

THE UNIVERSITY OF MANITOBA

COMPARISONS OF MODIFIED FORWARD CHAINING
AND TOTAL TASK PRESENTATION FORMATS
TO TEACH VOCATIONAL SKILLS TO THE RETARDED

by

Dickie C.T. Yu

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of Master of Arts

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COMPARISONS OF MODIFIED FORWARD CHAINING
AND TOTAL TASK PRESENTATION FORMATS
TO TEACH VOCATIONAL SKILLS TO THE RETARDED

BY

CHUNG TONG DICKIE YU

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the University of Manitoba in partial fulfillment of the requirements
of the degree of

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ABSTRACT

Three experiments were conducted, using a multi-element baseline design, to compare a modified forward chaining (MFC) procedure to total task presentation (TTP) procedure in teaching assembly tasks to retarded clients. The assembly tasks included a 13-part bicycle brake and a 13-part fishing reel for Experiment I; a 5-part Lego car and a 5-part Lego man for Experiment II; and two 20-part abstract Lego designs for Experiment III. Generally, MFC was found to be superior in training steps to initial step criterion and to the final task criterion with fewer steps contacted (steps that the subject was required to perform were counted as contacted a maximum of once per trial). The amount of time the subjects spent actually working with the tasks was also found to be less in MFC. However, the trainer required more time to apply the MFC procedure. This resulted in minimal differences between the procedures when total training time was considered. Overall, subjects had fewer errors in TTP and minimal differences were found in the work rate (speed) of the subjects in the two procedures. In addition, no apparent differences were revealed in the retention tests and no systematic interactions between the procedures and task complexity were noted across the three experiments. Finally, some implications of the present study were discussed and further modifications and examinations of training procedures were suggested.

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INTRODUCTION

Various training procedures such as forward chaining (FC), backward chaining (BC), and total task presentation (TTP) have been employed to teach the mentally handicapped to acquire self-care skills (Martin, England & England, 1971; Martin, Kehoe, Bird, Jensen & Darbyshire, 1971), and vocational skills (Gold, 1972, 1974, Note 1). Typically, these procedures involve breaking down a task into a number of smaller steps arranged in a sequence appropriate for the level of functioning of the client. In FC, the first step in the sequence is taught first; then the first two steps are linked together; then the first three steps; and so on until the end of the chain is reached. BC proceeds in a reverse order; that is, the last step is established first; then the last two steps are linked together; then the last three steps; and so on progressing backwards towards the beginning of the chain. In TTP, the client simply performs all the steps from the beginning to the end of the chain on each attempt.

Previous studies that compared training procedures have primarily used normal subjects and various verbal or non-motor tasks such as programmed materials in mathematics (Balson, 1971), poetry (Hartley & Woods, 1968), and the Markov prediction task (Naylor & Briggs, 1963). Findings were generally inconsistent and generalizations to the vocational training of the mentally handicapped were greatly limited. Blake and Williams (1969) compared FC, TTP, and a pure-part procedure (i.e., each step or component was taught in isolation and then they were combined) using retarded, normal, and superior subjects. The authors reported that the best performance occurred in the superior group, then the normal group, and then the retarded group. For all three groups, TTP was superior while the other two procedures did not differ. Although the level of functioning of the retarded subjects was not specified, it seemed that

they were quite high functioning judging from the nature of the task (paired-associate task using CVC trigrams as stimuli, and three digit numerals as responses). Nettelbeck and Kirby (1976) also compared FC, TTP, and pure-part procedures in teaching mildly retarded clients to thread an industrial sewing machine which consisted of 12 steps grouped together into four components. Both FC and pure-part procedures were found to be superior to TTP in errors and total training time. Some indications that FC was better than pure-part were present; however, the difference was not statistically significant. Furthermore, no difference was found in retention for all three groups. Weber (1978) compared FC and BC in teaching retarded clients to perform a simple assembly task. The task was a science kit which included some cranks and gears, with six parts in total. Results showed that BC was superior to FC in having fewer errors. Walls, Zane and Ellis (Note 3) also trained retarded clients on simple task assemblies using FC, BC, and TTP. The three assemblies, each consisting of six parts, were a meat gringer, a carburettor, and a bicycle brake. The two chaining procedures were found to have fewer errors than TTP, and BC was slightly superior to FC. However, the overall training time was similar among the training methods. It was suggested that the chaining procedures placed a restriction on the rate of acquisition in that the minimum possible trials were fewer for total task presentation.

