THE UNIVERSITY OF MANITOBA

# COMPARISON OF MODIFIED FORWARD AND BACKWARD CHAINING PROCEDURES TO TEACH ASSEMBLY TASKS TO SEVERELY RETARDED CLIENTS

by

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# COMPARISON OF MODIFIED FORWARD AND BACKWARD CHAINING PROCEDURES TO TEACH ASSEMBLY TASKS TO SEVERELY RETARDED CLIENTS

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ABSTRACT

Three experiments evaluated a modified chaining procedure and systematically replicated a study comparing the effectiveness of forward and backward chaining to teach assembly tasks to severely retarded subjects. To minimize trai-ing time, chaining procedures were modified so that each training trial consisted of only two steps, but all two-step sequences were trained. All learned steps were performed on probe trials at the beginning and end of sessions and on task criterion trials, conducted after the individual steps were trained.

Each experiment employed severely retarded subjects in a multi-element design with counterbalancing of tasks and procedures. In each experiment, subjects were taught one assembly task with modified forward chaining and a second assembly task with modified backward chaining. Task complexity was varied across Experiments 1, 2, and 3 by teaching tasks of 26, 9, and 57 steps, respectively.

Results suggest that backward chaining was generally more effective in training the tasks, but the modified format produced poor retention (reflected in large numbers of task criterion trials and high error rates).

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# INTRODUCTION

An emerging area of behavioral research is that of vocational habilitation for the severely retarded. Reviews by Bellamy, Peterson and Close (1975) and Bellamy (1976) have indicated that this population can learn complex work tasks, and procedures to enhance their work productivity are available. In another recent review (Martin & Pallotta-Cornick, 1979), it was noted that while there is a fairly substantial literature concerning productivity, there is a lack of research in the area of vocational training for severely retarded clients. An important research question they identified concerned what training format may be most effective in teaching workshop tasks to these clients.

Total task presentation (TTP), where the learner attempts all the steps of a behavioral chain in correct sequence on every training trial has often been reported in vocational training and research (Gold, 1972, 1974, 1976; Irvin & Bellamy, 1977; Walls, Ellis & Zane, 1978a). However, forward chaining (FC) and backward chaining (BC) are training formats that have frequently been used to teach a variety of complex behaviors to retarded clients (Martin & Pear, 1978) and are quite suitable for training packaging and assembly tasks (Pallotta-Cornick, Martin, Suthons, & Yu, 1978; Walls, Zane & Ellis, 1978b, Weber, 1978).

The recent research on training formats in vocational training of retarded subjects provides some interesting initial findings. Using severely retarded subjects, Pallotta-Cornick et al. (1978) found no differences between FC and BC when they were used to teach simple packaging tasks, but with more complex assembly tasks (28-step bicycle brake and fishing reel), their data suggested a slight superiority for BC in terms

of trials to criterion. However, precise analysis of this effect was hampered by the presence of a task effect, i.e., the reel seemed to be more difficult than the brake.

Walls et al. (1978b) investigated FC and BC as well as TTP to teach three assembly tasks (bicyble brake, meat grinder, and carburetor) to retarded clients in a sheltered workshop. They found there were fewer errors with FC and BC, and even though these two formats took more trials there were no differences in training time between all three formats. Their failure to find differences between FC and BC might be due to the apparent high level of functioning of their subjects (e.g., the authors reported that their subjects had community workshop placements, commuted to work daily, gave informed consent to participate in the research, and received pay for their work), and the apparent level of complexity of their experimental tasks (i.e., the tasks were broken down into only six parts, suggesting that they may have been fairly simple assemblies). The finding of Pallotta-Cornick et al. (1978) that there was only evidence of a superiority for BC with complex tasks with more steps (and possibly lower functioning subjects) may explain the lack of differences between FC and BC that Walls et al. reported.

Yu, Martin, Suthons and Pallotta-Cornick (1978) compared FC with TTP and found similar results to those of Walls et al. (1978). They noted that there were minimal differences between the two procedures in terms of training time, but FC had fewer errors and subjects worked faster as determined from the number of individual steps contacted during training per unit training time. These findings may have resulted from the structural differences between FC, BC, and TTP formats. As train-

ing progresses, each trial consists of a larger number of steps that have been learned. In effect, an increasing proportion of training time is spent repeating steps that have already reached criterion and this may account for the faster rate in FC. The above observation also suggests that the FC and BC formats and TTP may be somewhat inefficient in the use of training time, in that very quickly in the FC and BC, and eventually in TTP, a very high proportion of training time is spent having the subjects perform learned steps.

The present study was a systematic replication of the Pallotta-Cornick et al. (1978) comparison of FC and BC, using the brake and the reel (with altered task analyses to try to better equate these tasks), as well as tasks of fewer and many more steps. Several changes were made in the procedures of that study. First, in the chaining procedure used by Pallotta-Cornick et al. there was no differential reinforcement for quality of task performance, in that reinforcement was contingent only on task completion (or the required number of steps for the current stage of training). The present study introduced differential reinforcement for good quality performance. A second change was in correcting errors. Pallotta-Cornick et al. employed a correction and retraining procedure to correct errors. However, this procedure could have been reinforcing errors by increasing the frequency of experimenter-subject interactions when errors occurred. Irvin and Bellamy (1977) reported that they exienced a similar problem. This study eliminated retraining and minimized interactions when correcting errors. Finally, the chaining format was modified in such a way as to maximize the proportion of training time spent on teaching new steps and minimize (but not entirely eliminate)

the time spent practicing learned steps (see Methods section). As discussed by Yu et al. (1978), the rationale for modifying the chaining format was that if most of the extra practice of learned steps inherent to chaining and TTP formats could be eliminated without losing the performance and sequencing of learned steps, then the modified format could effectively reduce the number of individual steps contacted required to learn the tasks, thereby reducing training time.

## EXPERIMENT 1

### Method

#### Subjects

Subjects were selected from wards and sheltered workshops at the Manitoba School for Retardates. With the assistance of ward staff, a list of potential subjects was made. Clients were included on the list on the basis of a diagnosis of severe or low moderate retardation. Additional considerations were availability during experimental periods, no previous exposure to the experimental tasks, physical capability of performing the movements required to assemble the tasks (based on the opinion of the ward staff), and no serious behavior problems that would likely disrupt sessions. Baseline testing was then done with prospective subjects until four subjects were found whose scores were similar to one another on the brake and the reel. See Table 1 for descriptions of

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Insert Table 1 about here

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subjects.

#### Tasks and Materials

Task 1 was a Zebco #202 fishing reel and Task 2 was a Sturmey-Archer AW three-speed bicycle brake. Originally, the task analyses for these tasks was done by Pallotta-Cornick et al. (1978). Attempts were made to equate them in terms of number of steps, fine and gross motor movements and discriminations. For the present study two of the harder steps of the fishing reel were eliminated (identified by examining the original data), and two steps were also eliminated from the brake to maintain an

Table 1

Subjects

| Subject | Sex | Age | Years in Institution | Diagnosis | Etiology | Mental Age and I.Q. |
|---|---|---|---|---|---|---|
| 1 | F | 25 | 18 | severe | Encephalopathy (birth asphyxia) | M.A. 3 yr 8 mo<br>I.Q. 35 |
| 2 | F | 37 | 25 | severe | Phenylketonuria | M.A. 3 yr 0 mo<br>I.Q. unknown |
| 3 | F | 12 | 1 | severe | Unknown cause | M.A. 3 yr 5 mo<br>I.Q. unknown |
| 4 | F | 18 | 5 | severe | Environmental influence | M.A. 2 yr 2 mo<br>I.Q. less than 30 |
| 5 | M | 18 | 5 | moderate | Infantile autism | M.A. 3 yr 5 mo<br>I.Q. unknown |
| 6 | F | 20 | 10 | moderate | Psychiatric disorder autism | I.Q. 44 |

equal number of steps. In addition, two other steps in the reel were simplified, one by adding a colour cue to a hole in the back cover which subjects had to locate and second, by drilling out the hole in the handle of the fishing reel to make it fit more easily. Also, since there was a considerable variability in subjects' ability to thread nuts, the experimenter started any threaded part of either task if the subject had to do it appropriately, but failed on the first try. (See Appendices A and B for task analyses.)

Sessions were run in a research room at the Manitoba School for Retardates. A training tray (approximately 143 cm X 16 cm X 14 cm) was on a table in front of the subject. The tray was divided into 13 bins, open at the front, with movable cardboard covers so that a selected number of parts could be exposed. Parts for the tasks were put in the bins in the order for assembly. The experimenter sat to the left of the subject, recorded data, and gave assistance as necessary. Other materials included stopwatches, reinforcers and containers, data recording items, and a container for finished products.

Procedures

Learning criteria. Individual steps of the tasks were considered learned when subjects performed them correctly on two consecutive training trials with no help or prompting from the experimenter.

The entire task was considered learned when subjects performed all the steps correctly on three out of four trials. Thus, after all the individual steps reached criterion, task criterion trials (in effect TTP trials) were conducted until the learning criterion for the whole task was met.

Errors were defined as the failure of a subject to perform a learned step without corrective prompting or assistance from the experimenter.

Modified FC. Initially, subjects were trained on Step 1 to criterion, with each attempt constituting one training trial. Next, the training trial consisted of having the subject perform Step 1 and attempt Step 2, repeating both steps on each training trial until Step 2 reached criterion. Thus, subjects learned Steps 1 and 2, and the correct sequencing of them.

At this point, the modified format departed from the usual chaining procedure which would have simply added Step 3 to the training trials and had subjects perform the two learned steps plus the step being trained. In the modified format, Step 1 was now dropped from the training trial. The task materials were presented to the subject as they would be if he/she had just completed Step 1, but only Steps 2 and 3 were actually done or attempted by the subject, until Step 3 reached criterion. Thus, training trials only consisted of two steps, but by dropping and adding steps one at a time in the above manner, all the steps and two-step sequences were trained. At any given point in training, the experimenter presented the task materials to the subject as they would be if the subject had performed all the dropped steps. Parts not used in the two steps being performed were either assembled (if they were learned) or left in the bins with the covers down. Once all steps reached criterion, subjects performed the entire sequence on each trial (task criterion trials) until the task criterion was met.

While individual step training was still in progress, probe trials were conducted at the beginning and end of each session. On probe

trials, subjects performed all the steps that were at criterion at that point in training, with correction for errors and reinforcement following trial completion as described below. Probe trials were conducted to (a) provide a "warm-up" at the beginning of each session, (b) retain a minimal amount of practice of learned steps, and (c) provide a means to measure whether or not there were serious decrements in performance of learned steps as training progressed with the modified format.

Modified BC. The same basic format was used for BC, but the usual differences between FC and BC were present. Thus, subjects first learned Step 26 to criterion. Then training trials included Steps 25 and 26 until Step 25 reached criterion. After Step 25 was learned, subjects performed Steps 24 and 25, while Step 26 was dropped from the training trial. As steps reached criterion, more were added and dropped as above, until all steps reached criterion. As steps were dropped, parts for them were left in the covered bins. Probe trials and task criterion trials were conducted as in modified FC.

