Behavior Modification
http://bmo.sagepub.com/

Forward and Backward Chaining, and Whole Task Methods: Training Assembly Tasks in Vocational Rehabilitation

Richard T. Walls, Thomas Zane and William D. Ellis

Behav Modif 1981 5: 61
DOI: 10.1177/014544558151005

The online version of this article can be found at:
http://bmo.sagepub.com/content/5/1/61

Published by:
SAGE
http://www.sagepublications.com

Additional services and information for *Behavior Modification* can be found at:

Email Alerts: http://bmo.sagepub.com/cgi/alerts

Subscriptions: http://bmo.sagepub.com/subscriptions

Reprints: http://www.sagepub.com/journalsReprints.nav

Permissions: http://www.sagepub.com/journalsPermissions.nav

Citations: http://bmo.sagepub.com/content/5/1/61.refs.html

>> Version of Record - Jan 1, 1981

What is This?

Downloaded from bmo.sagepub.com at The University of Melbourne Libraries on September 12, 2014

The effects of training by whole task, forward chaining, and backward chaining methods were examined in teaching vocational rehabilitation clients the construction of three assembly tasks. Clients learned to assemble a bicycle brake, a meat grinder, and a carburetor on three successive days by the three training methods in a counterbalanced design. The percentage of responses that were errors was, on the average, more than twice as great for subjects in the whole task method as for subjects in either chaining method (which did not differ). Total time to criterion did not differ among chaining and whole methods. Slower learning subjects benefited substantially from the systematic chaining procedures.

Forward and Backward Chaining, and Whole Task Methods

Training Assembly Tasks in Vocational Rehabilitation

RICHARD T. WALLS and THOMAS ZANE
West Virginia University
WILLIAM D. ELLIS
Stout Vocational Rehabilitation Institute

Behavioral goals or objectives often include tasks that are composed of complex stimulus-response chains (Craighead et al., 1976; Millenson, 1967; Whaley & Malott, 1969) consisting of a sequence of stimuli and responses. In a stimulus-response chain, each response produces a change in the immediate environment which then acts as a stimulus for a subsequent response, the last of which produces reinforcement. For example, in assembling a tone oscillator circuit board, a worker would place on the board the first resistor, the first capacitor, the speaker switch, the second

AUTHORS' NOTE: *This research was supported in part by the Department of Health, Education and Welfare (RSA) through the West Virginia Rehabilitation Research and Training Center (West Virginia University and West Virginia Department of Vocational Re-*

BEHAVIOR MODIFICATION, Vol. 5 No. 1, January 1981 61-74
© 1981 Sage Publications, Inc.

from the SAGE Social Science Collections. All Rights Reserved. Downloaded from bmo.sagepub.com at The University of Melbourne Libraries on September 12, 2014

resistor, the second capacitor, and the transistor, and then solder them in that order. In terms of a stimulus-response chain, the response of placing on the first resistor acts as a stimulus for placing on the first capacitor, which acts as a stimulus for placing on the speaker switch, and so forth.

Previous research has examined what has been termed "whole" and "part" teaching methods that are used in training complex tasks (Blake & Williams, 1969; Naylor, 1961; Nettelbeck & Kirby, 1976). The "whole" method of teaching involves an organism attempting the entire task on each learning trial. For example, if a task consisting of four steps (A, B, C, and D) were being taught, the organism would be required to perform A, B, C, and D, in order, on each attempt (Naylor, 1961). In contrast, the "part" method might consist of the organism mastering one step at a time, and then combining the separate steps to perform the complete task. For example, in the "direct-repetitive-part" method, the organism masters step A, then masters A and B together, then A, B, and C, and finally A, B, C, and D (Naylor, 1961).

Blake and Williams (1969) tested the differences between pure-part (teach A, teach B, teach C, teach D, teach ABCD), progressive-part (teach A, teach B, teach AB, teach C, teach ABC, teach D, teach ABCD), and whole (teach ABCD, teach ABCD) methods. Retarded, normal, and "superior" subjects learned CVC trigram-numeral pairs. In each group of subjects, the whole method (learning all pairs at once) was reported to have produced the most correct responses, and there was no difference in efficiency between the pure and progressive part methods. However, subjects were not taken to a mastery criterion before going on to the next part. Further, the amount of practice prior to the final test appears to have differed with 360 response opportunities in the whole method, 180 in pure part, and 165 in

habilitation). We are indebted for outstanding cooperation and help to staff at the Vocational Rehabilitation Center, Pittsburgh, Pennsylvania (Morton Bregman, James Casper, James Madenfort, Victor Riva, William Tillman, and Nina Williams). Appreciation is also expressed to Becky Lou Swartz and Kathryn Zane. Requests for reprints should be sent to Richard T. Walls, 806 Allen Hall, West Virginia University, Morgantown, WV 26506.