A recent literature review on behavior modification in sheltered workshops (Martin & Pallotta-Cornick, 1979) indicated a lack of research in examining various training procedures in this area. Such research was suggested and viewed to be essential for the development and dissemination of a training technology. Following one of the suggestions by Martin

and Pallotta-Cornick, a study was conducted to compare FC and BC in teaching complex assembly tasks to retarded clients (Pallotta-Cornick, Martin, Suthons & Yu, Note 2). A 13-part bicycle brake and a 13-part fishing reel were used, and each task was broken down into 28 steps. Results were confounded by a task effect (i.e., the bicycle brake was easier to learn than the fishing reel). In spite of this, BC was found to have slightly fewer errors. Yu, Suthons, Pallotta-Cornick and Martin (Note 4) taught retarded clients the same tasks as in the previous study using FC and TTP. Regardless of the task being trained, the percentage of errors were twice as high in TTP than in FC, and subjects performed faster during training when the FC procedure was used. However, the total training time did not differ between the two procedures. These findings were similar to those reported by Walls et al. (Note 3). Yu et al. also noted that the FC format itself restricted the speed of acquisition in that the minimum possible trials (and steps contacted) to learn the task were greater than in TTP because subjects spent more time in repeating steps that were already learned.

Based on the findings reported by Yu et al., the present study compared TTP to a revised forward chaining procedure. It was presumed that by decreasing the amount of repetition of learned steps, and retaining the feature of teaching one step at a time, the effectiveness of the traditional FC procedure might be improved.

EXPERIMENT I

Method

Subjects and Setting

Four mentally retarded clients from the Manitoba School for the Retarded served as subjects (see Table 1). Two of the subjects

Insert Table 1 about here

had some previous sheltered workshop experience which included mainly simple packaging tasks. None of the subjects had prior experience with the experimental tasks.

Sessions were conducted in a room measuring approximately 6 m X 6 m, located at the Manitoba School. To minimize distractions, the training area had two small areas separated from each other by partitions. The experimenter and the subject were seated side by side, with the task materials located on a table in front of them.

Task Materials

A three-speed bicycle brake and a spin-cast fishing reel were used as experimental tasks. These were essentially the same tasks used by Yu *et al.* (Note 4). Some particularly difficult steps in the fishing reel were identified in the previous study, and were modified and/or eliminated as a further attempt to equate the tasks in terms of difficulty.

In this study, each task consisted of 12 parts and was broken down into 26 steps (see Figures 1 and 2 for task analyses). A training tray

Insert Figures 1 and 2 about here

approximately 1.3 m long with 13 compartments was used to hold the parts

Table 1

Description of Subjects for Experiments I, II, and III

Subject	Sex	Age	I.Q. (test)	Level of Retardation	Diagnosis	Workshop Experience	Years of Institutionalization
<u>Experiments I and II</u>							
S ₁	F	12	40 (S-B)	moderate	Autism		5½
S ₂	F	22	MA: 2 yr 9 mo (S-B)	severe	Down's Syndrome	some	11
S ₃ *	F	24	MA: 3 yr 9 mo (S-B)	severe	Infection and intoxication toxemia of pregnancy and environmental influence	minimal	13
S ₄	F	20	MA: 2 yr 7 mo (S-B)	severe	Gargoylism with congenital lymphedema		8
<u>Experiment III</u>							
S ₅	F	20	41 (WAIS)	moderate	Unknown prenatal influence	some	8
S ₆	M	16	MA: 3 yr 0 mo (S-B)	severe	Chromosomal abnormality Down's Syndrome	some	8
S ₇ *	F	24	MA: 3 yr 9 mo (S-B)	severe	Infection and intoxication toxemia of pregnancy and environmental influence	minimal	13
S ₈	F	26	24 (S-B)	severe	Chromosomal abnormality Down's Syndrome	some	20

* Subject 3 also participated in Experiment III as Subject 7.