Prompting and data recording. There were four levels of prompting relevant to the actual training procedure and two categories of general prompts. The four levels of training prompts were: (a) no help, recorded as Level 3; (b) specific command for a step, recorded as Level 2; (c) specific command plus extra verbal and/or physical prompts, recorded as Level 1; and (d) specific command plus physical guidance, recorded as Level 0. The general prompts were (a) work prompts which indicated the start of a trial (e.g., "Make the brake," or "Do the next two steps"), and (b) non-specific prompts, which were used once per step per trial if an outside distraction disrupted the subject's performance, or if the

subject emitted non-productive behavior for 5-10 seconds. In other words, the experimenter prompted subjects to stay on task if they stopped working.

For training trials, probe trials, and baseline testing, the same general procedure of prompting and data recording was employed. Whenever a step was attempted, subjects were given the opportunity to perform at Level 3, the target performance. If a subject did not perform at Level 3, the experimenter gave additional prompts, increasing the help by one level at a time until the step was performed. For each step done on each trial, the experimenter recorded the number corresponding to the level of help needed to get the subject to perform the step. Levels 3, 2, or 1 were recorded if response initiation occurred within about three seconds of the appropriate prompt or completion of the last step done, and the performance of the step was not interrupted by an interval of more than 10 seconds of non-productive behavior. (Note that a non-specific prompt was given first if one had not been used to get the response initiation, before increasing a level of prompting.) Behaviors such as stopping work, repetitive behaviors, manipulating materials in a way that would not likely lead to correct placement, staring at the experimenter, or asking for help or approval are examples of what was considered non-productive behavior.

Each trial started when the experimenter gave a general work prompt. Any incorrect response or violation of the above conditions was a cue for the experimenter to use the next level of prompting. Where appropriate, i.e., Levels 0 and 1, the specific command for a step was repeated with the extra prompting so that the behavior would eventually come

under the control of the command. See Table 2 for complete definitions

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Insert Table 2 about here

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of prompting levels.

Baselines. In baseline sessions, subjects were seated in the session room with all of the parts for the task (being tested) placed in the bins in the proper order and easily accessible. They were shown a completed product and then asked to make one. The experimenter recorded what behaviors the subjects emitted until a product was made or 30 seconds of continuous non-productive behavior occurred. Next, each step of the task was tested, using the prompting and recording procedures described above. The task was assembled to a particular step and the subject was given the opportunity to perform the next step. The experimenter recorded the level of prompting required to get the subject to perform the next step. Individual steps were tested in random order to minimize the learning that occurs during baseline. No reinforcement contingent on step or task completion was planned. At the beginning of baseline sessions, and at approximately 3 to 5 minute intervals, the experimenter asked subjects to perform some unrelated behavior (e.g., "Point to your toes") and reinforcers were delivered for those behaviors.

Baseline scores on the tasks for each subject were obtained by summing the numbers corresponding to the levels of prompting given for each step of a particular task.

Reinforcement procedures. During training, social and edible reinforcers were used. In the usual chaining format, a reinforcer is earned

Table 2

Definitions of Prompting Levels

Level 3, no help

- response was initiated within about 3 seconds (or longer for slow Ss) of (a) a work prompt, (b) completion of last step, or (c) a nonspecific prompt.
- response was emitted correctly.
- after a nonspecific prompt was given, there was no interval of nonproductive behavior during performance of the step that exceeded about 10 seconds.

Level 2, command only

- response was initiated within about 3 seconds of the specific command for a step.
- response was emitted correctly.
- after a nonspecific prompt was given, no interval of nonproductive behavior greater than about 10 seconds.

Level 1, command plus extra prompting

- response was initiated within about 3 seconds of the command and extra prompt.
- response was emitted correctly.
- after a nonspecific prompt was given, no interval of nonproductive behavior greater than about 10 seconds.
- extra prompts were verbal instructions, repetition of commands, physical prompts such as pointing or gesturing in an attempt to model a particular manipulation. After the response was initiated, more than one level 2 prompt was given if it looked like the S was working appropriately but was not quite successful (subjectively determined by the experimenter) and the additional prompt may have helped get the behavior.

Level 0, command plus guidance

- if the above levels did not produce the behavior, the experimenter repeated the command and physically guided the S through the step, either by manipulating the S's hands or the task materials. Experimenter tried to use as little guidance as possible, and subjectively tried to fade it out.

after the subject performs each trial (e.g., see Martin & Pear, 1978). In this study, on probe and task criterion trials the above procedure was followed with the additional requirement that the last step was done at Level 3 to earn an edible reinforcer. Otherwise, only social approval was delivered. During training trials, reinforcement rules were used which placed contingencies on quality of performance. To earn both social and edible reinforcement on a training trial, subjects had to perform the learned step at Level 3 and the step being trained had to be performed at least as well as it had been in earlier trials, or better. Improvement was determined from the subject's past performance on the step. In training a step initially, reinforcement for that step was earned if the subject performed it at the baseline level or better until the step was performed two consecutive times at that (or possibly a higher) level. Then on subsequent trials the subject had to perform with less help to earn reinforcement until the next (or higher) level of help was used on two consecutive trials and so on until the step reached criterion. If both steps were performed appropriately, social and edible reinforcement were delivered. If only one step was performed appropriately, social reinforcement was delivered. And, if neither step was performed appropriately, minimal interaction occurred.

Errors and corrections. When a learned step was not performed at Level 3, the experimenter had the subject correct it with as little interaction as possible. This was done to minimize potentially reinforcing consequences for errors. Thus, to correct an error, the experimenter simply pointed to a correct piece or placement, gave a brief verbal prompt, or quickly used guidance, and then continued with the trial,

making sure to point out at the end of the trial when errors had resulted in less reinforcement. The experimenter recorded the level of prompting that was used, or the lowest level if more than one level was used to correct an error.

Observer agreement. In observer reliability assessment sessions, a second observer sat at the end of the table opposite the experimenter and recorded the level of prompting used for each step on each trial. Agreements were calculated using the ratio of the number of steps on which there was agreement, over the total number of steps contacted in the session.

Research design and dependent variables. Four subjects were used in a multi-element design (Sidman, 1960; Ulman & Sulzer-Azaroff, 1975; Wrighton & Martin, 1978), with counterbalancing of tasks and procedures. In this study, the use of the multi-element design involved exposure of the subjects to alternating training procedures (i.e., modified FC and BC) within sessions, to train two different tasks (see also Pallotta-Cornick et al., 1978). Thus, two subjects learned the brake with modified FC and the reel with modified BC. The other two subjects learned the tasks with the reverse task-procedure combinations (see Table 3 for

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Insert Table 3 about here

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design of all three experiments).

The multi-element design permitted the evaluation of the effects of the two procedures in single subjects, thereby avoiding problems of inter-subject variability (Sidman, 1960) and it controlled for sources of intra-

Table 3

Research Design for All Three Experiments

| | Experiment 1 | | Experiment 2 | | Experiment 3 | |
|---|---|---|---|---|---|---|
| Subject | BC | FC | BC | FC | BC | FC |
| 1 | reel | brake | car | man | - | - |
| 2 | reel | brake | car | man | - | - |
| 3 | brake | reel | man | car | - | - |
| 4 | brake | reel | - | - | - | - |
| 5 | - | - | man | car | alarm | key |
| 6 | - | - | - | - | key | alarm |

subject variability (Wrighton & Martin, 1978). When used with topographically different responses, however, the design involves assumptions that the responses are equivalent (Wrighton & Martin, 1978).

Dependent variables in the study were, for each task, the number of steps contacted in training individual steps until the steps reached criterion (each attempt at a step was one step contacted), the number of task criterion trials required to reach criterion for the whole task, and the total number of steps contacted on probe, training and task criterion trials. In addition, for each task, percent errors were calculated, using the ratio of the number of errors on learned steps in a session, over the number of learned steps contacted in that session. Time on task (TOT) which was the time spent from the start of trials to the end of trials in a session, and total session time (TST), which was the continuous time from the beginning of the first trial in a session, to the end of that session, were also recorded. Finally, work rate was calculated using the ratio of total steps contacted in a session over the TOT in that session.

## Results and Discussion

In the complete task baseline, no subject was able to do more than pick up a few parts and try to assemble them (incorrectly). When individual steps were tested, the following scores were obtained (scores on the brake are shown first): Subject 1, 50, 33; Subject 2, 48, 24; Subject 3, 46, 40; Subject 4, 35, 29.

Observer agreement was obtained in 12 sessions, at least once per subject per task. Mean agreement was 96.5% and scores ranged from 82% to 100%.

Concerning Experiment 1, Figure 1 shows the total number of

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Insert Figure 1 about here

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training steps contacted for individual steps to reach criterion, and Figure 2 indicates the number of task criterion trials required until

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Insert Figure 2 about here

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the whole task reached criterion.

It can be seen in Figure 1 that for all subjects, the fishing reel required more training contacts for the individual steps to reach criterion than the bicycle brake, and for three of the subjects, the task trained with modified BC required more task criterion trials (Figure 2). Thus, it appears that in spite of efforts to make the brake and reel more equivalent, there was still a clear task effect in that the reel was more difficult. Also, in terms of task criterion trials, the tasks trained with FC generally required fewer trials. It does appear though, that in initially training the individual steps, BC was somewhat superior. This can be seen by looking at the performance on the reel (the difficult task) relative to the brake, when the reel was trained with FC or BC. For Subjects 1 and 2, who learned the reel with BC, the differences between the two tasks were fairly small as compared with Subjects 3 and 4 who learned the reel with FC. Thus, training the reel with BC tended to minimize the differences between the two tasks in initially learning the steps.

