differences between groups in age (P=.433), time since injury/illness (P=.181), GOSE (P=.503), and OARS-ADL (P=.415).

The results of the initial assessments are summarized in figure 1. There were no significant differences in the initial assessment scores on the secondary outcome measure of ADSES between treatment groups. However, there was a significant difference between the intervention and control groups on the: Visual Scanning Analyzer scores of neglect total time (P=.007) and scan 3 total seen (P=.033); and on the Abilities in Response Time Measures of 2 choice inspection (P=.007), response (P=.030) and reaction (P=.024) times.

There was no significant difference in the results of the on-road assessment between the control or intervention group (P=.223). A higher proportion of those in the intervention group (n=10, 76.9%, of which 5 were recommended lessons) passed the on-road assessment compared with the control
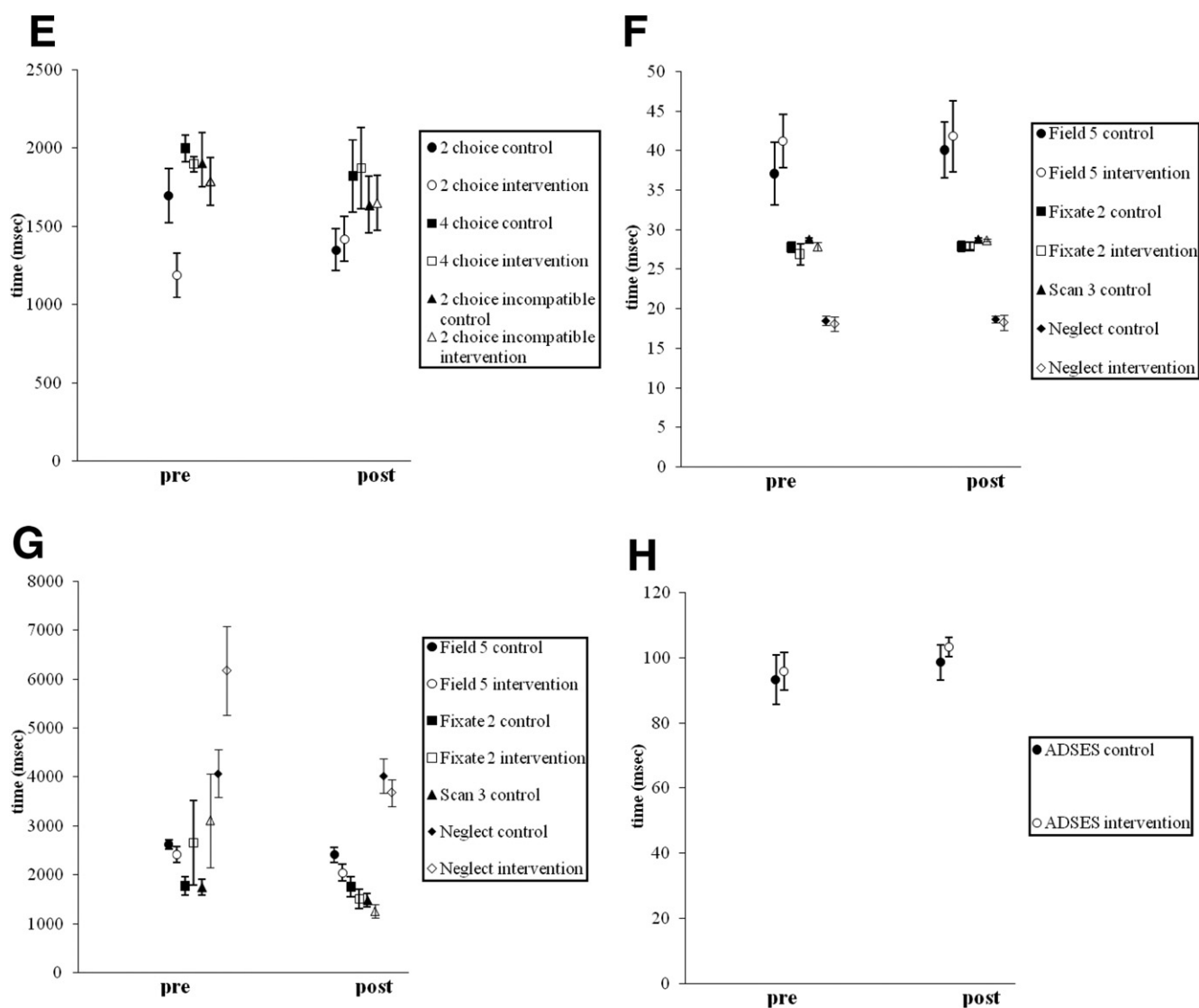
Fig 1. *(Continued)* (E) checking/preparation time, (F) VSA total seen, (G) VSA total time, (H) ADSES.

group (n=6, 46.2%, of which 3 were recommended lessons); however, this did not reach a statistical significance.