Downloaded from bmo.sagepub.com at The University of Melbourne Libraries on September 12, 2014

progressive part. Other authors have also reported superior performance for whole as opposed to part learning (McGuigan, 1960; McGuigan & MacCaslin, 1955).

In contrast, Nettelbeck and Kirby (1976) found part methods produced fewest errors and shortest time to criterion. They trained mildly retarded females to thread an industrial sewing machine, using groups trained by pure-part progressive-part, and whole methods. In a one-month retention test, there was no difference between the whole and part methods. The authors proposed that it was advantageous to use part training when teaching a task consisting of individual components.

Part methods have produced better performance than the whole method with retarded subjects in three of four reports: Denny, (1966), Gold (1968), and Nettelbeck and Kirby (1976) versus Blake and Williams (1969). In the studies favoring part methods of instruction, manipulative-type tasks were used (i.e., sorting bolts and beads, threading a sewing machine, and lever positioning). In contrast, the one favoring whole method with retarded subjects (Blake & Williams, 1969) used a cognitive nonsense syllable task. It appears that with retarded populations learning manipulative and assembly tasks, part methods were more efficient means of training.

Backward chaining is mentioned in the behavioral literature as an effective way of conditioning complex chains of behavior (Whaley & Malott, 1969; Millenson, 1967). Indeed, it appears to be a prevalent training method in settings where mentally retarded or other handicapped learners are taught (Baker et al., 1976; Fredericks et al., 1976). This method has been termed (by Naylor, 1961) "reverse-direct-repetitive-part" (teach D, teach CD, teach BCD, teach ABCD). A similar but opposite method of training teaches the responses in a forward rather than backward order (Smith & Snell, 1978). This method has been termed "direct-repetivie-part" (teach A, teach AB, teach ABC, teach ABCD). Holland et al. (1976) comment that, "Backward chaining may be used in much human response-chain learning also." But by the use of established reinforcers, humans can learn "each individual response in the chain in any order" (1976: 158).

Downloaded from bmo.sagepub.com at The University of Melbourne Libraries on September 12, 2014

Although they are prevalent in practical settings, there has been virtually no systematic study comparing these chaining approaches. The purpose of the present study was to investigate the effects of forward chaining (direct-repetitive-part), backward chaining (reverse-direct-repetitive-part), and whole task training methods with retarded learners. As in past research, manipulative-type tasks were taught, requiring assembly of three complex apparatuses—carburetor, bicycle brake, and meat grinder.

METHOD

SUBJECTS

The subjects were twenty-two (twelve males, ten females) vocational rehabilitation clients from the Vocational Rehabilitation Center (Allegheny County, Pennsylvania). These clients were from one of two prevocational training classes or from the sheltered workshop. Clients attended the Vocational Rehabilitation Center to be evaluated for vocational rehabilitation potential. The clients were considered mildly to moderately retarded. The ages ranged from eighteen to forty-six years. The subjects commuted to the center each work day. Some were bused from an institution for the mentally retarded. The nature and purpose of the experiment were explained to the subjects, and informed consent was obtained. The subjects were paid for their participation in the experiment.

SETTING

Experimental sessions were conducted in the research room of the Vocational Rehabilitation Center on three consecutive days. The room was approximately 18 m by 12 m and was furnished with three tables and six chairs. During training sessions, one subject sat at each table facing one of the three experimenters. The three subjects during any given training session sat facing separate corners of the room.

Downloaded from bmo.sagepub.com at The University of Melbourne Libraries on September 12, 2014

Apparatus

Three different assemblies were put together by the subjects. Each assembly consisted of six separate parts. One assembly was composed of the (1) bottom half of the shell, (2) float, (3) pin, (4) arm, (5) top half of the shell, and (6) bolt of a Carter truck carburetor. A second assembly was the (1) axle, (2) threaded collar, (3) drum, (4) brake collar, (5) bearing, and (6) nut of a Schwinn bicycle brake. The third assembly was composed of the (1) main body, (2) auger, (3) handle, (4) handle nut, (5) strainer, and (6) strainer nut of a Sargent meat grinder.