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

Figure 1. Task analysis for the bicycle brake.

1. Pick up the body assembly (with flaps already out).
2. Pick up the crank shaft.
3. Put crank shaft into body assembly through side opening.
4. Pick up center shaft.
5. Put center shaft into body assembly through center.
6. Move lower flap inside (experimenter takes assembly, locks in and returns to subject).
7. Move upper flap over center shaft.
8. Turn body assembly over with bottom facing up.
9. Pick up the spool.
10. Put the spool onto the body assembly.
11. Lock in the spool (with thumb on edge of spool and lifting lever with forefinger).
12. Pick up the spinner head
13. Put spinner head over spool onto the center shaft.
14. Pick up spinner head nut.
15. Screw spinner head nut onto center shaft.
16. Turn and hold body assembly by the edge such that spinner head faces into palm, with crank shaft pointing upwards.
17. Pick up back cover with open face away from palm and hole on the side facing upwards.
18. Put body assembly into the back cover (with crank shaft and drag going into the appropriate openings).
19. Turn the whole assembly such that the spinner head faces upwards (to avoid body assembly falling out of the back cover).
20. Pick up front cover with the larger opening facing away from palm.
21. Screw front cover onto back cover.
22. Pick up crank handle.
23. Put crank handle onto the crank shaft.
24. Pick up the crank nut.
25. Screw crank nut onto the crank shaft.
26. Put finished product into box.

Figure 2. Task analysis for the fishing reel.

during training. Each compartment had a cover so that only the parts currently being trained were displayed.

Experimental Design

A multi-element baseline design (Sidman, 1960; Ulman & Sulzer-Azaroff, 1975) with counterbalancing of tasks and training procedures across subjects was used (see Figure 3, Experiment I) for counterbalancing arrange-

 Insert Figure 3 about here

ments. The order in which the tasks were trained was randomly determined within each session day. Two sessions, one on each task, were conducted daily with each subject from Monday to Friday. All sessions were conducted by the same experimenter.

Modified Forward Chaining (MFC) Procedure

The modified forward chaining procedure proceeded in a forward fashion according to the natural order of the chain. First, step 1 was taught to step criterion (i.e., until the subject could perform the step correctly without help for two consecutive trials). Then step 2 was introduced on trials in which the subject was also required to perform step 1. The training of these two steps continued until step 2 reached criterion. Next, step 3 was introduced and the subject was then required to perform steps 2 and 3, and step 1 was dropped from the chain. After criterion was reached on step 3, step 2 was dropped and step 4 was introduced to link with step 3. This procedure continued until the end of the chain. After the last step of the sequence was learned, the subject was required to meet a task criterion, which was to perform the whole task correctly on three out of four consecutive trials, in order for the task to be con-

MFC - Modified forward chaining

TTP - Total task presentation

	<u>Experiment I</u>	<u>Experiment II</u>		<u>Experiment III</u>
<u>Subject 1</u>	MFC - brake TTP - reel	MFC - car TTP - man	<u>Subject 5</u>	MFC - blue/white (BW) design TTP - red/yellow (RY) design
<u>Subject 2</u>	MFC - brake TTP - reel	MFC - car TTP - man	<u>Subject 6</u>	MFC - BW design TTP - RY design
<u>Subject 3</u>	MFC - reel TTP - brake	MFC - man TTP - car	<u>Subject 7</u>	MFC - RY design TTP - BW design
<u>Subject 4</u>	MFC - reel TTP - brake	MFC - man TTP - car	<u>Subject 8</u>	MFC - RY design TTP - BW design

Figure 3. Multi-element baseline design with counterbalancing of tasks and procedures across subjects for Experiments I, II, and III.

sidered learned.