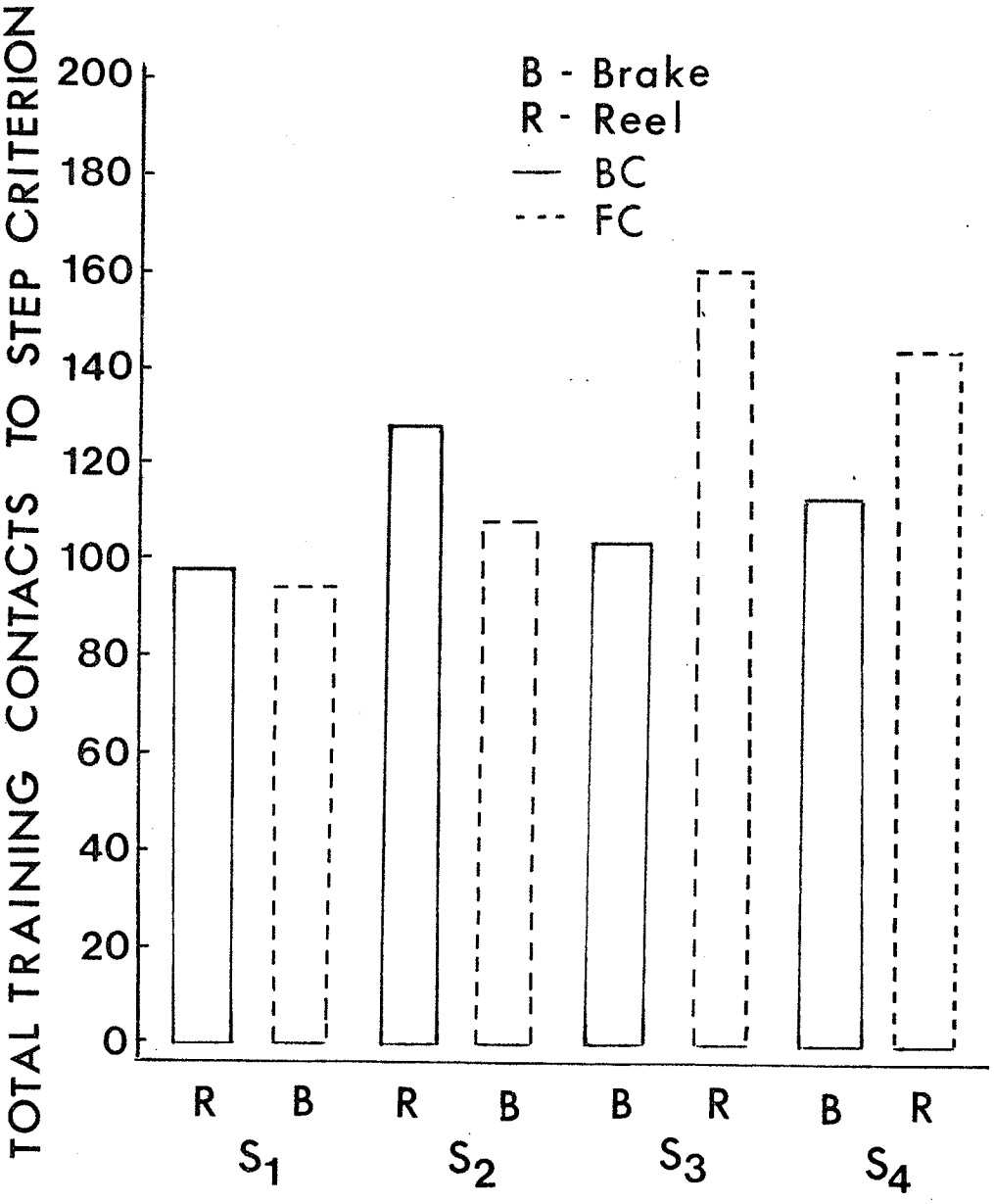


Figure 1. Total training contacts to step criterion, Experiment 1.

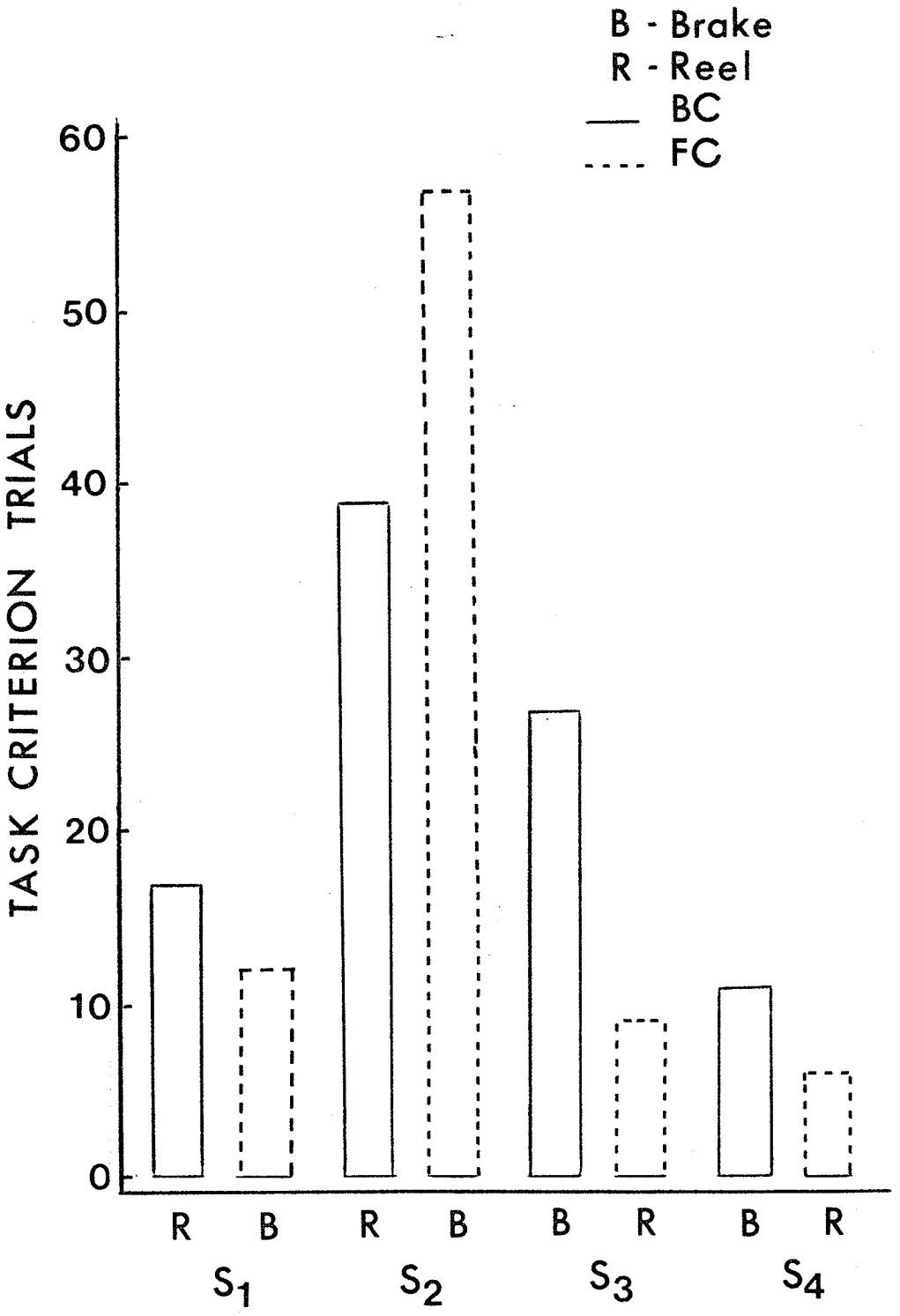


Figure 2. Total number of task criterion trials, Experiment 1.

Figure 3 shows the total number of steps contacted per session, for

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Insert Figure 3 about here

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all the types of trials. Three out of four subjects took more contacts to reach step criterion with BC. Thus, although there may have been a superiority for BC in initially learning the steps, it was negated because the task trained with BC usually required more task criterion trials.

Figure 4 shows the amount of TOT and Figure 5 shows TST. These

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Insert Figures 4 and 5 about here

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variables were consistent with total contacts to task criterion data. For three out of four subjects, the task trained with BC took more TOT and TST. The shaded portion of the TOT and TST graphs indicates the time spent on task criterion trials. This shows that for some subjects, and especially for Subjects 1 and 2, a substantial proportion of training time was spent repeating learned steps in task criterion trials.

Percent errors on all contacts of learned steps are shown in Table 4.

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Insert Table 4 about here

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Asterisks indicate the session in which the last individual step reached criterion. It can be seen in Table 4 that errors occurring before all steps reached criterion were generally high, ranging from about 10% to 40%, and in one session for Subject 4, as high as 60%. Once task cri-

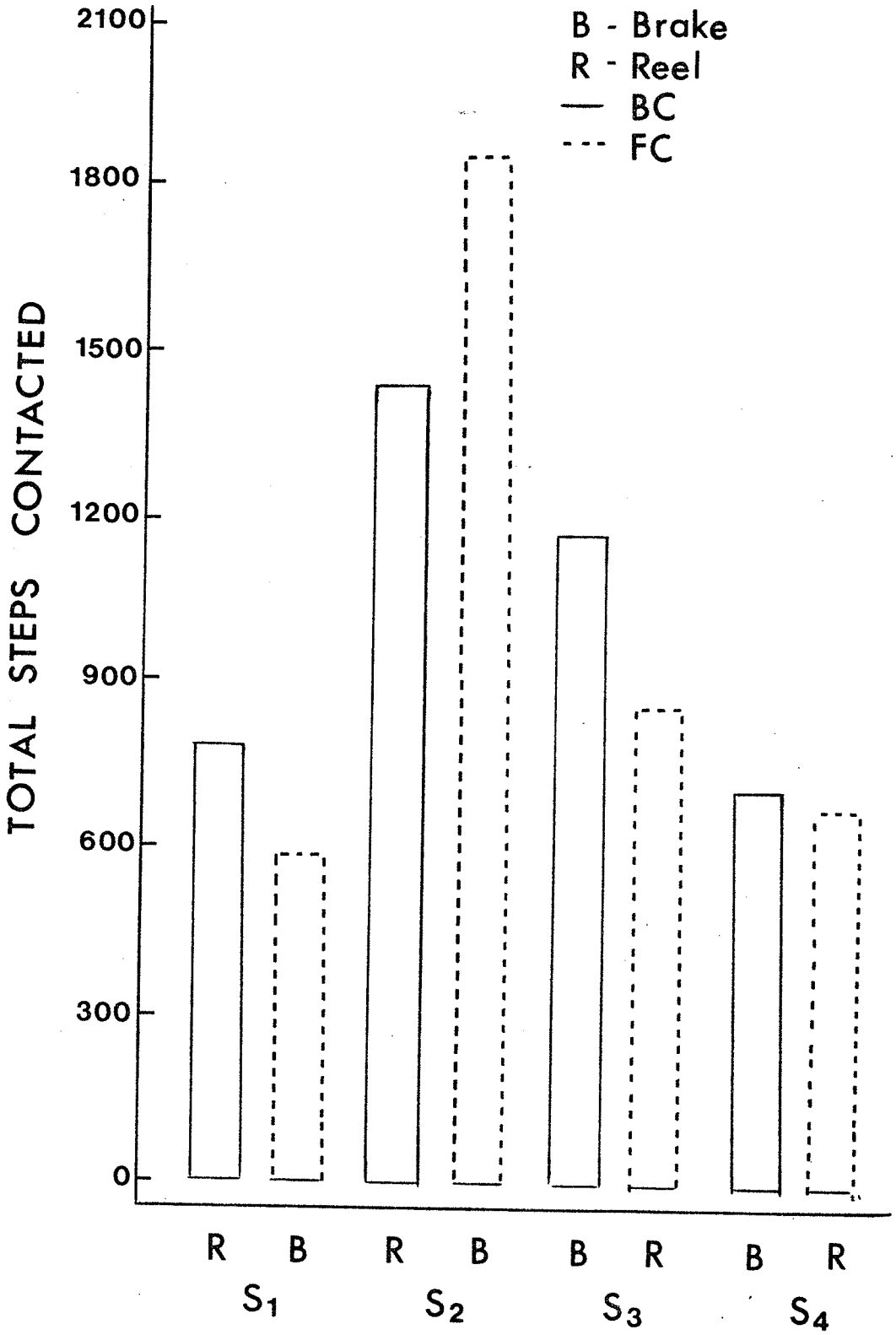


Figure 3. Total steps contacted to task criterion, Experiment 1 (all types of trials).

