

archive

UM-HSRI-81-12

**PRELIMINARY TESTING OF
TECHNIQUES TO IMPROVE
DRIVING PERFORMANCE OF
PERSONS WITH BRAIN DAMAGE
VIA PERCEPTUAL/COGNITIVE
TRAINING**

**Michael Sivak
Carole S. Hill
Paul L. Olson
Donald L. Henson**

**PREPARED FOR
THE UNIVERSITY OF MICHIGAN
REHABILITATION ENGINEERING CENTER**

**INTERIM REPORT
MARCH 1981**



**THE UNIVERSITY OF MICHIGAN
HIGHWAY SAFETY RESEARCH INSTITUTE**

1. Report No.		2. Government Accession No.		3. Recipient's Catalog No.	
4. Title and Subtitle PRELIMINARY TESTING OF TECHNIQUES TO IMPROVE DRIVING PERFORMANCE OF PERSONS WITH BRAIN DAMAGE VIA PERCEPTUAL/COGNITIVE TRAINING				5. Report Date March 1981	
				6. Performing Organization Code 018523	
7. Author(s) Michael Sivak, Carole S. Hill, Paul L. Olson, and Donald L. Henson				8. Performing Organization Report No. UM-HSRI-81-12	
9. Performing Organization Name and Address Highway Safety Research Institute University of Michigan Ann Arbor, Michigan 48109, and Huron High School, Ann Arbor, Michigan 48105				10. Work Unit No. (TRAIS)	
				11. Contract or Grant No. 23-P-5922115-03/04	
12. Sponsoring Agency Name and Address National Institute of Handicapped Research Department of Education Washington, D.C.				13. Type of Report and Period Covered	
				14. Sponsoring Agency Code	
15. Supplementary Notes This research was conducted for the University of Michigan Rehabilitation Engineering Center					
16. Abstract This interim report documents preliminary investigations on the modifiability of driving-related perceptual/cognitive skills in persons with brain damage. The first part of the report critically reviews past research on remediation of perceptual/cognitive deficits in adults with brain damage; the second part describes the methods, findings, and implications of a pilot experiment on modifiability of driving performance of persons with brain damage via retraining of their perceptual/cognitive skills. The literature review showed that the systematic study of rehabilitation of perceptual and cognitive deficits in adults with brain damage is in its infancy. Frequently, articles offer suggestions for therapy without adopting an experimental approach to assess its effectiveness, or present only case studies as opposed to well-controlled experiments. Reassuringly, however, the few well-controlled experiments suggest that perceptual/cognitive deficits of persons with brain damage might be amenable to improvement via training. The results of the pilot experiment indicate that laboratory training sessions designed to improve underlying perceptual/cognitive skills had a substantial effect on subsequent driving performance. The magnitude of the driving-performance improvement was comparable to that obtained by laboratory training sessions designed to directly foster improvements in driving performance. These findings are discussed and the necessary follow-up research is outlined. If the present preliminary findings are confirmed by a larger study, and the relevant issues (e.g., the optimal training content, training length, durability of the effects, and transfer of the effects) are resolved, the present approach could prove to be a valuable therapeutic method in returning persons with brain damage to the mainstream of society.					
17. Key Words Brain damage, driving, perception, cognition, rehabilitation, retraining, intervention			18. Distribution Statement Unlimited		
19. Security Classif. (of this report) Unclassified		20. Security Classif. (of this page) Unclassified		21. No. of Pages 29	22. Price

TABLE OF CONTENTS

INTRODUCTION	1
REMIEDIATION OF PERCEPTUAL/COGNITIVE DEFICITS IN ADULTS WITH BRAIN DAMAGE: A CRITICAL REVIEW OF RESEARCH	2
Background	2
Methodological Considerations	3
Overview of Relevant Studies	5
Conclusions	11
A PILOT EXPERIMENT	12
Rationale	12
Overall Design of the Study	13
Subjects	13
Perceptual/Cognitive Testing	14
Driving-Performance Evaluation	16
Experimental Training	19
Control Training	23
Results	23
Discussion	23
REFERENCES	27

LIST OF FIGURES

1. Cancellation "H" task	17
2. A schematic of the open-road driving course	18
3. Pathfinding task	21
4. Pattern visualization/identification task	22

LIST OF TABLES

1. Subject Characteristics	14
2. Pre- and Post-Training Perceptual/Cognitive and Driving Scores of all Subjects	24

ACKNOWLEDGEMENTS

This research was supported by Research Grants No. 23-P-5922115-03/04 from the National Institute of Handicapped Research, Department of Education, Washington, D.C. to the Rehabilitation Engineering Center at the University of Michigan.

Appreciation is extended to:

Elizabeth Brunner, for help in designing the study and for administering the perceptual/cognitive tests,

Barclay Butler, for scoring the driving performance,

Flora Simon, for efficient secretarial assistance,

and the six subjects, for participation in the study.

INTRODUCTION

Brain damage often impairs psychological functions that are critical in a range of daily activities. For example, there is evidence that brain damage affects perceptual/cognitive skills, and that these skills, in turn, affect driving performance (Sivak et al., 1980).

Being able to provide personal transportation for oneself in today's society is often a necessity and not a privilege. Furthermore, the ability to drive allows freedom of action, flexibility, and self-reliance. In contrast, what frequently follows after brain damage is a reliance on limited and rigid public transportation systems or dependence on others for individual transportation. It follows from the foregoing that rehabilitation techniques capable of improving the affected driving-related capabilities of persons with brain damage would contribute to their physical and psychological well-being.

The first part of this interim report critically reviews past research on remediation of perceptual/cognitive deficits in adults with brain damage; the second part describes the methods, findings, and implications of a pilot experiment on modifiability of driving performance of persons with brain damage via retraining of their perceptual/cognitive skills.

REMEDICATION OF PERCEPTUAL/COGNITIVE DEFICITS IN ADULTS WITH BRAIN DAMAGE: A CRITICAL REVIEW OF RESEARCH

Background

As noted recently by several researchers (e.g., Diller, 1968; Diller and Weinberg, 1977; Golden, 1976), despite a voluminous literature on the deficits in perception and cognition which follow brain damage in adults, little work has been addressed to the possibilities of systematic remedial training for these deficits. Perhaps this situation reflects a belief that to the extent that recovery is possible, a patient's normal environment should be adequate to induce it, without the need for special training. However, this seems an unjustifiable stance to take, given the number of persons whose lives might be positively affected if in fact their problems could be alleviated by some form of intervention.

This section presents a brief overview of the literature on the topic of remediation of perceptual/cognitive deficits in brain-damaged adults. Several allied areas that may have relevance to the topic have not been included. These comprise:

1. Animal research. The most relevant studies would be those on the effects of post-lesion environment on problem-solving abilities (e.g., Will, Sutter, and Offerlin, 1977), and those which seek the neurophysiological mechanisms involved in recovery from brain lesions. Because of the difficulties of extrapolating from animals to humans in the domains of interest, this research was not included.