A general command such as "(Name), please make a bicycle brake. Do the next two steps," was given to initiate a training trial. Starting at the second session, a probe trial was given at the beginning of each session in which the subject was required to perform the task from the beginning up to the last step that had been learned to criterion. Figure 4 illustrates how this procedure proceeded differently from the traditional

Insert Figure 4 about here

FC and TTP procedures, assuming a 10-step response chain, imposing the step and task criteria in this study, and assuming perfect learning.

Total Task Presentation

TTP also proceeded in a forward fashion. As in MFC, a general command initiated each trial but the subject was required to perform the whole task from the first step to the last step (see Figure 4). The step and task criteria were the same as in MFC.

Prompting and Fading Procedures

All data collected during baseline and training in both procedures were scored according to the following codes which closely approximate those described by Martin, Murrell, Nicholson and Tallman (1975):

Level 4 - Subject performed a step correctly without
any help.

Level 3 - Subject performed a step correctly when given
one verbal instruction, e.g., "(Name), screw the
nut onto the axle."

Traditional Forward Chaining Procedure

		Trials																					
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	
Steps	1	R1	R1	R1	R1	R1	R1	R1	R1	R1	R1	R1	R1	R1	R1	R1	R1	R1	R1	R1	R1	R1	
	2			R2	R2	R2	R2	R2	R2	R2	R2	R2	R2	R2	R2	R2	R2	R2	R2	R2	R2	R2	
	3					R3	R3	R3	R3	R3	R3	R3	R3	R3	R3	R3	R3	R3	R3	R3	R3	R3	
	4							R4	R4	R4	R4	R4	R4	R4	R4	R4	R4	R4	R4	R4	R4	R4	
	5									R5	R5	R5	R5	R5	R5	R5	R5	R5	R5	R5	R5	R5	
	6											R6	R6	R6	R6	R6	R6	R6	R6	R6	R6	R6	
	7													R7	R7	R7	R7	R7	R7	R7	R7	R7	
	8																R8	R8	R8	R8	R8	R8	
	9																		R9	R9	R9	R9	R9
	10																				R10	R10	R10

Minimum number of steps contacted = 115

Modified Forward Chaining Procedure

		Trials																																
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23										
Steps	1	R1	R1	R1	R1																		R1	R1	R1									
	2			R2	R2	R2	R2																	R2	R2	R2								
	3					R3	R3	R3	R3																R3	R3	R3							
	4							R4	R4	R4	R4															R4	R4	R4						
	5									R5	R5	R5	R5														R5	R5	R5					
	6											R6	R6	R6	R6													R6	R6	R6				
	7														R7	R7	R7	R7											R7	R7	R7			
	8																R8	R8	R8	R8										R8	R8	R8		
	9																			R9	R9	R9	R9	R9	R9	R9	R9	R9	R9	R9	R9			
	10																														R10	R10	R10	R10

Minimum number of steps contacted = 68

Total Task Presentation

		Trials		
		1	2	3
Steps	1	R1	R1	R1
	2	R2	R2	R2
	3	R3	R3	R3
	4	R4	R4	R4
	5	R5	R5	R5
	6	R6	R6	R6
	7	R7	R7	R7
	8	R8	R8	R8
	9	R9	R9	R9
	10	R10	R10	R10

Minimum number of steps contacted = 30

Figure 4. Illustrations of the traditional forward chaining procedure, the modified forward chaining procedure and total task presentation for a 10-step response chain, assuming perfect learning and imposing the step and task criteria of this study.