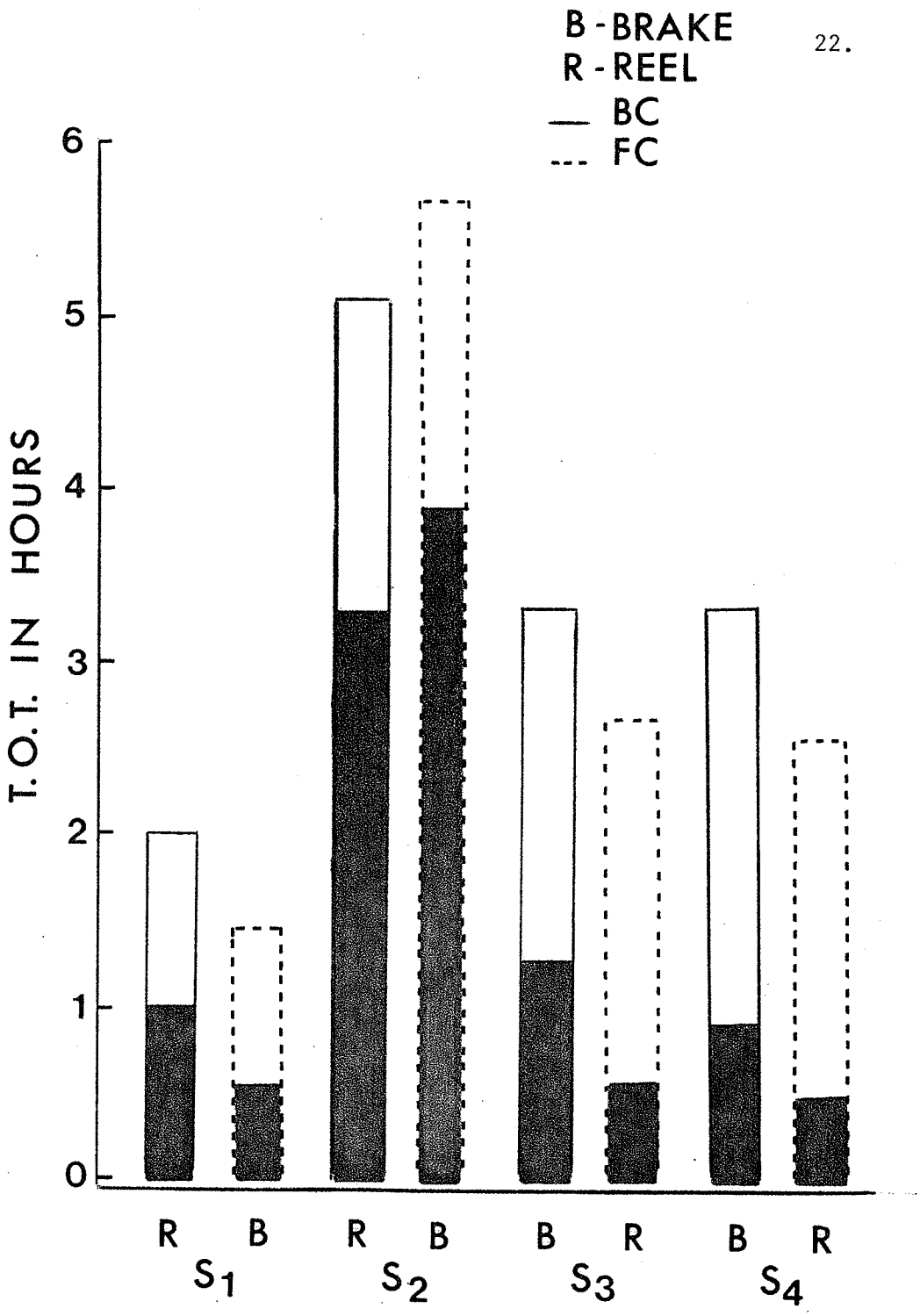


Figure 4. Total time on task in hours, Experiment 1 (shading indicates time taken on task criterion trials).

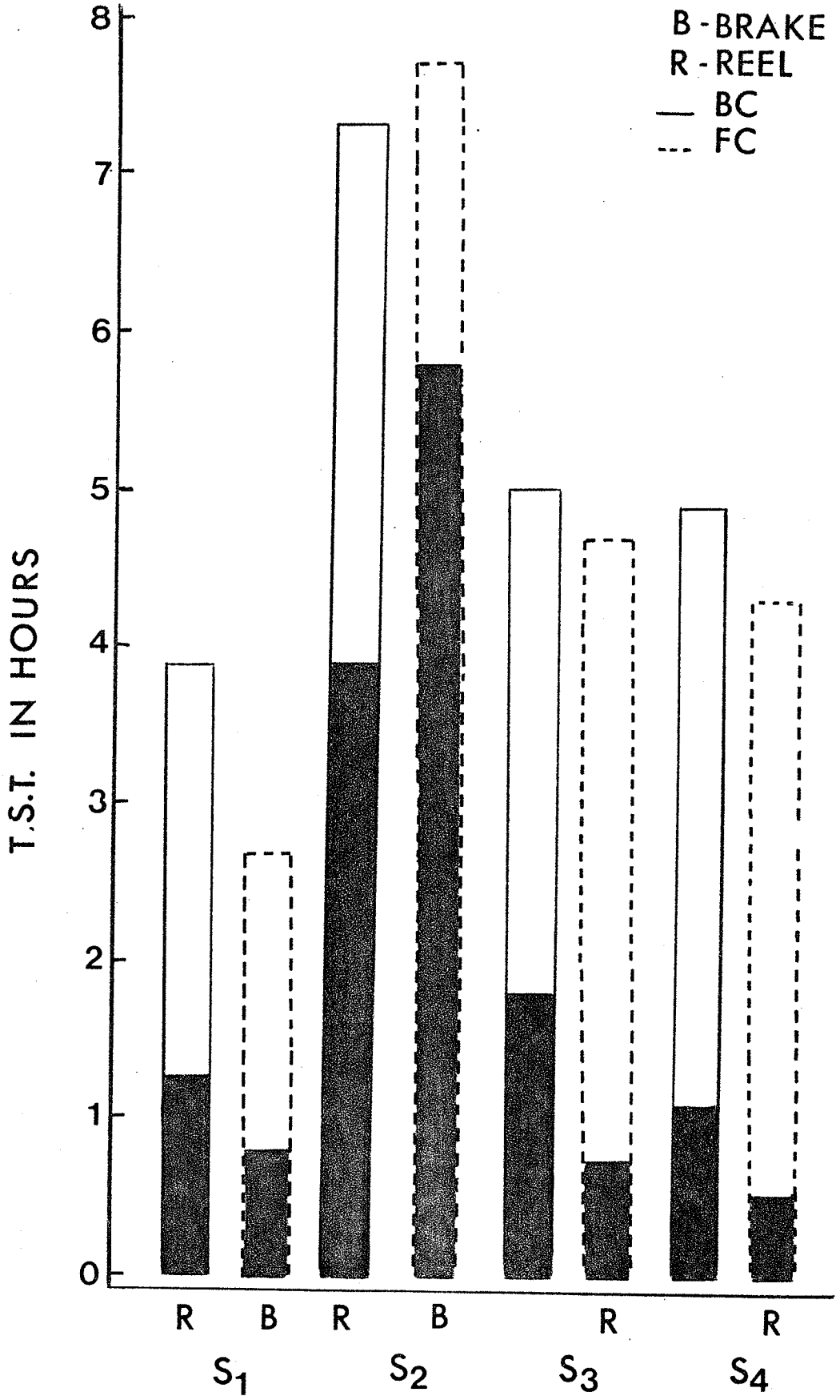


Figure 5. Total session time in hours, Experiment 1 (shading indicates time taken on task criterion trials).

Table 4

Percent Errors - Experiment 1

| Sessions | $S_1$ | | $S_2$ | | $S_3$ | | $S_4$ | |
|---|---|---|---|---|---|---|---|---|
| | BC | FC | BC | FC | BC | FC | BC | FC |
| 1 | 12.5% | 34.5% | 29.4% | 24.0% | 15.4% | 0.0% | 42.9% | 12.5% |
| 2 | 3.5% | 29.6% | 38.5% | 40.0% | 42.1% | 35.7% | 58.3% | 20.8% |
| 3 | 19.4% | 19.5% | 28.6% | 40.9% | 18.2% | 43.5% | 30.8% | 24.0% |
| 4 | 17.7% | 22.2% | 20.0% | 38.9% | 10.3% | 18.4% | 21.7% | 5.0% |
| 5 | 35.5% | 17.0% | 24.2% | 17.0% | 4.4% | 6.9% | 19.1% | 10.3% |
| 6 | 18.4% | * 8.2% | 15.8% | 31.9% | 27.7% | 8.8% | 22.7% | 18.4% |
| 7 | 9.6% | 9.6% | 25.9% | 35.7% | 28.3% | 18.9% | 13.6% | 7.7% |
| 8 | *12.1% | 9.0% | 24.0% | *25.0% | 13.7% | 14.3% | 18.0% | 28.6% |
| 9 | 2.9% | 3.9% | *20.0% | 25.6% | 31.6% | 19.1% | 42.9% | 23.3% |
| 10 | 6.7% | | 25.0% | 19.2% | *16.3% | 12.5% | 29.4% | 12.0% |
| 11 | 4.6% | | 24.4% | 15.4% | 15.4% | 6.1% | *13.6% | * 3.5% |
| 12 | 2.6% | | 19.2% | 29.5% | 6.2% | 7.3% | 9.6% | 17.3% |
| 13 | | | 21.2% | 25.0% | 6.4% | *15.6% | 5.1% | 0.0% |
| 14 | | | 19.2% | 17.3% | 3.9% | 16.7% | 3.1% | |
| 15 | | | 19.2% | 15.4% | 6.2% | 2.9% | | |
| 16 | | | 15.4% | 14.4% | 0.0% | 0.0% | | |
| 17 | | | 15.4% | 13.6% | | | | |
| 18 | | | 14.4% | 5.4% | | | | |
| 19 | | | 14.1% | 9.2% | | | | |
| 20 | | | 13.1% | 6.9% | | | | |
| 21 | | | 6.7% | 9.6% | | | | |
| 22 | | | 0.0% | 6.4% | | | | |
| 23 | | | | 3.1% | | | | |
| Retention | 10.0% | 17% | 26% | 10% | 4.0% | 15.0% | 15.0% | 4.0% |

terion trials began, error rates showed a gradual decline until task criterion was met. No differences in error rates between the two procedures were apparent. This data, along with the number of task criterion trials, indicates quite clearly that a retention problem existed with the modified chaining format. Until task criterion trials were run, error rates were seldom below 10%. Also, follow-up retention tests were conducted eight weeks after training had finished. Results from these tests are also included in Table 5. In the retention tests, the error rates were fairly high, ranging from 4% to 26%, and generally about 10% or 15%. No consistent differences can be seen between the two procedures in the error rates.

The subjects rate of working was also calculated. However, no consistent differences between the procedures were observed in this variable. The rates gradually increased as training progressed, but there was a great deal of variability and overlap in these data points.

Four conclusions are tenable based on the results of Experiment 1. First, the data suggest that in initially training the steps of a task, BC was superior. Second, any initial advantages that there were for BC were eliminated because BC tended to require more task criterion trials, which increased the total number of steps contacted to reach task criterion and also increased the amount of time spent learning the task. Third, it was clear from the error rate and time spent on task criterion trials, that retention was fairly poor using the modified format. Finally, in spite of the efforts to equate the tasks, a task effect was still present. An attempt was made to correct this latter problem in Experiments 2 and 3.

## EXPERIMENT 2

### Method

In Experiments 2 and 3, the same general procedures were followed with minor changes. Only the differences from Experiment 1 are described.

#### Subjects

The same subjects were used in Experiment 2 with the exception of Subject 4. She had to be dropped because in baseline testing she was able to assemble both tasks with no errors. Subject 5 was added, using the same selection criteria as in Experiment 1. He also had experience in a previous study with the brake and reel but was unable to perform the tasks for Experiment 2 in the baseline test.