2. Remedial intervention in neurologically impaired children. While this research has an apparent similarity to the current topic, it is not clear that the learning processes are sufficiently similar for the two cases, since (a) there is evidence that children may have more potential for plastic reorganization of the brain than adults (e.g., Walsh, 1978), and (b) the impairments have preceded initial learning in the children, whereas the adults have accumulated many years of "normal" world experience and education, and still retain much of this information.

3. The work of A. R. Luria. An early advocate of retraining of persons with brain damage, Luria reports positive results in overcoming perceptual and cognitive deficits (e.g., Luria, 1963). However, he relies on case histories, rather than experimental work.

4. Therapy for memory deficits. Several recent studies have reported success in the retraining of memory in brain-damaged patients. Techniques have included contingent reinforcement (Dolan and Norton, 1977), visual imagery (Gasparrini and Satz, 1979), and mnemonic elaboration (Gianutsos and Gianutsos, 1979).

5. Aphasia therapy. Aphasia is perhaps the most studied consequence of brain damage, and therapeutic attempts to treat aphasia go back at least to the turn of the century (e.g., Mills, 1904). Though aphasia falls outside the range of deficits under consideration here, strong evidence of the efficacy of aphasia therapy would be encouraging to the view that perceptual/cognitive deficits might also be susceptible to remediation; however, there is a shortage of well-controlled research in this area.

Methodological Considerations

In a critical review of the literature on aphasia therapy, Darley (1972) considers the requirements of research to establish therapeutic efficacy. These requirements apply equally well to studies of perceptual/cognitive retraining:

1. The need for accurate description of the kinds of patients treated. Darley was referring here to the coexistence of a number of different classification systems for aphasia, and the resulting ambiguity of nomenclature. With respect to perceptual/cognitive pathology, the situation is even less clear. The known set of possible deficits is extensive, and clustering among these deficits is not sufficient to allow a parsimonious classification of patient types. Thus, specifying the "kinds of patients treated" will in the present context mean providing neuropsychological measures from a variety of tests tapping a broad spectrum of abilities.

2. The need for empirical data on the time course of spontaneous recovery, and on the time period during which treatment proves most beneficial. Darley does not mention the possible importance of etiology as a factor here, but it seems likely that differing etiologies would result in different recovery patterns. Furthermore, we might well expect the time course for spontaneous recovery to vary with the particular pattern of perceptual/cognitive deficits exhibited by a patient. Finally, there is the issue of whether treatment is effective only at a certain stage in recovery.

3. The need for accurate and objective measurement of behavior change. Research must be "more than an interested clinician's artistic and intuitive reporting of change observed in his patients. Reliable quantitative data must be gathered with rigorous objectivity" (Darley, 1972, p. 11).

4. The need for "specification of the nature, intensity, duration and quality of the therapy" (Darley, 1972, p. 14).

5. The need for assessing and controlling for the effects of various patient parameters. These parameters include age at onset, educational level, intelligence, current health status, social milieu, etiology of the disorder, site and extent of the lesion, and personality characteristics.

To the considerations dealt with by Darley we might add:

6. The necessity of controlling for the "Hawthorne Effect" (exerting extra effort because of the feeling of being involved in something new and/or special). If measured improvement is merely the result of motivational factors, there is no need for elaborate, carefully designed therapy. To adequately control for this factor is difficult. The approach of using a control group engaged in standard occupational therapy is perhaps the best so far employed, but even so, experimental subjects might be aware of being in a select group and may entertain higher expectations of themselves.

The above-mentioned requirements are difficult to meet. As Darley commented, "obviously, it will be difficult to design adequate studies of the efficacy of therapy....Perhaps there will never be one complete,

definite study....At least professionals can be highly aware of the complexity of the issue and sensitive to some of the components of that complexity" (p. 19).

Overview of Relevant Studies

In the earliest (and most pessimistic) study to be reviewed here, Carroll (1958) examined test performance of a group of left-hemiplegic, post-CVA (cerebrovascular accident) patients. They were reported to have a "set of problems concerned with a deficit in judgment about visuomotor, temporal and spatial concepts which do not respond to any known therapy because these patients appear unable to generalize in relearning" (p. 14). However, the exact form of therapy attempted was not described, so it is not clear what to infer about the "singularly discouraging" (p. 14) results.

In an attempt to ascribe to somesthetic imbalance the defective visual verticality judgments made by left hemiplegics, Birch et al. (1962) compared performance when a ten pound weight was attached to the subject's right or left shoulder. They found that "when somesthetic imbalance is aggravated, there is a worsening of judgment, whereas an increased input to the affected side causes some slight [though statistically not significant] degree of improvement in capacity to judge the visual upright correctly" (p. 556).

A study with similarly narrow scope was a (reportedly) successful attempt by Goldman (1966) to improve hemiplegics' performance on the DSS (double simultaneous stimulation) test. The training consisted of presenting the stimuli in order of increasing difficulty, and giving the patient immediate feedback about mistakes, with patients repeating any incorrect trials (extinctions) with eyes open. While the improvements reported (after two weeks' training) were considerable, the author reports that these patients were typically depressed at the outset, and "seemed to look forward to the short teaching sessions and subsequently became more attentive to the task and eager to please" (p. 685). Since there was no adequate control group, it is not possible to rule out the possibility that increased cooperation and motivation of the part of the subjects accounted for their improved performance, rather than any sensory learning.

Several articles offered suggestions for therapy for various patient groups, without adopting an experimental approach to assess its effectiveness. Forster and Shields (1959) discussed presumed parietal lobe functions and emphasized "the need for careful sensory evaluation and specific therapy aimed at retraining the patient in the sensory aspects" (p. 56). They recommended practice on specific manual manipulation tasks with visual feedback at the outset, to improve position sense, weight discrimination, and stereognosis. They reported "encouraging" (p. 60) preliminary results (but no data) with a small number of patients, and presented a case history.

Adams (1966) discussed a variety of sensory deficits seen in hemiplegia, and suggested how physiotherapy should be modified to suit these cases. He emphasized the need to make the patient aware of his problems, drawing attention to the "bad side" through the use of exercises before a large mirror, cutaneous stimulation, and visual feedback of passive movement. The aim of therapy here was improved motor performance, rather than improved perceptual skills per se.

A third article proposing therapy in a nonexperimental vein is that by Pigott and Brickett (1966), dealing with the syndrome of visual neglect. Specific activities recommended include: practice in shifting the eyes toward the hemianopic side; the use of visual guides (marker or finger) while scanning or reading; scanning exercises in which the patient calls out letters or object names in a right-to-left direction; oral reading; and incidental visual activities (games, writing, drawing). Again, no data on the effectiveness of these techniques were presented.