A correct assembly was defined as putting the six parts together in the orders listed above, and with all parts placed in the correct positions. Subjects were required to add one or more parts of the assembly in the specified order. The number of assembled parts presented initially to the subject as well as the number of unassembled parts to be added to the assembly depended on the particular training method and step of that method, as described subsequently.

TRAINING METHODS

Each subject was randomly assigned to a counterbalanced order of training methods and assemblies so that he or she learned a new assembly by a different training method on each of three consecutive days. That is, each subject was exposed to each of the three training methods, forward chaining, backward chaining, and whole task, each used with a different assembly.

Forward chaining required the subject to: (step 1) put parts 1 and 2 together (to criterion, described later); (step 2) put parts 1, 2, and 3 together (to criterion); (step 3) put parts 1, 2, 3, and 4 together (to criterion); (step 4) put parts 1, 2, 3, 4, and 5 together (to criterion); and (step 5) put parts 1, 2, 3, 4, 5, and 6 together (to criterion). For example, when teaching the meat grinder assembly using forward chaining, a given subject was presented with part 1 (the main body) and part 2 (the auger) and was required to put them together. These parts were then disassembled and the

Downloaded from bmo.sagepub.com at The University of Melbourne Libraries on September 12, 2014

subject was required to put together parts 1, 2, and 3 (the handle), and so on until all parts were included in the assembly. All parts not involved in any given step were not visible to the subject.

Backward chaining required the subject to: (step 1) add part 6 to an otherwise completed assembly (to criterion); (step 2) add parts 5 and 6, in order, to an otherwise completed assembly; (step 3) add parts 4, 5, and 6, in order, to an otherwise completed assembly; (step 4) add parts 3, 4, 5, and 6, in order, to an otherwise completed assembly; and (step 5) add parts 2, 3, 4, 5, and 6, in order, to part 1. For example, when teaching the carburetor assembly using backward chaining, a given subject was presented with the completed carburetor, with part 6 (the bolt) presented separately. The subject was required to put them together. Part 6 and part 5 (the top half of the shell) were then removed from the assembly. The subject was required to add parts 5 and 6, and so on until all parts were included in the assembly.

Whole task required the subject to put together all six parts correctly and to criterion. For example, when teaching the bicycle brake assembly using the whole task method, a given subject was presented with all six parts disassembled and was required to put them together.

PROCEDURE

Subjects were individually seated across a table and facing the experimenter. Following preliminary comments and explanations, a cardboard screen (55 cm by 35 cm) was placed between the subject and the experimenter. The experimenter laid out the required parts behind the screen in a mixed order, with no part touching any other. Then the screen was removed, and a trial commenced. A stop watch was started to time the trial as the experimenter instructed, "Put it together."

As the subject attempted to put together the assembly, the experimenter recorded the client's responses as either correct or incorrect. Errors were of two types: An order error was recorded when the subject picked up a part in the wrong order (sequence). A placement error was recorded when (1) a part chosen out of

Downloaded from bmo.sagepub.com at The University of Melbourne Libraries on September 12, 2014

sequence was placed on the assembly or (2) a part chosen in sequence was placed on a wrong position on the assembly. Any response that occurred after an *uncorrected* placement error was scored as either an order or a placement error. A correct response was scored (1) when a part was chosen in the prescribed sequence or (2) when a part that was chosen in sequence was placed on the assembly in the correct position. Retroactive correct responses were scored after the assembly was completed for each part placed on the assembly in the correct position, but in the wrong sequence.

Each daily training session consisted of two types of trials. In *help trials,* as long as the subject made correct responses, the experimenter did not intervene. When the subject made an order error, the experimenter said, "No, try this one," and immediately grasped the subject's hand and placed it on the correct part. When the subject made a placement error, the experimenter said, "No, try it here," and immediately grasped the subject's hand and guided correct placement.

A *test trial* was identical to a help trial, except that no help was given. Correct responses and errors were scored as they occurred. Both help and test trials were concluded, and the stop watch stopped (1) when the subject completed the assembly correctly or incorrectly, or (2) when a three-minute time limit expired. At the end of each trial, the subject was verbally praised for working.

With each assembly, two baseline trials were given before training to determine whether or not the subject could put the assembly together correctly. Each baseline trial was conducted using all six parts of the assembly and in the same manner as a test trial. If the subject failed to put the assembly together correctly in the first baseline trial but succeeded in the second, a third baseline trial was given. If a subject was successful in putting together the assembly on two consecutive baseline trials, he or she was not trained further on that assembly.