#### Tasks and Materials

In order to minimize the differences between tasks, tasks were developed that required repetitive behaviors within the task, and the same behaviors between tasks. This was accomplished by devising two assemblies using Lego building blocks. Task 3 was a 5-part toy man, requiring nine steps to assemble. Task 4 was a toy car with the same number of parts and steps. See Appendix C for task analyses of the man and the car.

#### Baselines

Due to the simplicity of these tasks, individual steps were not tested because the potential for learning the tasks in baseline seemed too great, especially after Subject 4 had been able to assemble them both, with no instructions, prompting, etc. The complete task was tested using the procedure described in Experiment 1. Subjects were shown the completed product and then asked to make one. Since only one of each task was available, subjects did see the tasks disassembled between the

time they were shown the finished produce and the time that they were asked to make it themselves, but they did not see the task put together.

## Results and Discussion

In the complete task baseline, none of the subjects used in the research were able to correctly assemble either task. All subjects attempted to put pieces together, but selected them in the wrong order and placed them incorrectly. Eventually, all subjects emitted 30 seconds of non-productive behavior.

Observer agreement was obtained in six sessions, once per subject per task, except for Subject 5 who learned both tasks in one session. Mean agreement was 95.3% and scores ranged from 89% to 99%.

Figure 6 shows that for three out of four subjects, modified BC was

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Insert Figure 6 about here

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again slightly superior in initially training individual steps to criterion. Also, unlike the results in Experiment 1, Figure 7 shows that three

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Insert Figure 7 about here

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of the four subjects required fewer task criterion trials with modified BC. Since the steps contacted to criterion for individual steps and task criterion trials both tended to favor modified BC, the variable total steps to task criterion for all trials simply repeats information that can be seen in Figures 6 and 7 in that three of the four subjects required fewer steps contacted with modified BC.

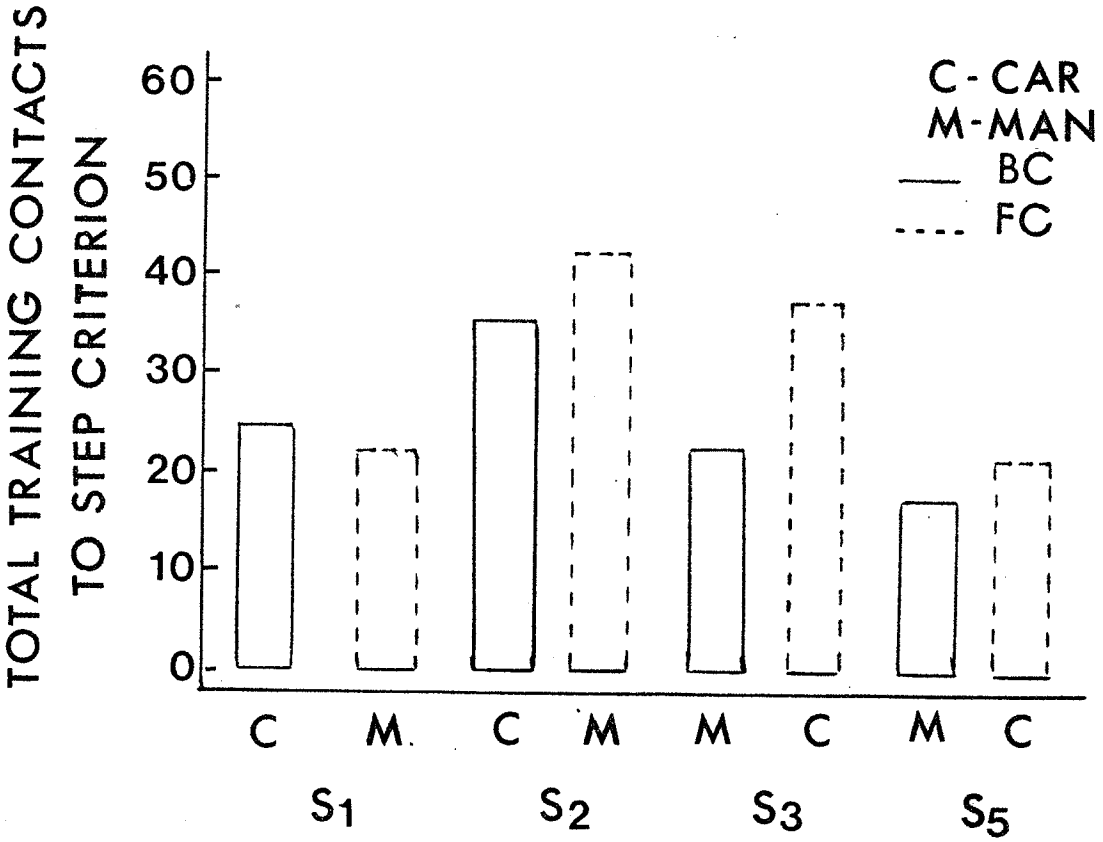


Figure 6. Total training contacts to step criterion, Experiment 2.

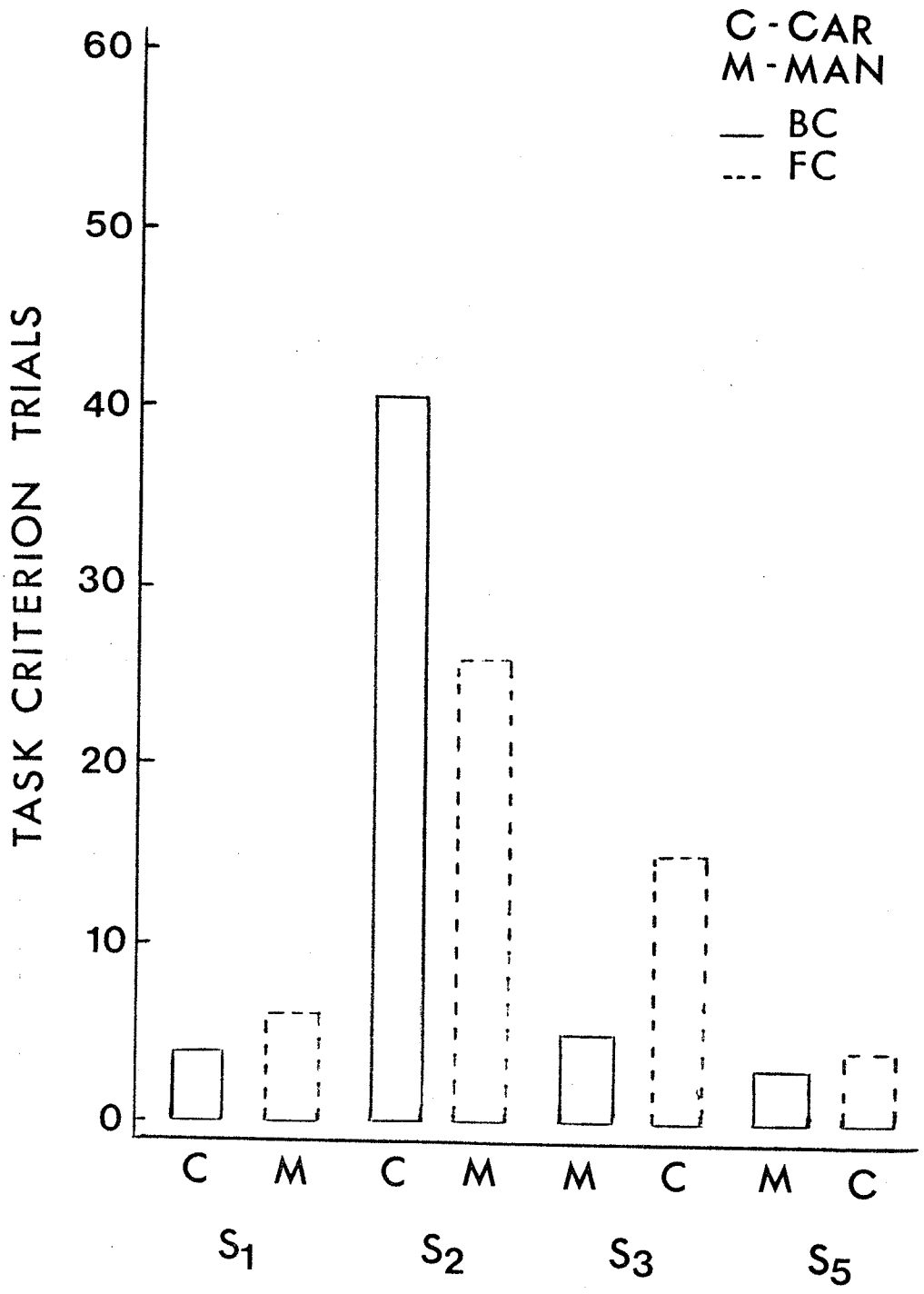


Figure 7. Total number of task criterion trials, Experiment 2.

Figures 8 and 9 show TOT and TST, respectively. These results were

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Insert Figures 8 and 9 about here

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consistent with the steps contacted to criterion data. Three of the four subjects required less time to learn the tasks with modified BC. Since the man and the car were learned quite quickly by most subjects, the TOT spent on task criterion trials does not appear to be substantial. However, for Subject 2, who was considerably slower than the others, TOT in task criterion trials represents a major proportion of training time.

Percent errors on learned steps contacted for all types of trials are shown in Table 5. Again, no clear differences between the procedures

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Insert Table 5 about here

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were seen in error rates. Although the errors were lower than in Experiment 1, they still ranged from about 10 to 20%, and even higher for Subject 2. In the follow-up retention test, however, three of the subjects had fewer errors with modified BC.

Since the simple tasks in the Pallotta-Cornick et al. (1978) and the presumably simple tasks in the Walls et al. (1978b) studies had failed to reveal any differences between FC and BC, no differences were expected in these short Lego assembly tasks. The results, however, were fairly similar to those of Experiment 1. They suggest again that initially learning the steps was accomplished more easily with modified BC. However, this advantage tended not to be lost in task criterion trials with the simpler tasks. Errors on learned steps also continued to be fairly high.