An experimental study by Taylor et al. (1971) examined the effect of perceptual training on ADL (activities of daily living) ratings and PCMF (perceptual-concept-motor function) test battery scores. All subjects had a history of recent (14-180 days prior) CVA, and were randomly assigned to either the experimental (N=25) or control (N=21) group. Each experimental subject received 20 days of individually prescribed training directed to his/her perceptual/cognitive deficits, as revealed by pretraining PCMF scores. Training procedures included:

1. Gait training, emphasizing verticality and position sense.
2. Map following (within the treatment area).
3. Visual tracking of a moving light.
4. Tactile object recognition.
5. Assembly tasks.

Each control subject received physician-prescribed treatment directed to his/her motor deficit. Results showed equal improvement for both groups on 14 out of 14 ADL ratings and on 11 out of 24 PCMF measures; on none of the ratings or measures did the experimental group improve more than the control group. An interesting observation was that "all of the improved PCMF variables had some relation to vision or visual concept. This would suggest that, of the various deficits tested, visual problems were most susceptible to training and relearning or spontaneous recovery. Non-visual functions such as manual perception, kinesthesia, and proprioception showed no change" (p. 163).

Related to this observation about susceptibility of visual problems to improvement are several recent studies which have reported success with various eye-movement training procedures. In a case history by Block (1978), biofeedback from EOG (electrooculogram) monitors was used in training designed to improve reading in a cerebral-palsied adolescent boy. In the first phase of treatment, the goal was to improve fixation by turning the head while eyes remained fixed. Reading rate increased from 5 to 17 pages/hour during two months of this training. In the second phase (1-1/2 years later), the goal was to track with the eyes, while the head remained still. After eleven months of this training, the reading rate was 40 pages/hour, and the EOG tracings had acquired a highly regular pattern. The treatment program also included ancillary instruction in reading, but this type of instruction alone had been insufficient to instill adequate reading prior to the use of biofeedback.

A dissertation study by Dunning (1977) used the "Gaeke-Smith Visual Tracking Program" to improve reading in aphasic adults (six or more months post-CVA, restricted to left hemisphere damage). The dissertation abstract reported "significant temporary gains in the rate

of letter discrimination and silent reading rate... associated with more stable reductions in error frequency" (p. 2625), and noted that "this contrasts with the commonly held view that significant performance [improvements] in adult aphasics cannot be expected after a six-month recovery period" (p. 2625).

Zihl (1980) has examined the effect of practice on the "blindsight" phenomenon (i.e., ability to detect and localize visual targets located within a portion of cortically blind visual field, and believed to be mediated by the extrastriate retinotectal pathway). Three patients with large scotomas resulting from CVAs were tested for accuracy of saccadic eye movements to a small visual target presented briefly along the horizontal meridian in the blind hemifield. Accuracy was found to increase after ten practice sessions, despite the absence of any direct feedback. In speculating as to the mechanism of the facilitation, Zihl stated, "systematic practice might facilitate the use of the capacity to detect and localize targets in our patients without conscious perception. If the patient's attention is focussed on this capacity his eye movements are directed towards the stimuli presented in the 'blind' hemifield" (p. 76). It remains to be seen whether greater improvement would result from giving the subject direct feedback, and whether or not this capacity is of functional value to the patients.

A common element in the preceding three studies (Block, 1978; Dunning, 1977; Zihl, 1980) is the suggestion that visual motor behavior is amenable to training in patients with varied histories of brain damage. This element is again present in the extensive work of Diller and Weinberg and their colleagues at the Institute of Rehabilitation Medicine, New York University Medical Center. On the hypothesis that a number of perceptual deficits seen in hemiplegia are due to an underlying problem in visual scanning, a series of studies were carried out to see if scanning could be improved by systematic training, and if so, whether the improvement would carry over to related tasks.

The basic task used by Diller et al. to measure visual scanning is a cancellation task in which the subject is presented with an array of digits or letters and must make a mark through all instances of a specified target digit or letter in the array. The measures of interest

are number of errors and time to complete the task. Good performance is thought to reflect "well-regulated visual search of the environment" (Diller et al., 1974, p. 87). When tested on the visual cancellation task, left hemiplegics were found to make significantly more errors of omission than normals or right hemiplegics. It was found that subjects could be usefully classified into subgroups reflecting degree of impairment (mild to severe) based on their combined performance on a cancellation task and a visual confrontation task (the latter being a screening test for visual neglect or field defect).

To evaluate the effectiveness of therapy for post-CVA patients, all subjects were administered an extensive test battery before and after the training period. Tests included both those thought to involve scanning (such as reading, picture identification, and WAIS Picture Completion) and those considered non-scanning tests (e.g., WAIS Digit Span Forward, Purdue Pegboard). The therapy consisted of daily sessions for subjects in the experimental group (in addition to standard occupational therapy received by experimental and control subjects alike), with training on the following tasks:

1. Digit cancellation.
2. Visual tracking of a moving target.
3. Visual search (responding when target lights were detected).

On all three tasks, difficulty was progressively increased by varying stimulus parameters, in accordance with each patient's improvement.

In a preliminary study using this design (Diller et al., 1974), 15 experimental subjects received ten 40-minute training sessions. They exhibited significantly greater pre/post gains than 16 control subjects, both on cancellation tasks and on other tests judged to tap visual scanning.

A later, expanded study (Weinberg et al., 1977) used more subjects (25 in the experimental group and 32 in the control group) and extended the training both in its duration (20 one-hour sessions over a one-month period) and in content (by including reading exercises). Again, greater overall gains on the test battery were made by the experimental group than by the control group, in both mild and severe subgroups, though

"the effects of treatment are more striking in the case of severe patients" (p. 482).

Weinberg et al. (1979), noting that certain test measures had not improved following treatment in the previous study, hypothesized that "disturbances in sensory awareness and spatial organization (the skills tapped by the tasks which were not changed by the initial treatment program) are secondary to the visual neglect of space" (p. 492). In this study, two tasks (in addition to the tasks in Diller et al., 1977) were therefore included in the training phase to treat this secondary deficit: (1) "Sensory awareness training." Subjects practiced estimating the location of the spot on their backs touched by the experimenter, responding by pressing the corresponding button on an array. (2) "Spatial organization." Subjects estimated lengths of plexiglass rods. Immediate feedback as to the correctness of the response was given on both tasks. As in Weinberg et al. (1977), experimental subjects showed pre-post gains on more of the test battery items than control subjects, and again the severe experimental group made more gains (improving on 24 of the 26 test battery scores) than the mild experimental group (which showed improvement on only 15 of 26 scores). As hypothesized, greater improvement was seen in both severe and mild patients in Weinberg et al. (1979) than in Weinberg et al. (1977). The authors concluded that, "a program which incorporates the treatment of the organization of spatial and sensory cues into a visual scanning training program is more powerful than one which deals with visual scanning training alone. The effects are greater not only for nonvisual tasks, but also for visual tasks" (p. 495).