Level 2 - Subject performed a step correctly when given instruction plus extra verbal and/or gestural prompts, e.g., "(Name), screw the nut on the axle. Turn like this," while modelling turning motion with hand.

Level 1 - Subject performed a step correctly only after physical guidance was given.

For each step being trained, the subject was always given an opportunity to perform at Level 4. The experimenter would record a 4 if the step was performed correctly at this level; if not, Level 3 prompting was given. The subject would score a 3 if the step was performed correctly; if not, Level 2 prompting was given, and so on. The subject was allowed 10-15 seconds to initiate responding after the general command was given, or after the completion of the previous step, or after a level of prompting had been given. If the subject did not respond, made an error, or engaged in non-productive behavior, the experimenter would provide the next lower level of prompting. A step was considered learned if the subject scored a 4 on two consecutive trials (step criterion).

A non-specific prompt such as, "What's next?" or "Carry on," was given for a step that had reached step criterion if the subject was distracted or engaged in non-productive behavior (e.g., playing with the task materials) for about 10 seconds. If the subject resumed work and performed correctly, a 4 would still be scored; if not, necessary prompts would be provided and the level was recorded.

Incorrect performance of a step that had reached step criterion was corrected immediately by the experimenter by providing the necessary prompts. Any score less than 4 after a step reached criterion was consid-

ered to be an error.

Interobserver Reliability

Reliability checks were taken by a trained observer who sat at the end of the table, and recorded the level of help provided by the experimenter for each step. Interobserver reliability was calculated by dividing the number of agreements by the number of agreements plus disagreements and multiplying by 100. The experimenter's data were always used for data analysis. Reliability results are presented in Table 2 (Experiment I).

 Insert Table 2 about here

Consequence Management

For both training procedures, verbal approval (such as "good", "well done", etc.) was contingent on the subject's performing a step at a level that was equal to or better than the best of his/her previous performance, until that level reached criterion (i.e., performed at the same level for two consecutive trials). No consequence was applied if the subject continued to perform at the same level for more than two trials or if the subject regressed to a lower level. Therefore, social approval occurred only at the end of the trial in the MFC procedure because only the last step was being trained. However, in TTP, social approval could occur during a trial for the steps that were still being trained (i.e., had not reached criterion).

Edible reinforcers consisted of a variety of food and drinks such as smarties, peanuts, raisons, fruit juice and coke (given in small cups). The subject was allowed to choose one item at the end of each trial

Table 2

Interobserver Reliability Results for Experiments I, II, and III

	Subject	Procedure-Task	Number of Sessions With Reliability Checks	Mean IOR (%)	Range
Experiment I	S ₁	MFC - brake	1 out of 7	98	98
		TTP - reel	1 out of 10	100	100
	S ₂	MFC - brake	1 out of 8	87.8	87.8
		TTP - reel	1 out of 15	92.3	92.3
	S ₃	MFC - reel	1 out of 8	97	97
		TTP - brake	1 out of 8	98.7	98.7
	S ₄	MFC - reel	1 out of 16	84.6	84.6
		TTP - brake	1 out of 15	94.2	94.2
Experiment II	S ₁	MFC - car	-	-	-
		TTP - man	-	-	-
	S ₂	MFC - car	2 out of 3	98.4	96.8-100
		TTP - man	-	-	-
	S ₃	MFC - man	-	-	-
		TTP - car	1 out of 2	97.2	97.2
	S ₄	MFC - man	1 out of 5	100	100
		TTP - car	1 out of 8	96.3	96.3
Experiment III	S ₅	MFC - BW design	1 out of 8	97.4	97.4
		TTP - RY design	1 out of 10	95	95
	S ₆	MFC - BW design	7 out of 33	98.2	95-100
		TTP - RY design	8 out of 37	98.5	95-100
	S ₇	MFC - RY design	6 out of 30	97.1	92.5-100
		TTP - BW design	6 out of 30	98	92.3-100
	S ₈	MFC - RY design	6 out of 39	98.7	98-100
		TTP - BW design	5 out of 44	94.6	83-100

only if the last step was performed correctly at the appropriate level.