After all baseline trials were completed, a help trial was given. Following each help trial, a test trial was given. If there were errors on the test trial, a help trial always followed. However, if a test trial was perfect, a second test trial followed.

Downloaded from bmo.sagepub.com at The University of Melbourne Libraries on September 12, 2014

Criterion for correct assembly was two consecutive trials, without error, within a three-minute time limit per trial. Thus, in the whole task method, when the subject had put together all six parts with no errors on two consecutive trials, training was completed. Similarly, in both the forward and backward chaining methods, a new step was begun only after the subject had accomplished the previous step with no errors on two consecutive trials. In both chaining methods, training of a new step always began with a help trial.

RELIABILITY

There were eight interobserver reliability checks over the three days. These included all three experimenters, all three assemblies, and all three methods. Each reliability check consisted of the experimenter training the subject and recording correct responses and errors as usual, and a second independent observer recording simultaneously. Since order and placement errors were coded differently, each individual error could be scored as an agreement or disagreement between the two observers. The agreement on correct responses was determined by the absolute number recorded by each observer. Total reliability for a session was computed by dividing the total number of agreements (on correct responses and errors) by the total number of agreements plus disagreements, multiplied by 100.

RESULTS

Reliability was computed by the procedure described previously. The eight independent reliability observations yielded interobserver reliabilities of 98%, 100%, 91%, 97%, 98%, 100%, 100%, and 86%. The overall interobserver reliability was 96%.

The number of responses emitted in the baseline trials was similar for the three training methods. The mean number of responses per baseline trial was 26.09 for forward chaining, 25.00 for backward chaining, and 24.27 for whole task. Also, the

Downloaded from bmo.sagepub.com at The University of Melbourne Libraries on September 12, 2014

proportion of these baseline responses that were errors was similar, with 80% for forward chaining, 89% for backward chaining, and 88% for whole task.

During training, the total number of responses in test trials emitted by subjects differed, with M = 104.66 for forward chaining, M = 92.42 for backward chaining, and M = 58.84 for whole task. This difference is largely a function of the constraints defined by the forward and backward chaining procedures. For example, in the first test trial for the forward procedure, the subject has only two parts available. In subsequent test trials the number of parts is gradually increased. The definitions of the forward and backward chaining procedures dictate a minimum of 10 test trials and a minimum of 60 responses, whereas a minimum of only 2 test trials and 20 responses could occur in the whole task method.

Thus, although the average number of errors per subject was forward, 21.4, backward, 16.3, and whole, 27.5, appearing to favor chaining methods, the salient interest is not the total number of responses or total number of errors for each training method. Rather, the proportion of emitted responses that are errors (or are correct) is the major concern. Individual subject data are presented in Table 1, showing the percentage of errors per method. Overall means for each subject in each training method were computed by dividing the total number of errors by the total number of responses in that training method. The proportion of training responses (in test trials) that were errors was similar for the forward and backward chaining procedures, with only 9% and 8% errors respectively. However, the proportion of responses that were errors in whole task training was more than twice as great (19% errors). A within-subjects analysis of variance of these data yielded a significant effect ($F_{2, 29} = 7.99$, $p < .01$), and multiple comparisons by Fisher's LSD indicated no difference between forward and backward chaining, but both differed from the whole task training procedure ($p < .01$). Thus, subjects emitted a significantly greater proportion of errors in whole training than in either forward or backward chaining, but forward and backward chaining were equally effective in controlling the proportion of errors.

Downloaded from bmo.sagepub.com at The University of Melbourne Libraries on September 12, 2014

TABLE 1
Mean Percentage of Errors Per Subject for Each Training Method (Number of Errors/Total Number of Responses × 100)

Subject	Forward	Backward	Whole
1	5	0	a
2	2	0	0
3	14	16	33
4	2	9	39
5	a	0	4
6	3	7	0
7	a	14	0
8	a	1	9
9	4	1	31
10	22	13	30
11	0	a	22
12	9	a	33
13	a	27	34
14	17	3	32
15	13	0	20
16	9	0	2
17	17	17	a
18	a	9	2
19	0	a	a
20	a	7	10
21	11	24	49
22	a	0	6

a. Correct assembly achieved during baseline trials.