Other forms of treatment for deficits seen in hemiplegia, aside from those based on visual scanning, have also been investigated at the New York University Medical Center. Diller et al. (1974) reported success in improving performance on WAIS Block Designs through systematic training. The subjects were again stroke patients receiving standard rehabilitation therapy, and were divided into control and experimental groups matched for initial competence on Block Designs. The experimental group received ten hourly sessions over a two-week interval in which they were given individualized practice with graded

cueing on variants of the WAIS Block Designs. At retest, both experimental groups (right and left hemiplegic) had improved significantly more than their respective control groups on the WAIS Block Design task. Significant carryover improvement (again, relative to controls) was seen on several tests involving eye-hand coordination (Object Assembly, Motor Impersistence, and parts of the Bender-Gestalt), though not on other tests in the battery (Visual Cancellation, and WAIS Picture Completion, Digit Span, and Similarities).

Still other rehabilitation efforts by the New York University Medical Center group have been designed to ameliorate a range of problems, but report only case histories to support their effectiveness. These include procedures for improving psychomotor alertness, eye-hand coordination, attention, and abstract reasoning in brain-injured patients (New York University Medical Center, 1978, 1979, 1980).

Conclusions

As can be seen from this review, the systematic study of rehabilitation of perceptual/cognitive deficits in adults with brain damage is in its infancy. Frequently, articles offer suggestions for therapy without adopting an experimental approach to assess the therapy effectiveness, or present case studies as opposed to well-controlled experiments. Reassuringly, however, the few well-controlled experiments suggest that perceptual/cognitive deficits of persons with brain damage might be amenable to improvement via training.

A PILOT EXPERIMENT

Rationale

The underlying premises of this research are (1) brain damage frequently affects perceptual/cognitive skills, which in turn affect driving performance (Sivak et al., 1980); and (2) these changes in perceptual/cognitive skills are not permanent and are amenable to modifications via appropriate training (e.g., Diller et al., 1974).

Specifically, Sivak et al. (1980) have shown that from among 12 perceptual and cognitive tests, the best predictor of in-traffic driving performance of persons with brain damage was an abridged version WAIS Picture Completion ($r=.72$). Furthermore, the results of analyses of covariance indicated that the data were consistent with the hypothesis that the driving-related problems encountered by some of the persons with brain damage were due to impaired skills measured by WAIS Picture Completion. Thus, training procedures that would be successful in improving the skills evaluated by WAIS Picture Completion are likely to improve the driving performance (and potential) of persons with brain damage.

Previous research attempts at improving perceptual and cognitive skills of persons with brain damage are reviewed in the preceding section. Of special relevance to the current research is a study by Diller et al. (1974). The results of that study indicate that performance of persons with brain damage on WAIS Picture Completion can be improved via training designed to enhance visual scanning by performing the following set of tasks: digit cancellation, visual tracking of a moving target, and target detection.

The current pilot study was designed to evaluate the effects of a training module on WAIS-Picture-Completion performance and on in-traffic driving performance. The training module included activities aimed at practicing skills with face-valid relation to WAIS Picture Completion: visual scanning, visual imagery, and visual memory.

Overall Design of the Study

The testing involved six persons with brain damage (four in the experimental group and two in the control group). The experimental subjects participated in the following sequence of activities:

- (1) Evaluation of a range of perceptual and cognitive skills by administering several tests, including WAIS Picture Completion.
- (2) Evaluation of driving performance on a specially designed and validated in-traffic driving course.
- (3) Eight one-hour training sessions designed to improve perceptual/cognitive skills in general and the skills measured by Picture Completion in particular.
- (4) The same as in (1).
- (5) The same as in (2).

The control subjects participated in the same activities except that the training was replaced by eight one-hour sessions consisting of presentation of standard driver-education material via sound film strips.

Subjects

The subjects were selected based on the recommendation of a driver educator who has worked extensively with handicapped drivers. The criteria for selection of subjects were: (1) a history of known or suspected brain-damage, and (2) marked difficulty in learning to drive, which was judged by the driver educator to be primarily the result of perceptual, rather than physical, problems.

The first four subjects referred constituted the experimental group; the last two, the control group. Personal history data are summarized in Table 1 for all six subjects.

All subjects were told that the purpose of the study was to investigate ways of improving driving potential, but that as the study was of an exploratory nature, there was no guarantee that they would

TABLE 1
SUBJECT CHARACTERISTICS

S	AGE	SEX	YEARS EDUCATION	DIAGNOSIS	PRIOR DRIVING EXPERIENCE
1	17	F	10	Spina bifida	Three Driver Education Classes
2	18	F	10	Premature, anoxia	Two Driver Education Classes
3	18	M	11	Cerebral palsy	Three Driver Education Classes
4	25	M	12.5	Closed head injury	Licensed driver for three years prior to the injury
5	17	M	11	Premature, "learning disabled"	Four Driver Education Classes
6	16	F	11	Cerebral palsy	Two Driver Education Classes

benefit directly from their participation. Each subject was paid \$50.00 plus a mileage allowance upon completing the study.

Perceptual/Cognitive Testing

The psychological testing (both prior to and following the training) was administered by a school psychologist, who was not informed as to subjects' group membership (experimental or control). The testing was conducted individually in a small, quiet office, and it took approximately 45 minutes to complete. The following psychological tests were administered:

1. Picture Completion (based on a subtest of the Wechsler Adult Intelligence Scale [Wechsler, 1955].) This is a test of perceptual discrimination, in which the subject must identify the most important missing element in each of a series of sketched figures. A 13-item version of the WAIS was used (items # 1-7, 10, 12, 15-18). This abridged version had been found to be a good predictor of driving performance among subjects with brain damage (Sivak et al., 1980), and to be sensitive to brain damage (Sivak et al., 1980). The standard procedure was used.

2. Picture Arrangement (a subset of the Wechsler Adult Intelligence Scale [Wechsler, 1955]). This test involves eight sets of pictures that subjects arrange in proper sequence so that each series will tell a story. According to Zimmerman and Woo-Sam (1973), Picture Arrangement measures factors such as "visual perception, synthesis into wholes through planning, and ability to see cause-effect relationships" (p. 154). Picture Arrangement had been shown to correlate significantly with driving performance among subjects with brain damage (Sivak, et al., 1980), and to be sensitive to brain damage (e.g., Sivak et al., 1980). The standard procedure was used.