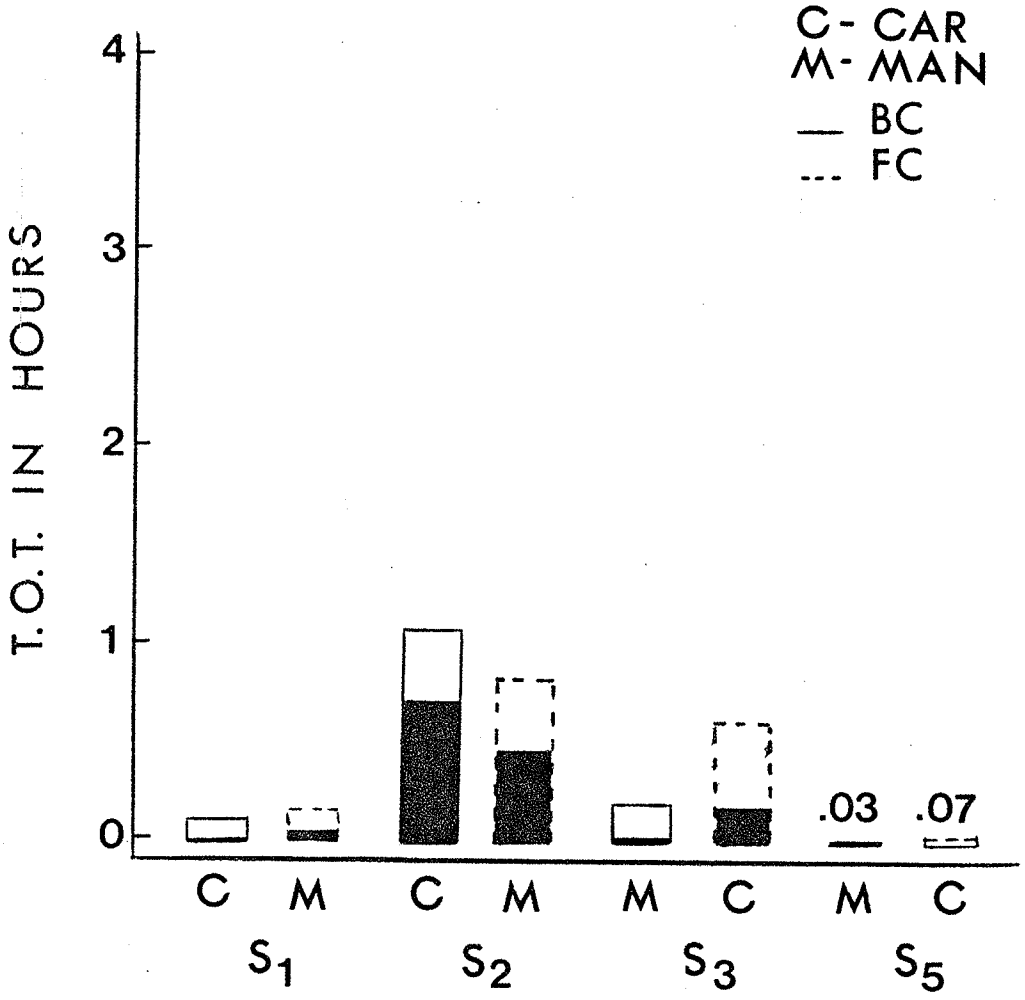


Figure 8. Total time on task in hours, Experiment 2.

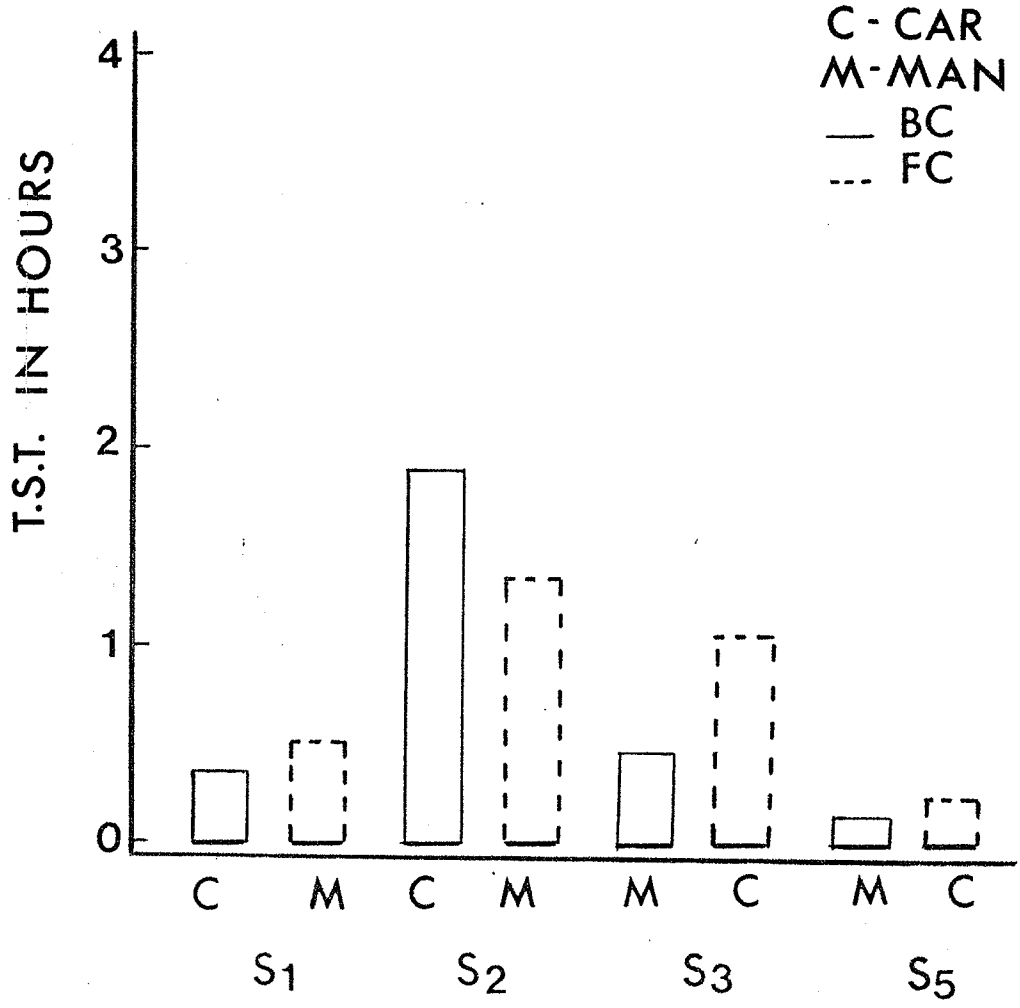


Figure 9. Total session time in hours, Experiment 2 (shading indicates time taken on task criterion trials).

Table 5

Percent Errors - Experiment 2

| | $S_1$ | | $S_2$ | | $S_3$ | | $S_5$ | |
|---|---|---|---|---|---|---|---|---|
| Sessions | BC | FC | BC | FC | BC | FC | BC | FC |
| 1 | 17.7% | 16.7% | 0.0% | 12.5% | 6.7% | 11.8% | 0.0% | 10.7% |
| 2 | * 5.8% | * 4.3% | 11.5% | *20.9% | * 8.6% | 20.0% | | |
| 3 | | | *29.2% | 29.6% | | *10.1% | | |
| 4 | | | 29.1% | 22.2% | | | | |
| 5 | | | 17.1% | 7.9% | | | | |
| 6 | | | 4.9% | | | | | |
| Retention | 4.0% | 15.0% | 7.0% | 19% | 0.0% | 7.0% | 11.0% | 0.0% |

## EXPERIMENT 3

### Method

#### Subjects

Between Experiments 2 and 3, Subject 3 was lost due to a transfer and Subject 1 became available only on a limited basis due to increased participation in recreational and vocational activities. In addition, it was felt that the large amount of time required to teach Subject 2 to assemble the tasks in the first two experiments made her continued participation impractical since long, complex tasks were used in Experiment 3. In Experiment 3 only two subjects were studied. From Experiment 2, Subject 5 was retained and a sixth subject, who also had experience learning the man, car, brake and reel in other experiments, was added.

#### Tasks and Materials

Tasks 5 and 6 were electronic circuit assemblies obtained from a Science Fair 20-in-1 hobby kit. In this kit, electronic components were individually mounted on plastic blocks approximately two inches square. On the blocks there were openings along each side so they could be joined together with plastic clips, and there was a coil spring terminal in each corner. Components were pre-wired to these spring terminals so different components could be linked together by bending back the spring terminals and inserting the end of a wire, which was held in place when the spring was released. Thus, various circuits could be made by first joining together the appropriate blocks and then making the correct connections between the terminals with short pieces of wire, according to diagrams provided in an instruction manual.

Task 5 was a 57-step morse code key powered by a solar cell and

Task 6 was a 57-step light loss alarm which employed both a solar cell and batteries to sound an alarm when there was insufficient light to charge the solar cell. These tasks were equated in several respects. They each had seven blocks (all but two components were common to the two tasks), seven clips, 11 wires to make connections between terminals, and each provided auditory output via an earphone. In addition, each task had four multiple connections, i.e., two wires were connected to one terminal. Two minor discrepencies existed. One of the earphone wires was the third wire in one terminal on the light alarm, and in the morse key there was an extra block connection that could be made but was not included in the task analysis to keep the number of connections, parts, and steps the same. Finally, spring terminals that were used in the assemblies were indicated by circling them with a blue felt marker. See Appendices D and E for task analyses.

The training tray was used for these tasks but since there were more parts than bins, the 11 wires were put in one bin, and clips were put in with the blocks. This made using the covers for the bins impractical, so all parts were exposed throughout training.

Baselines

Due to the large number of steps and the repetitive nature of the steps, the individual steps were not tested to avoid the learning that could occur. Instead, seven component steps were identified and each was tested once. Thus, subjects were asked to pick up two blocks, position them, clip them, pick up a wire and connect the ends to two terminals. Subjects were also given the opportunity to try the whole task, following the same procedures as in Experiments 1 and 2.

## Results and Discussion

In the complete task baseline, neither subject was able to put the tasks together and eventually emi-ted 30 seconds of non-productive behavior. Seven component behaviors were tested individually but the tasks were equated in terms of the component behaviors, so any differences in acquisition could not be due to differences in baseline performance.

Observer agreement was obtained in six sessions, at least once per subject per task. Mean agreement was 95.6% and scores ranged from 93% to 98%.

Figure 10 shows the cumulative training contacts to criterion,

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Insert Figure 10 about here

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and Figure 11 shows the task criterion trials. Both subjects required

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Insert Figure 11 about here

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slightly fewer contacts to learn the individual steps with modified BC regardless of tasks. Also, there were fewer task criterion trials required with modified BC for both subjects. Thus, as in Experiment 2, there were fewer total contacts to task criterion (including all trials) with modified BC.

Figures 12 and 13 show TOT and TST, respectively. Again, these are

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Insert Figures 12 and 13 about here

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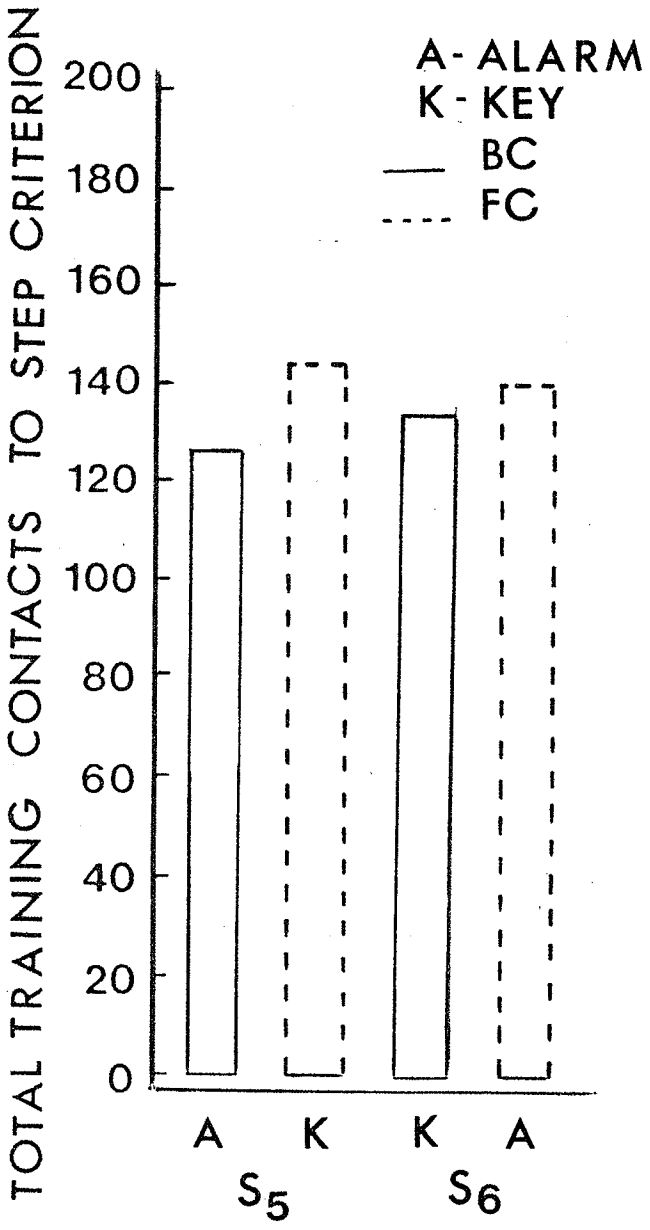


Figure 10. Total training contacts to step criterion, Experiment 3.