Downloaded from bmo.sagepub.com at The University of Melbourne Libraries on September 12, 2014

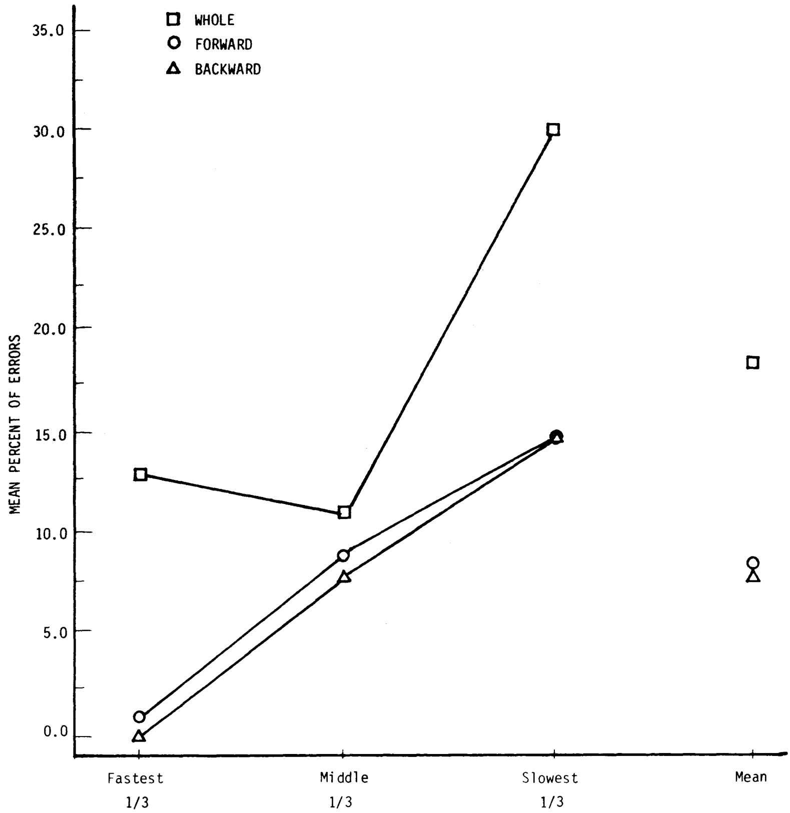

Figure 1: Mean Percentage of Responses That Were Errors for the Fastest, Middle, and Slowest Learning Subjects in Forward Chaining, Backward Chaining, and Whole Task Training Methods

Inspection of Figure 1 reveals another apparent difference among the training methods. It depicts an aptitude by treatment interaction in which the subjects who required the most trials to learn the task (the slowest clients) produced the greatest proportions of errors. For this display, each of the three treatments were divided into the fastest learning one-third of subjects, middle learning one-third of subjects, and slowest learning one-third of subjects (approximate thirds based on number of trials to criterion). For subjects who were fastest at learning the tasks, whole method subjects produced a higher percentage of errors

Downloaded from bmo.sagepub.com at The University of Melbourne Libraries on September 12, 2014

than subjects in either chaining method (t tests for independent means, $p < .05$). Similar effects were found for slowest learning subjects ($p < .05$). However, no differences occurred for the middle subjects ($p > .05$). Since other analyses revealed that total errors for test trials did not differ among the three apparatus assemblies (bicycle brake, carburetor, and meat grinder), $p > .05$, among the three days (day 1, day 2, and day 3), $p > .05$, nor among the three experimenters (experimenter 1, experimenter 2, and experimenter 3), $p > .05$, it is likely that such differences are attributed to the different training methods.

Overall training times did not differ statistically among the three methods (F 2, 29 = 0.87, $p > .05$). These means for minutes were 25.0, 26.2, and 20.6 for forward, backward, and whole, respectively.

DISCUSSION

Although previous studies did not systematically evaluate the effects of chaining procedures, results of the present experiment are largely consistent with Denny (1966), Gold (1968), and Nettelbeck and Kirby (1976). These three studies advocated part methods used in forward order as opposed to working with all of the parts at once. The present investigation also yielded a superiority for forward-order chaining but found the backward-order chain to be of equal effectiveness. Thus, the statement of Holland et al. (1976) concerning the efficiency of either forward or backward orders is supported.

On the average, subjects in the whole task method committed more than twice the percentage of errors as subjects in either chaining method. This may be due to the fact that in the whole method, all parts of the assembly were presented to the subject at the beginning of each trial. Thus, the chances for selecting or placing a part incorrectly are increased as an inherent characteristic of the whole method. These data may be instructive for trainers concerned with the commission of errors by clients while learning assembly tasks. It seems that a greater proportion of

Downloaded from bmo.sagepub.com at The University of Melbourne Libraries on September 12, 2014

correct responses and consequent reduction of errors might be achieved with the chaining procedures for both fast-and slow-learning clients.