3. Symbol Digit Modalities Test (Smith, 1973). The task in this test is to substitute a number for a randomized presentation of geometric figures. The substitution is performed according to a key that pairs different figures with numbers from one to nine. Since the language symbols (digits) are presumably processed primarily by the left hemisphere, and language-free symbols (figures) by the right hemisphere, the substitution of numbers for geometric figures tests "the efficiency of many different central mechanisms in the two hemispheres" [Smith, 1973, p.1]. This test has been shown to be sensitive to brain damage (e.g., Smith, 1968; Sivak et al., 1980). The standard procedure was used for both written and oral response administrations of the test.

4. Reitan's Trail Making Test (Reitan, 1956). In form A, the numbers 1 through 25 appear in randomly distributed circles on the page. The subject's task is to draw connecting lines between the circles in numerical order (as in a "dot-to-dot" puzzle). In form B, the encircled numbers 1 through 13 and encircled letters A through L are randomly arranged on the page. The subject is to connect the circles, alternating between numbers and letters as follows: 1, A, 2, B, 3, C, etc. This test, which taps visual scanning and short-term memory, is sensitive to brain damage (Walsh, 1978). Times to complete parts A and B were recorded in seconds.

5. Cancellation Task. An array of letters (see Figure 1) was presented to the subject. The subject was told to draw a line through each "H," working quickly but trying to avoid mistakes. This task has been used by Diller et al. (1974) as a measure of visual scanning

performance. The time to complete the task and number of errors were recorded.

In addition to the above-mentioned psychological tests, binocular acuity and stereodepth were also evaluated using a Titmus Vision tester. This screening was included to ensure the adequacy of subjects' vision, and was not expected to be affected by either experimental or control training.

Driving Performance Evaluation

Driving performance was evaluated on a specially designed and validated in-traffic driving course (Sivak et al., 1980). Each subject's in-traffic driving was tested on the same 10.4 mile course in the northeast section of Ann Arbor. The traffic on the route during the testing was light-to-moderate with light pedestrian traffic. Approximately half of the route has a speed limit of 25 mph; additional sections have a limit of 30, 35, and 40 mph. Approximately two-thirds of the route is a two-lane road (with sections of one-way only); additional sections are four-lanes wide (both divided and undivided) and five-lanes wide (with a center turn lane). All driving was done during the daytime.

Each subject drove a car equipped with dual-brake system, hand controls for accelerator and brakes, and (if desired) a steering knob. A driver educator (in the front seat) and a performance evaluator (in the rear seat) accompanied each subject. The performance evaluator was charged with rating the performance of each subject on 144 predetermined actions along the route. Figure 2 illustrates the route with all of the test actions and their locations on the route. (Due to the traffic conditions the actual number of the evaluated actions varied from subject to subject: the mean was 120.5 with a standard deviation of 8.7.)

The rating was done using a 2-point scale: Well executed and not well executed. The evaluated actions belonged to one of the following five categories:

B H D F H H C C F H G H I C I B H D A C F B D H E H D A F H I C F B H H A F E H F H C B D F H G E E H G
F H E H D F C B F A H D C E I H D H G G E H H B I H E G H I C E H F C I E H B H G F D H H B E B A H A E
B C H F A F G H H C G D H C H B A G D H E C B H E D H G D H H A F B H I H F E B D H E G D G A C H F H B
A H F E B H F C D F H G H E B D H H F A C C H F D I H C H B I B A C D H F B E B H G H B I C H H E A H E
I E B H G H F B F A H E B H H G H G F E D H B B H H C F H A D C H E I F G H D C B E H H D G A D F H B I
A H B D G A I F H B A F H H E B F H C A D H F G H E B D F H H C F H C H D I G C B H I B H A D C H H F B
H E I H A C F H D C B G H F D A C H H B F E B A H B G E D G H B H G E I B H F D H H A H G D E B H C D H
H G E H G D E C H G H H D E H B A F B H C H D A G B C H D F C A I H H B D F C H C E G D H F A C H F B H
D E H H D C B H E D H G A D F B H I H G E H H B G D E H G B H A B E H F B C H H A D F H G B C D E C H A
G F H I E C D A H H B C A F H D E G F H G B E H I C H H A F H E C F G H D H H E B H E C I A H G H D C D

Figure 1. Cancellation "H" task.

Gap Acceptance. Did the driver, in merging into traffic, accept a gap of a safe size as opposed to accepting a gap too short or rejecting a gap long enough?

Limit Line. Did the driver position himself (herself) correctly at a stop sign, yield sign, or a traffic light?

Observation. Did the driver make the necessary observations (directly or via a mirror) at a stop or yield sign, prior to a requested change of lanes, and on turns? (Observations on turns and on straight portions were tabulated separately.)

Path. Did the driver stay within his/her lane without unsafe deviations from the intended direction? (Paths on turns and straight portions were tabulated separately.)

Speed. Did the driver stay within + 5 mph from the speed limit? Did the driver maintain a smooth speed profile in turns and during acceleration? (Speeds on turns and straight portions were tabulated separately.)

Neither the driver educator nor the performance evaluator was informed as to the subject's group membership (experimental or control).

As a global index of the driving performance, a Composite Driving Index was computed, which was the mean of the percent correct of each of the category of driving actions. Thus, an obtained Composite Driving Index could be between 0 and 100.

Experimental Training

Subjects in the experimental group were seen individually for eight one-hour training sessions (with the exception of one subject who completed only five sessions). A variety of training tasks were used, including:

1. Cancellation tasks. Approximately one-half of the training time was spent on this type of task. The following parameters were varied: (1) size of the array (single, double, or triple sheets), (2) size of the stimuli, (3) stimulus type (letters, arrows, percent signs, brackets, pictures) (4) target/nontarget ratio, (5) direction of scanning requested (left to right, right to left, up/down), (6) mode of

response (mostly written [requiring only a check mark], but some oral), and (7) difficulty of discriminating targets from non-targets. Immediate feedback (experimenter pointed out omitted items) was given beginning on the second day of training.

The skills involved in performing these cancellation tasks include directed scanning, visual discrimination, and left/right differentiation (for example,] vs. [).

2. Pathfinding tasks. The subject was shown either a small display (8.5" x 11" sheet, placed on a table) or a large display (2' x 3', suspended on the wall) each containing randomly arranged circled letters with associated arrows to direct the gaze from one circle to the next (see Figure 3). The subject was given a starting point and asked to read the letters within the circles, following the order given by the arrows.

This task was devised to practice directed visual scanning as well as short-term memory and visual imagery (the subject must extrapolate the lines of the arrows to reach each successive target).

These tasks were incorporated in the training on two of the eight days.