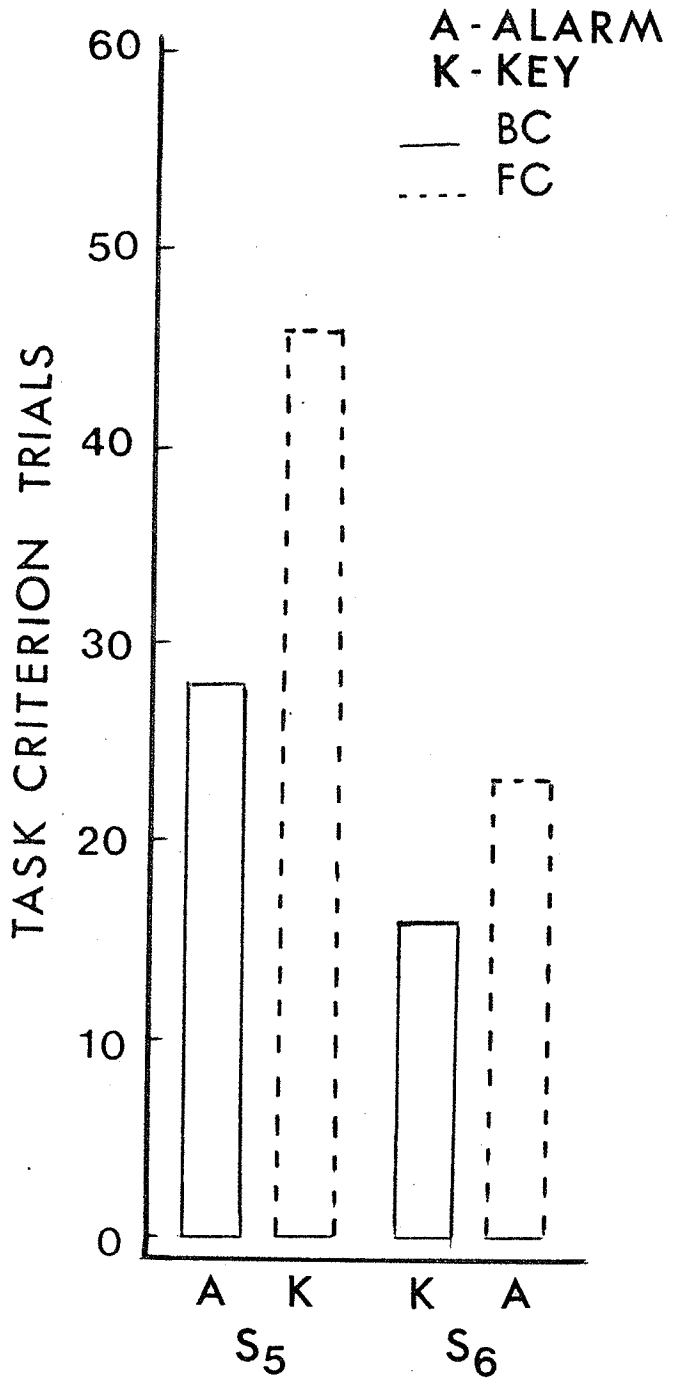


Figure 11. Total number of task criterion trials, Experiment 3.

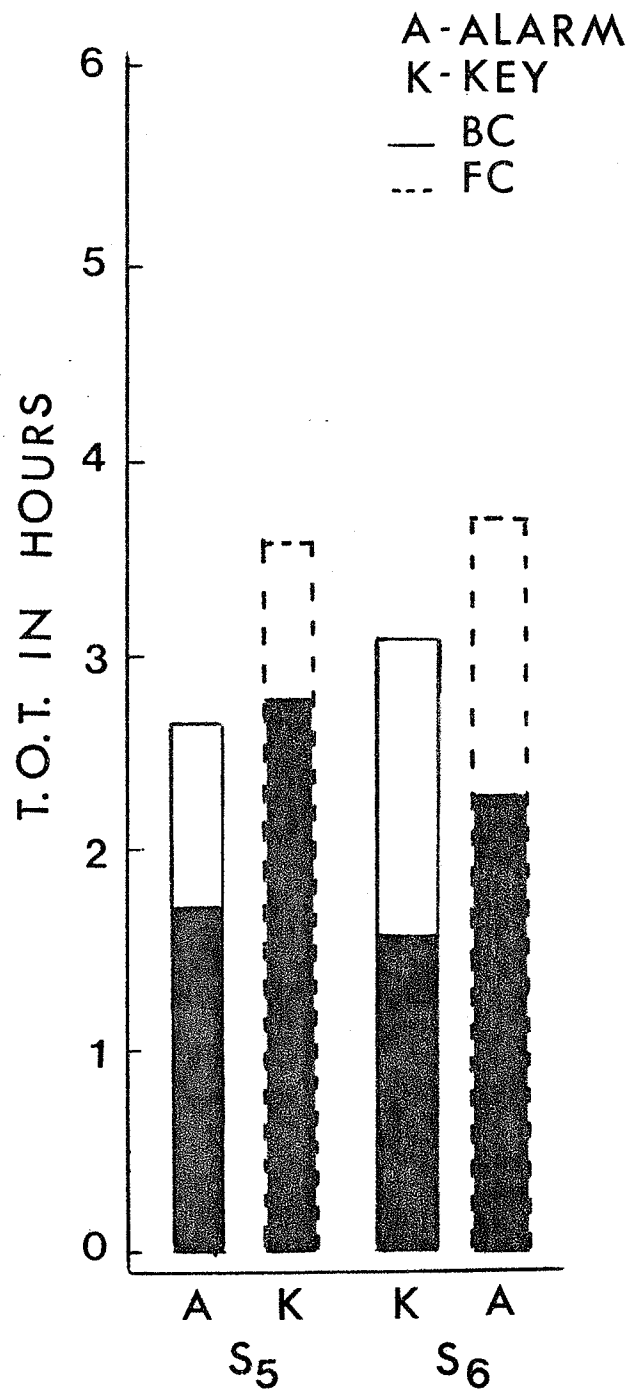


Figure 12. Total time on task in hours, Experiment 3 (shading indicates time taken on task criterion trials).

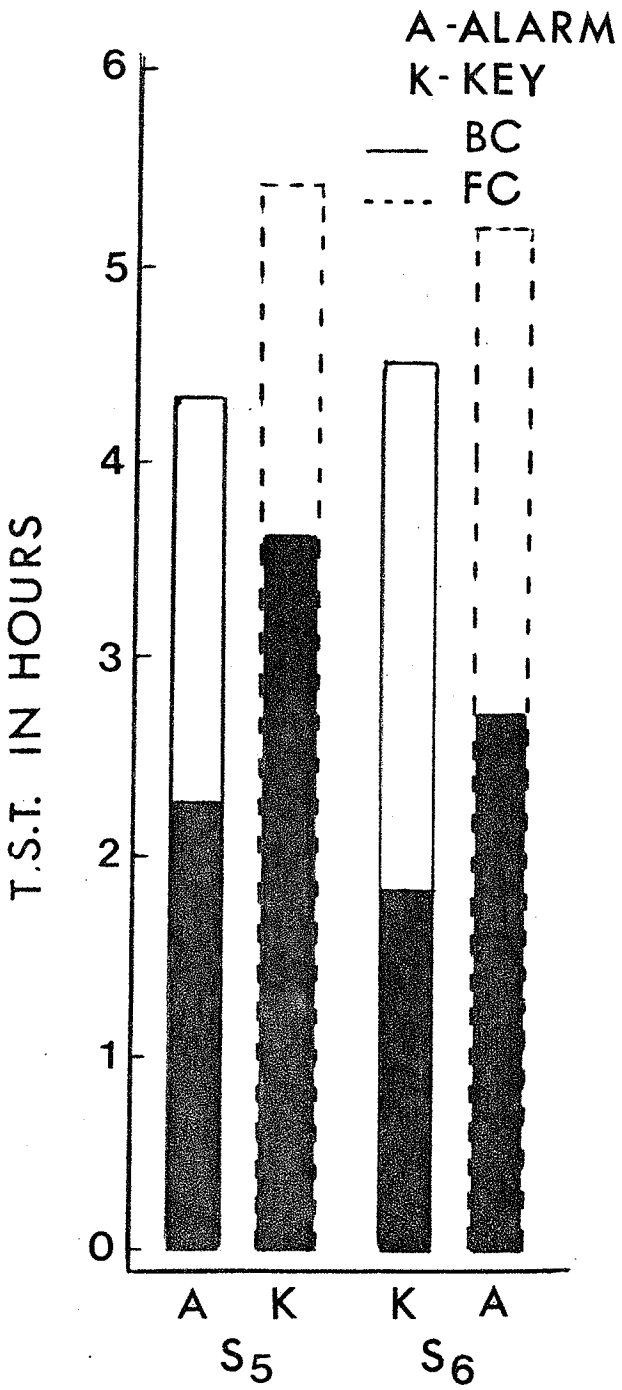


Figure 13. Total session time in hours, Experiment 3 (shading indicates time taken on task criterion trials).

consistent with the data shown in Figures 10 and 11, with the task being trained with modified BC taking less time to be trained. Although the differences in task criterion trials and training contacts to step criterion do not appear exceptionally large, with these larger tasks, the the differences in terms of TST amount to about 79 and 45 minutes for Subjects 5 and 6, respectively, in favor of modified BC. The shaded portion of the TOT and TST graphs indicates the time spent on task criterion trials. For both subjects, a substantial proportion of total training time was required for task criterion trials.

Errors are shown in Table 6. After the steps had reached criterion,

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Insert Table 6 about here

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and task criterion trials were being run, there was no clear difference between the two procedures as error rates for both tasks gradually decreased. Before all steps reached criterion, however, for both subjects the task being trained with modified BC had higher error rates. This was likely due to the fact that the latter steps of the tasks required subjects to make wire connections, while the earlier steps were block connections, suggesting that block connections were easier. As in the first two experiments, error rates tended to be high, generally between 10% and 30%, until task criterion trials were begun and rates gradually decreased. In the follow-up retention tests, no clear differences emerged between procedures, but for both subjects errors were between 6% and 10% for both tasks.