Although the total number of responses was lower in the whole task method, total time did not differ among chaining and whole methods. Nettelbeck and Kirby (1976) reported faster times for pure part and progressive part methods as opposed to a whole method. But whereas Nettelbeck and Kirby (1976) timed only test trials, the total training session was timed in the present experiment. The latter measure appears more relevant to practical training settings.

In all, these data suggest that both chaining methods are superior to the whole procedure method in reducing the number and proportion of errors. The degree to which these training methods resemble types of actual on-the-job training would vary across trainers, trainees, and tasks. It would be interesting to determine the extent to which these methods, or idiosyncratic combinations of them, occur in real-life training. Since assembly tasks are a prominent part of production in environments such as sheltered workshops, these results appear to hold relevance for initial training of tasks in vocational environments.

REFERENCES

Baker, B. L., Brightman, A. J., Heifetz, L. J., & Murphy, D. M. *Steps to independence: A skills training series for children with special needs.* Champaign, IL: Research Press, 1976.

Blake, K. A., & Williams, C. L. Retarded, normal, and superior subjects' learning of paired associates by whole and parts methods. *Psychological Reports,* 1969, 25, 819-824.

Craighead, W. E., Kazdin, A. E., & Mahoney, M. J. *Behavior modification: Principles, issues, and applications.* Boston: Houghton Mifflin, 1976.

Denny, M. R. A theoretical analysis and its application to training the mentally retarded. In N. R. Ellis (Ed.), *International review of research in mental retardation.* Vol. 2. *New York:* Academic Press, 1966.

Fredericks, H.D.B., Riggs, C., Furey, T., Grove, D., Moore, W., McDonnell, J., Jordan, E., Hanson, W., Baldwin, V., & Wadlow, M. *The teaching research curriculum for moderately and severely handicapped.* Springfield, IL: Charles C Thomas, 1976.

Gold, M. W. Preworkshop skills for the trainable: A sequential technique. *Education and Training of the Mentally Retarded,* 1968, 3, 31-37.

Downloaded from bmo.sagepub.com at The University of Melbourne Libraries on September 12, 2014

Holland, J. G., Solomon, C., Doran, J., & Frezza, D. *The analysis of behavior in planning instruction.* Reading, MA: Addison-Wesley, 1976.

McGuigan, F. J., & MacCaslin, E. F. Whole and part methods in learning a perceptual motor skill. *American Journal of Psychology,* 1955, 68, 658-661.

McGuigan, F. J. Variation of whole and part methods of learning. *Journal of Educational Psychology,* 1960, 51, 213-216.

Millenson, J. R. *Principles of behavioral analysis.* New York: Macmillan, 1967.

Naylor, J. C. Parameters affecting the relative efficiency of part and whole practice methods: A review of the literature. Report No. NAVTRADEVCEN 950-1. Port Washington, NY: U.S. Naval Training Device Centers, July, 1961.

Naylor, J. C., and Briggs, G. E. Effects of task complexity and task organization on the relative efficiency of part and whole training methods. *Journal of Experimental Psychology,* 1963, 65, 217-224.

Nettelbeck, T., & Kirby, N. H. A comparison of part and whole training methods with mildly mentally retarded workers. *Journal of Occupational Psychology,* 1976, 49, 115-120.

Smith, D. D., & Snell, M. E. Intervention strategies. In M.E. Snell (Ed.), *Systematic instruction of the moderately and severely handicapped.* St. Louis: Charles E. Merrill, 1978.

Whaley, D. L. & Malott, R. W. *Elementary principles of behavior.* Kalamazoo, MI: Behaviordelia, 1969.

Richard T. Walls is Professor of Educational Psychology and Research Associate at the Rehabilitation Research and Training Center, West Virginia University. His primary research interests include behavior checklists and stimulus conditions in human learning.

Thomas Zane is a doctoral candidate in the Psychology Department and Research Assistant for the Rehabilitation Research and Training Center, West Virginia University. His research interests involve child development and training of the severely and profoundly retarded.

William D. Ellis is a Research Specialist at Stout Vocational Rehabilitation Institute. His primary research interests include stimulus conditions for learning, vocational decision making, and self-control procedures for rehabilitation.

Downloaded from bmo.sagepub.com at The University of Melbourne Libraries on September 12, 2014