3. Pattern visualization/identification. A regular matrix of circles containing letters and/or numbers was shown to the subject (see Figure 4). The subject's task was to listen to a short sequence (3-6) of the letters and/or numbers read aloud by the experimenter and to visualize the pattern which would be formed if a line were drawn connecting the corresponding circles in the sequence read. This target pattern was either a simple geometric shape (diamond, square, or rectangle) or a letter of the alphabet.

If a subject had difficulty with correctly identifying the pattern in this way, the task was made easier by allowing him/her to trace connecting lines with a finger.

This task was designed to give practice on visual scanning, visual imagery, and visual memory; it was included in 2 of the 8 sessions.

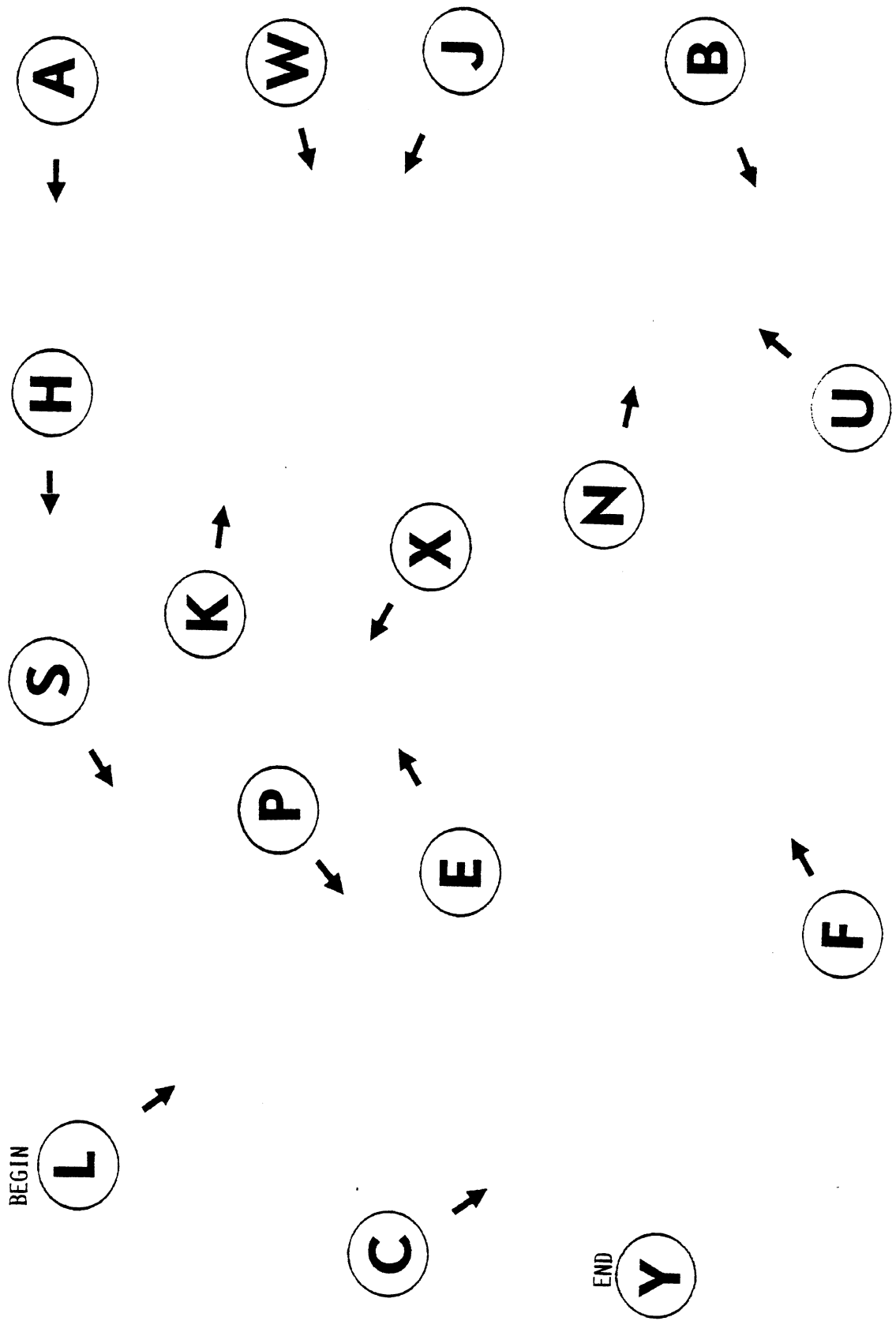


Figure 3. Pathfinding task.