Contacts per minute was not presented since both subjects showed a

Table 6

Percent Errors - Experiment 3

| Sessions | $S_5$ BC | $S_5$ FC | $S_6$ BC | $S_6$ FC |
|---|---|---|---|---|
| 1 | 8.3% | 2.6% | 23.5% | 19.4% |
| 2 | 31.1% | 4.0% | 9.1% | 18.2% |
| 3 | 29.7% | 12.5% | 23.8% | 10.9% |
| 4 | *19.1% | 13.4% | 22.2% | 3.9% |
| 5 | 19.9% | *15.5% | 17.0% | 5.2% |
| 6 | 15.4% | 21.6% | 21.1% | 15.3% |
| 7 | 17.0% | 20.5% | 20.7% | *16.9% |
| 8 | 12.3% | 17.6% | *10.9% | 18.1% |
| 9 | 13.6% | 17.1% | 12.3% | 14.6% |
| 10 | 6.7% | 14.0% | 11.4% | 6.1% |
| 11 | 2.1% | 12.3% | 2.7% | 10.5% |
| 12 | | 9.1% | 2.9% | 7.0% |
| 13 | | 6.1% | 5.3% | 4.7% |
| 14 | | 6.7% | 2.9% | 5.3% |
| 15 | | 1.8% | | 1.3% |
| Retention | 11.0% | 10.0% | 6.0% | 5.0% |

gradual increase in rate as training progressed, but there were no clear differences between procedures as the data points were variable and overlapping.

The results of Experiment 3 support the conclusion that modified BC was more effective in training these tasks. Training required fewer training steps contacted to teach the individual steps, fewer task criterion trials (hence fewer total steps contacted) and considerably less training time (both TOT and TST) with modified BC. Retention with the modified chaining format again seems to have been poor as reflected in the high error rates, large number of task criterion trials, and large amount of time spent on task criterion trials.

## DISCUSSION

The present research was conducted to systematically replicate a study (Pallotta-Cornick et al., 1978) comparing the effectiveness of training assembly tasks in a forward or backward fashion. In addition, data on a modified chaining format was obtained.

With respect to training in a forward or backward fashion, the most consistent finding was that the task trained with the modified BC procedure required fewer training steps contacted for the individual steps to reach criterion. This conclusion was made in all three experiments, although the difference was small in Experiment 2 (the short tasks) and Experiment 3 (the long tasks). In Experiments 2 and 3, the task trained with modified BC also required fewer task criterion trials, with the exception of one subject in Experiment 2. In Experiment 1, however, the initial advantages of training with modified BC were negated for three of the subjects because more task criterion trials were required when modified BC was used. Thus, in Experiment 1, the total contacts to task criterion on all types of trials tended to show no difference, or favored modified FC, while in the other two experiments, total contacts to task criterion facored modified BC. TOT and TST for every subject in all three experiments were consistent with the steps contacted variables. No clear differences were seen between the procedures in errors on learned steps or steps contacted per minute.

There are three points of applied interest that may be made based on the above conclusions. First, training in a backward fashion was generally better in terms of number of steps contacted and training time. The failure to fully replicate this in Experiment 1 is interesting. After

Experiment 1 was conducted, it was apparent that in spite of continued efforts to equate the brake and reel, a task effect still existed. Thus, tasks with more homogeneous component steps, both within and between tasks, were selected for the next two experiments and it was in these two experiments that it was concluded that modified BC was more effective in terms of learning contacts to individual step criterion and number of task criterion trials. In Experiment 1, as noted, modified FC tended to require fewer task criterion trials. This suggests a possible interaction between task characteristics and training in a forward or backward fashion such that tasks with homogeneous component behaviors required fewer task criterion trials when trained with modified BC, but with tasks having heterogeneous component behaviors, fewer task criterion trials were required with modified FC.

The second point to note is the fact that differences (from the findings of Pallotta-Cornick et al., 1978) were observed in Experiment 2 using the least complex tasks. Pallotta-Cornick et al. (1978) did not find any differences with their simple packaging tasks, so none were expected with the simpler tasks in the present study. However, three of the four subjects showed at least small differences favoring modified BC. The packaging tasks used by Pallotta-Cornick et al. lacked the homogeneity of component steps that was a feature of the Lego tasks in this research. If an interaction does exist between task characteristics and direction of chaining as suggested above, it could account for the inconsistency of the findings between the two studies.

The third point of interest is that there was no difference in steps

contacted per minute between tasks learned in a forward or backward fashion, indicating that neither procedure produced faster work rates in the subjects. Thus, even small differences in terms of steps contacted were seen in training time (TOT and TST). Even small, replicable differences may be important in an applied setting such as a sheltered workshop where several clients may require training as new contracts and/or clients come into the shop, since the small difference would accumulate when training a group of clients. Also, as seen in Experiment 3, a difference in total steps contacted that appears fairly small can translate into substantial differences in training time (e.g., for Subject 6 the difference was over one-half hour) when long tasks are being taught.

With respect to investigating the modified chaining format, it seems clear from the error rates, number of task criterion trials, and proportion of time spent on task criterion trials that retention was fairly poor with this training format. Errors on learned steps tended to occur at a rate seldom under 10%, and sometimes as high as 40% or more across all three experiments. These high rates prevailed until task criterion trials began and the rates gradually dropped until the task criterion was met. Error rates on follow-up retention tests were high, ranging from 0% to 31%, but generally above 10%. Similarly, the number of task criterion trials required before subjects reached task criterion was high in Experiments 1 and 3, rarely under 10, and sometimes as high as 40 or more. Even in Experiment 2, one subject required 41 and 26 task criterion trials for the two tasks to be learned. Thus, the error rates and number of task criterion trials required to reach task criterion indicate that although the

individual steps were learned, there was poor generalization over time. The costliness of this result in terms of training time can easily be seen in the TOT and TST graphs. When training time was greater, it appears that the proportion of training time spent on task criterion trials was also high. This is seen especially in Experiment 3 where the proportion of training time spent on task criterion trials was a substantial portion of TOT and TST. In effect then, with the modified format much time was spent repeating steps that had already been learned. This would appear to be a serious shortcoming of the modified format. It was introduced because it eliminated most of the practice on learned steps inherent to the usual chaining format. However, the poor retention found with the modified format probably negated any potential advantages in terms of required number of steps contacted and training time required to learn the tasks.

The present study indicated that modified BC was generally more effective than modified FC to train retarded clients in the low moderate to high severe range of functioning to perform various assembly tasks. This conclusion must be qualified however because the differences tended to be small, and they were not universally replicated across all subjects in all experiments. A possible source of variability was the degree of homogeneity in the component behaviors within and between tasks. This should be investigated in future research. For the present, it would appear that the modified BC format was more effective in training tasks with homogeneous component behaviors and that as task length was increased, the saving in training time could be substantial.

Training with the modified chaining format had a serious shortcoming

in that error rates tended to be high and training was often prolonged due to the generally large number of task criterion trials required before task criterion was met. It should be pointed out that the present research modified the chaining format to the extreme so that very nearly all the practicing on learned steps was eliminated. However, there are other modifications that could be made which would cut down on session time used for practicing learned steps, but not to such an extent as is found in the traditional chaining procedures. These should be investigated to determine whether or not some of the practice on learned steps can be eliminated while still maintaining good retention. Some ways this could be done are: (a) increase the learning criterion; (b) chain in blocks of steps, e.g., 2 or 5, but still not all learned steps on every trial, or (c) during task criterion trials provide massed practice on single steps on which errors consistently occur.

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# APPENDIX A

## Bicycle Brake Task Analysis

1. Pick up housing.
2. Pick up axle.
3. Insert axle in housing.
4. Turn housing over.
5. Pick up nut A.
6. Screw nut A onto axle.
7. Turn housing over.
8. Pick up planet cage.
9. Put planet cage onto axle.
10. Pick up washer A.
11. Put washer A onto axle.
12. Pick up washer B.
13. Put washer B onto axle.
14. Pick up washer C.
15. Put washer C onto axle.
16. Pick up gear ring.
17. Put gear ring onto axle.
18. Pick up dust cap.
19. Screw dust cap onto housing.
20. Pick up driver.
21. Put driver onto axle.
22. Pick up nut B.
23. Screw nut B onto axle.
24. Pick up nut C.
25. Screw nut C onto axle.
26. Put brake in box.

# APPENDIX B

## Fishing Reel Task Analysis

1. Pick up body.
2. Pick up crank shaft.
3. Insert crank shaft in hole.
4. Pick up centre shaft.
5. Insert centre shaft in hole.
6. Move lower flap and give assembly to experimenter.
7. Receive assembly and move top flap.
8. Turn body over.
9. Pick up spool.
10. Put on spool.
11. Pick up spinner head.
12. Put on spinner head.
13. Pick up nut A.
14. Screw on nut A.
15. Turn body so crank handle is pointing up with spinner in palm.
16. Pick up back cover.
17. Turn so the hole is pointing up.
18. Put body into back cover with crank shaft pointing up.
19. Turn so spinner is pointing up.
20. Pick up front cover.
21. Screw front cover onto back cover.
22. Pick up crank handle.
23. Put crank handle onto crank shaft.
24. Pick up nut B.
25. Screw on nut B.
26. Put reel in box.

# APPENDIX C

## Man and Car Task Analyses

| Man | Car |
|---|---|
| 1. Pick up legs. | 1. Pick up chassis. |
| 2. Pick up body. | 2. Pick up block 1. |
| 3. Snap body on legs. | 3. Snap block 1 on chassis. |
| 4. Pick up arm 1. | 4. Pick up cab. |
| 5. Snap arm 1 on body. | 5. Snap cab on block 1. |
| 6. Pick up arm 2. | 6. Pick up block 2. |
| 7. Snap arm 2 on body. | 7. Snap block 2 on chassis. |
| 8. Pick up head. | 8. Pick up engine. |
| 9. Snap head on body. | 9. Snap engine on block 2. |

# APPENDIX D

## Light Alarm Task Analysis

### Chassis Assembly

1. Pick up battery block.
2. Pick up blank block.
3. Position 1 and 2.
4. Clip 1 and 2.
5. Pick up earphone block.
6. Position 5.
7. Clip 5.
8. Pick up transistor block.
9. Position 8.
10. Clip 8.
11. Pick up solar cell block.
12. Position solar cell block.
13. Clip solar cell block.
14. Pick up resistor block.
15. Position resistor block.
16. Clip resistor block.
17. Pick up transformer block.
18. Position transformer block.
19. Clip transformer block.
20. Clip transformer block.

### Wire Connections

21. Pick up wire 1.
22. Bend back spring for first connection, insert one end of wire and release.
23. Repeat 22 for other end of connection.

24-53. Repeat steps 21-23 for wire connections 2-11.

54. Pick up one earphone wire.
55. Bend back first earphone terminal, insert wire and release.
56. Pick up other earphone wire.
57. Repeat 55 for second earphone terminal.

# APPENDIX E

## Morse Key Task Analysis

### Chassis Assembly

1. Pick up key block.
2. Pick up transistor block.
3. Position 1 and 2.
4. Clip 1 and 2.
5. Pick up .01 MFD block.
6. Position 5.
7. Clip 5.
8. Pick up transformer block.
9. Position 8.
10. Clip 8.
11. Pick up earphone block.
12. Position earphone block.
13. Clip earphone block.
14. Pick up blank block.
15. Position blank block.
16. Clip blank block.
17. Pick up solar cell block.
18. Position solar cell block.
19. Clip solar cell block.
20. Clip solar cell block.

### Wire Connections

21. Pick up wire 1.
22. Bend back spring for first connection, insert one end of the wire and release.
23. Repeat 22 for other end of connection.

24-53. Repeat steps 21-23 for wire connections 2-11.

54. Pick up one earphone wire.
55. Bend back first earphone terminal.
56. Pick up other earphone wire.
57. Repeat 55 for second earphone terminal.