Baseline Procedures

Two baselines were taken for each subject on each task. The first baseline simply tested whether the subject could assemble the whole task. All necessary items to complete a task were placed appropriately in the training tray, which was then presented to the subject. Then the experimenter gave a general command, such as, "(Name), please make a bicycle brake. Do all you can. Make one like this," while showing a completed product. The subject was allowed one minute to initiate responding. If the subject responded within a minute, the experimenter recorded the steps performed until all parts were used up or until the subject stopped responding for one minute.

The second baseline tested the subject's level of performance at each step in random order. For example, testing step 7 in the bicycle brake task, the experimenter assembled the first 6 steps and tested step 7 alone. The level at which the subject performed that step was determined by using the prompting procedure described earlier.

No consequences were applied for baseline performance. Social approval and edibles were given about every five minutes contingent upon the performance of an alternate response, such as asking the subject to put his/her hand on his/her head.

Dependent Variables

Time on task (TOT). TOT was measured during each trial using a stop watch and was defined as the time from the general command at the beginning of each trial to the end of the trial upon completion of the last step. A session ended after the completion of a trial when the cumulative TOT was as close as possible to 15 minutes.

Total session time (TST). TST was measured for each session with a second stop watch. This was defined as the time from the general command for the first trial of each session to the time when reinforcement was dispensed at the end of the session.

Total number of steps contacted to task criterion. Steps that the subject was required to perform on a trial were counted as contacted a maximum of once each per trial. This dependent variable included the total number of steps contacted from the beginning of training until the task criterion was reached.

Total number of steps contacted to initial step criterion. This was defined as the total number of steps contacted for all steps to reach the initial step criterion.

Steps contacted per minute. This was calculated by dividing the total number of steps contacted to task criterion by the total TOT.

Total number of errors. Incorrect performance (any score less than 4) after a step reached step criterion was considered to be an error.

Retention

Six months after training was completed, each subject was asked to perform the tasks three times. Errors were corrected as they occurred, and were tabulated as the dependent measure.

Results

None of the subjects were able to assemble the whole task prior to training. Baseline scores for individual steps were summed for each task. The highest score that could be obtained was 78 (perfect score). For the bicycle brake and fishing reel tasks, respectively, the scores were: 48 and 40 for Subject 1; 50 and 44 for Subject 2; 45 and 34 for Subject 3; and 25 and 42 for Subject 4.

In spite of the further equating of the two tasks in terms of difficulty, regardless of training procedures, all subjects required more time to learn the fishing reel task (see Figure 5), implying that the fishing

Insert Figure 5 about here

reel was still more difficult to learn than the brake. This task effect confounded the procedural effect and produced inconsistent results among the subjects when the tasks were counterbalanced with training procedures.

However, the average TOT for MFC was slightly less than TTP, while the average TST was the same. The difference between TOT and TST (shaded area in Figure 5) indicated the amount of time spent by the trainer in performing necessary activities (which included rearranging task materials in between trials, some data recording, and reinforcement time), and was consistently greater in MFC than in TTP.

Figure 6 shows the total number of steps contacted to step and task

Insert Figure 6 about here

criteria. Three out of four subjects (Subjects 1, 2 and 4) had fewer steps contacted to task criterion when taught by MFC. Also, three out of four subjects (Subjects 1, 2 and 3) required fewer steps contacted to reach initial step criterion in MFC. The group average favored MFC both in terms of the total number of steps contacted to initial step criterion and the total number of steps contacted to task criterion.