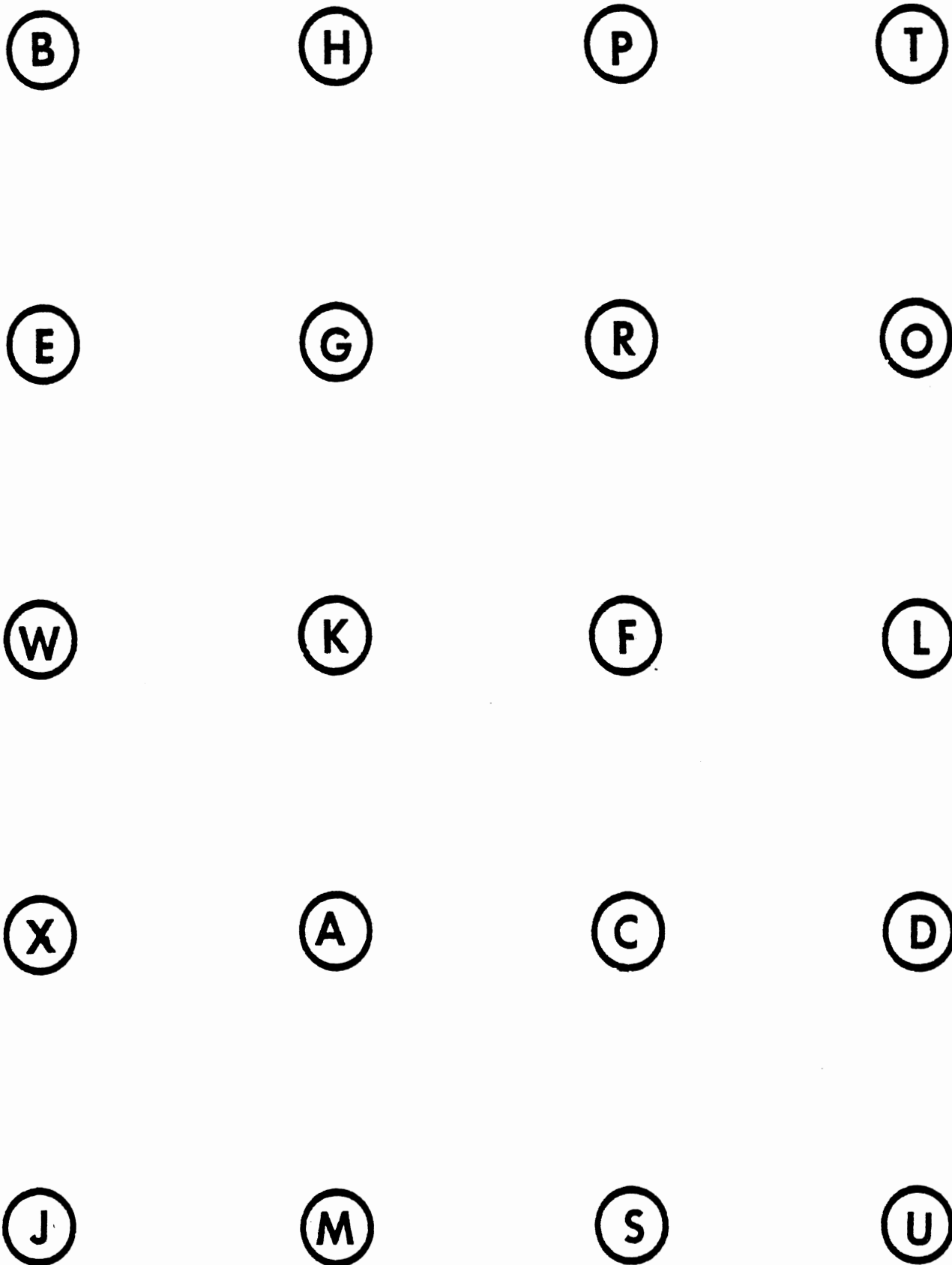


Figure 4. Pattern visualization/identification task.

4. Embedded figures. Subjects were first given standard administration of selected plates from the Southern California Figure-Ground Visual Perception Test (Ayres, 1966). The task in this test is to identify which three of six patterns are embedded in a complex pattern. The test was then made easier by allowing the subject to overlay transparencies of the six alternatives on the test plates, thus allowing for a direct perception of whether each was or was not embedded in the complex pattern. Successful performance on this task entailed figure/ground discrimination, pattern perception, visual imagery, and mental rotation.

5. Additional tasks. A number of other perceptual tasks were used, including:

- a) Immediate memory for line drawings.
- b) Practice on WAIS Block Designs (Wechsler, 1955).
- c) Identification of mirror-image pairs of rotated letters.

These tasks involved visual memory, visual imagery, spatial organization, and mental rotation.

Control Training

On each of the eight training days, the two control subjects spent approximately one hour viewing two or three driver education sound filmstrips. A total of twenty filmstrips were used, covering such topics as proper turning, passing, and emergency maneuvers. This "control" training was designed to be much more than a "nontreatment" condition. It might better be regarded as an alternative training, which while not directed at underlying perceptual skills, might be expected to produce improvement due to the "Hawthorne effect," plus improvement in driving skills due to explicit driving instruction.

Results

Table 2 presents the pre- and post-training perceptual/cognitive and driving scores for all subjects.

Discussion

The data in Table 2 indicate the following:

TABLE 2

PRE- AND POST-TRAINING PERCEPTUAL/COGNITIVE AND DRIVING SCORES OF ALL SUBJECTS

MEASURES	SUBJECTS											
	EXPERIMENTAL						CONTROL					
	1	2	3	4	5	6	1	2	3	4	5	6
	PRE	POST	PRE	POST	PRE	POST	PRE	POST	PRE	POST	PRE	POST
<u>Perceptual/Cognitive Measures</u>												
Picture Completion*	10	12	10	11	10	12	11	12	11	12	11	12
Picture Arrangement*	22	22	12	16	20	20	20	20	20	20	20	29
SDMT-written*	31	34	40	23	40	41	36	41	35	41	35	34
SDMT-oral*	46	42	22	38	36	45	42	45	36	45	36	35
Trails A (sec.)#	79	77	145	101	58	60	48	60	55	46	55	50
Trails B (sec.)#	100	98	225	240	179	180	105	180	90	68	90	120
Cancellation "H"												
time (sec.)#	180	195	260	190	220	360	193	360	180	207	180	175
errors#	0	1	2	4	2	3	4	4	4	2	13	2
<u>Driving Measure</u>												
Composite Driving Index*	63	81	37	85	49	56	95	69	70	92	36	55

*A larger score indicates better performance.

#A smaller score indicates better performance.

Experimental subjects. The comparison of the pre- and post-training scores shows, in general, that following the training sessions, the perceptual/cognitive measures (including Picture Completion, the target measure) showed an improvement. Furthermore, and most importantly, the driving-performance measure also showed a substantial improvement for each subject.

Control subjects. The comparison of the pre- and post-training scores indicates (as expected) no clear effect of the training sessions on the perceptual/cognitive measures. The only consistent effects for both control subjects were the improvements on the error measure of the cancellation task, Picture Completion, and Trails A. Since the film strips (which constituted the control training) involved frequent references to visual scanning and search, this finding is not unexpected. The driving-performance measures showed a substantial improvement for each of the two control subjects. Again, this finding is not surprising, since the film strips were designed to improve driving performance.

The present pilot study was performed with a limited number of subjects. Nevertheless, the results are encouraging, since the laboratory training sessions designed to improve underlying perceptual/cognitive skills had a substantial effect on subsequent driving performance. The magnitude of the driving-performance improvement was comparable to that obtained by laboratory training sessions designed to directly foster improvements in driving performance.

The present findings raise a range of important issues, including the following:

1. Is the observed improvement of driving performance due to "Hawthorne effect"? The answer to this question would come from an experiment using a non-treatment control group.

2. Is the observed improvement of driving performance due to additional driving practice? This is unlikely in view of the following analysis performed on the current data: The data from the first half of the pre-training driving course were combined with the data from the

first half of the post-training driving course. This aggregate was compared to the combined data from the second half of the pre-training driving course and the second half of the post-training driving course. This analysis showed no improvement on the second halves in comparison to the first halves of the driving courses. The corresponding pre- and post-training Composite Driving Indexes were as follows: 73 vs. 71, 52 vs. 35, 74 vs. 68, 79 vs. 85 (experimental subjects); 88 vs. 75, 57 vs. 33 (control subjects).

3. Which of the various driving-related perceptual/cognitive skills are amenable to training?

4. What are the optimal training techniques for improving the amenable skills?

5. What are the time courses of the training processes? Can certain driving-related perceptual/cognitive skills be improved substantially faster than other skills?

6. Do the improvements on a given skill transfer to other related skills?

7. What are the long-term benefits of the training? Do the benefits persist long after the training is completed?

8. Is the etiology of brain damage important in determining the success of the training?

The answers to these issues will determine whether the promising retraining approach used in the current study will prove to be a viable and efficient method to maximize the accessibility of personal transportation for persons with brain damage.