Results of outcome assessments and change scores for the treatment groups are presented in figure 1. There were no significant differences between the control and retraining groups in the change on the Visual Scanning Analyzer, Abilities in Response Time Measures, or ADSES scores.

DISCUSSION

This is the first randomized controlled trial evaluating retraining with Dynavision, and we were unable to show significant improvements in driving ability after stroke, indicated by the pass or fail result on the on-road driving assessment. Furthermore, no improvement was found on the impairment level skills of response times and visual scanning or self-efficacy as a result of the Dynavision training. Although the small numbers limit the conclusions we can draw, the results raise issues for the design of future trials.[27] Controversy exists surrounding the mechanisms related to remedial retraining in the area of vision rehabilitation after stroke,[14] and it is unclear

whether tailored computerized intervention improves visual fields because of visual cortex changes or whether they lead to improved compensation to the visual deficit.[14] Dynavision is thought to retrain at the compensatory level,[17] but we could not find any evidence to suggest that the approach retrained the compensatory skills of scanning or response time. More work is required to determine which, if any, mechanisms are amenable to retraining for driving after stroke. In particular, a more detailed understanding of visual deficits and the response of individuals with differing deficits to retraining is needed.[14] Trials assessing interventions could be improved if they included more detailed specific assessment at the impairment level including the neuro-ophthalmologist assessment of perimetry.[28]

Additionally, the remedial approach to training, on which the Dynavision is based, assumes that retrained cognitive, perceptual, and visual skills will transfer to improvement in the performance of functional tasks, such as in driving.[13] We were unable to show this; however, we did not find any improvement in the cognitive and visual skills that the Dynavision is thought

to retrain (ie, response speed and visual scanning, respectively). Interestingly, the other study[12] based on the remedial approach performed by using the Useful Field of View was also a negative study. Results of the Useful Field of View study[12] indicate that training should be targeted at specific skills suggesting that in future study designs stroke patients with reduced visual scanning and response speeds should be targeted for the evaluation of Dynavision training.

A number of theoretic and methodologic limitations may have contributed to the negative findings in this study. The use of the on-road assessment as the primary outcome assessment measure poses difficulties because even when the route and procedures are standardized, differences in weather conditions and traffic density can occur. Standardized screening of visual neglect, visual attention, and motor severity were not included as part of the research design and thus could not be controlled for in the analysis. No exclusion occurred for age or driving frequency, which may be potential confounding factors as those who are older or who drove less before their stroke may have reduced on-road driving skill.

Furthermore, the practice effects of the outcome measures are not known; however, practice effects are limited by the Visual Scanning Analyzer and the Abilities in Response Time Measures because they display random sequences of stimuli. Another possible limitation is that adjustments for multiple comparisons were not made, adopting Rothman's position that such adjustments may be unnecessary.[29] The effect of Dynavision training on the measured outcomes were a priori expected to be relatively small. For this reason, a decision was made not to adjust for multiple comparisons. Nonetheless, the possibility of inflated type I errors because of the number of statistical tests performed cannot be ruled out. Irrespective of one's philosophical position on adjustment for multiple comparisons, none of the individual comparisons were significant at the .05 level in the present study. Thus, no null hypothesis has been rejected because of the number of comparisons performed in our study.

With an increasing number of people with perceptual and cognitive impairments after stroke wishing to resume driving because of an increasing survival rate and longevity,[7,8] it is necessary to evaluate methods available for retraining of driving skills. A variety of driving rehabilitation techniques including programs emphasizing self-awareness have been shown to improve driving skills in the area of older drivers, which may have application in the area of stroke.[30] At present, evidence on the efficacy of remedial approaches in driving rehabilitation remains inconclusive, and, therefore, further work evaluating both remedial and functional training approach methods, including lessons, is warranted. It is unclear whether the functional or remedial approach to driving rehabilitation should be included in clinical practice.

CONCLUSIONS

This is the first randomized controlled trial, with the largest sample to date, evaluating the Dynavision, and we were unable to show an effect on on-road driving performance. The small size of the trial limits the conclusions that can be drawn but provides useful information for the design of future trials. Driving rehabilitation is an increasingly important area for stroke rehabilitation professionals, and expensive devices are currently being promoted as providing recovery via plasticity as well as via compensatory retraining. Although devices that address underlying motor and visual deficits such as scanning and response speed appear to have potential, without a more detailed understanding of the mechanisms behind these interventions, it is difficult to design evaluations. As in many areas of rehabilitation, more rigorous research is needed to identify the role of new technologies in driving rehabilitation and to identify those most likely to respond.

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