REFERENCES

- Adams, G.F. Treatment of hemiplegia complicated by sensory defects. Physiotherapy, 1966, 52, 345-349.
- Ayres, A.J. Southern California Figure-Ground Visual Perception Test. Los Angeles, California: Western Psychological Services, 1966.
- Birch, H.J., Belmont, I., Reilly, T., and Belmont, L. Somesthetic influences on perception of visual verticality in hemiplegia. Archives of Physical Medicine and Rehabilitation, 1962, 43, 556-560.
- Block, J.D. Teaching reading and writing skills to a teen-aged spastic cerebral palsied person: A long-term case study. Perceptual and Motor Skills, 1978, 46, 31-41.
- Carrol, V.B. Implications of measured visuospatial impairment in a group of left hemiplegic patients. Archives of Physical Medicine and Rehabilitation, 1958, 39, 11-14.
- Darley, F.L. The efficacy of language rehabilitation in aphasia. Journal of Speech and Hearing Disorders, 1972, 37, 3-21.
- Diller, L. Brain damage, spatial orientation, and rehabilitation. In S.J. Freedman (Ed.), The neuropsychology of spatially oriented behavior. Homewood, Ill.: Dorsey Press, 1968.
- Diller, L., Ben-Yishay, Y., Gerstman, L.J., Goodkin, R., Gordon, W., Weinberg, J., Mandleberg, I., Schulman, P., and Shah, N. Studies in cognition and rehabilitation in hemiplegia. New York University Medical Center, Institute of Rehabilitation Medicine, Rehabilitation Monograph No. 50, 1974.
- Diller, L. and Weinberg, J. Hemi-inattention in rehabilitation: the evolution of a rational remediation program. In E.A. Weinstein and R.P. Friedland (Eds.), Hemi-inattention syndromes. Advances in Neurology, Vol. 18. New York: Raven Press, 1977.
- Dolan, M.P. and Norton, J.C. A programmed training technique that uses reinforcement to facilitate acquisition and retention in brain-damaged patients. Journal of Clinical Psychology, 1977, 33, 496-501.
- Dunning, D.P. Visual tracking: its implications as a therapeutic strategy in adult aphasia. Dissertation Abstracts International, 1977, 38, (6-B), 2625-B.
- Foster, F.M. and Shields, C.D. Cortical sensory defects causing disability. Archives of Physical Medicine and Rehabilitation, 1959, 40, 56-61.

- Gasparri, B. and Satz, P. A treatment for memory problems in left hemisphere CVA patients. Journal of Clinical Neuropsychology, 1979, 1, 137-150.
- Gianutsos, R. and Gianutsos, J. Rehabilitating the verbal recall of brain-injured patients by mnemonic training: an experimental demonstration using single-case methodology. Journal of Clinical Neuropsychology, 1979, 1, 117-135.
- Golden, C.J. The role of the psychologist in the training of the neurologically impaired. Professional Psychology, 1976, 7, 579-584.
- Goldman, H. Improvement of double simultaneous stimulation perception in hemiplegic patients. Archives of Physical Medicine and Rehabilitation, 1966, 47, 681-687.
- Luria, A.R. Restoration of function after brain injury. New York: MacMillan, 1963.
- Mills, C. Treatment of aphasia by training. Journal of American Medical Association, 1904, 43, 1940-1949.
- New York University Medical Center. Working approaches to remediation of cognitive deficits in brain damaged. New York University Medical Center, Institute of Rehabilitation Medicine, Department of Behavioral Sciences, Supplement to 6th Annual Workshop for Rehabilitation Professionals, June 1978.
- New York University Medical Center. Working approaches to remediation of cognitive deficits in brain damaged. New York University Medical Center, Institute of Rehabilitation Medicine, Department of Behavioral Sciences, Supplement to 7th Annual Workshop for Rehabilitation Professionals, May 1979.
- New York University Medical Center. Working approaches to remediation of cognitive deficits in brain damaged. New York University Medical Center, Institute of Rehabilitation Medicine, Department of Behavioral Sciences, Supplement to 8th Annual Workshop for Rehabilitation Professionals, May 1980.
- Pigott, R. and Brickett, F. Visual neglect. American Journal of Nursing, 1966, 66, 101-105.
- Reitan, R.M. Trail Making Test: Manual for administration, scoring, and interpretation. Indianapolis, Indiana: 1956. (Mimeo)
- Sivak, M., Olson, P.L., Kewman, D.G., Won, H., and Henson, D.L. Perceptual Cognitive Skills and Driving: Effects of Brain Damage. Ann Arbor, Michigan: Highway Safety Research Institute, The University of Michigan, Report No. UM-HSRI-80-3, January 1980.
- Smith, A. The symbol-digit modalities test: A neuro-psychologic test of learning and other cerebral disorders. In J. Helmuth (Ed.),

- Learning Disorders. Seattle, Washington: Special Child Publications, 1968, pp. 83-91.
- Smith, A. Symbol Digit Modalities Test. Los Angeles, California: Western Psychological Services, 1973.
- Taylor, M.M., Schaeffer, J.N., Blumenthal, F.S., and Grisell, J.L. Perceptual training in patients with left hemiplegia, Archives of Physical Medicine, 1971, 52, 163-169.
- Walsh, K. W. Neuropsychology. Edinburg, Great Britain: Churchill Livingstone, 1978.
- Wechsler, D. Manual for the Wechsler Adult Intelligence Scale. New York: Psychological Corporation, 1955.
- Weinberg, J., Diller, L., Gordon, W.A., Gerstman, L.G., Lieberman, A., Lakin, P., Hodges, G., and Ezrachi, O. Visual scanning training effect on reading-related tasks in acquired right brain damage. Archives of Physical Medicine and Rehabilitation. 1977, 58, 479-486.
- Weinberg, J., Diller, L., Gordon, W.A., Gerstman, L.G., Lieberman, A., Lakin, P., Hodges, G., and Ezrachi, O. Training sensory awareness and spatial organization in people with right brain damage. Archives of Physical Medicine and Rehabilitation, 1979, 60, 491-496.
- Will, B.E., Sutter, A.R., and Offerun, M.R. Effets de la methamphetamine et d'un environnement complexe sur la recuperation comportementale apres atteinte cerebrale [Effects of methamphetamine and enriched experience on behavioral recovery after brain damage]. Psychopharmacology, 1977, 51, 273-277.
- Zihl, J. "Blindsight": Improvement of visually guided eye movements by systematic practice in patients with cerebral blindness. Neuropsychologia, 1980, 18, 71-77.
- Zimmerman, I.L., and Woo-Sam, J.M. Clinical Interpretation of the Wechsler Adult Intelligence Scale. New York: Grune and Stratton, 1973.