Figure 7 shows the total number of steps contacted per minute for

Insert Figure 7 about here

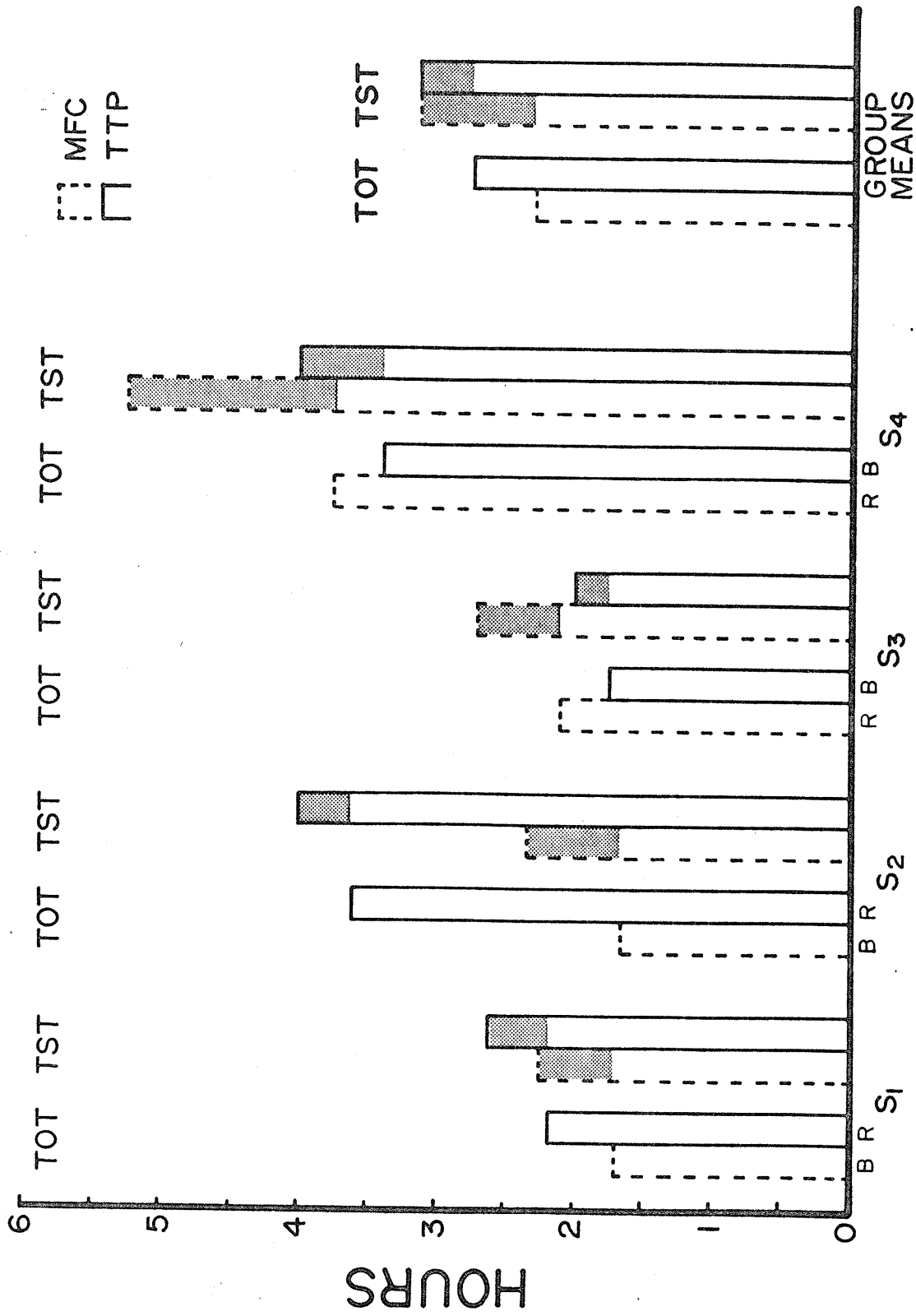


Figure 5. Total time on task (TOT) and total session time (TST) for each subject and the group means for all subjects to reach task criterion on the bicycle brake (B) and the fishing reel (R).

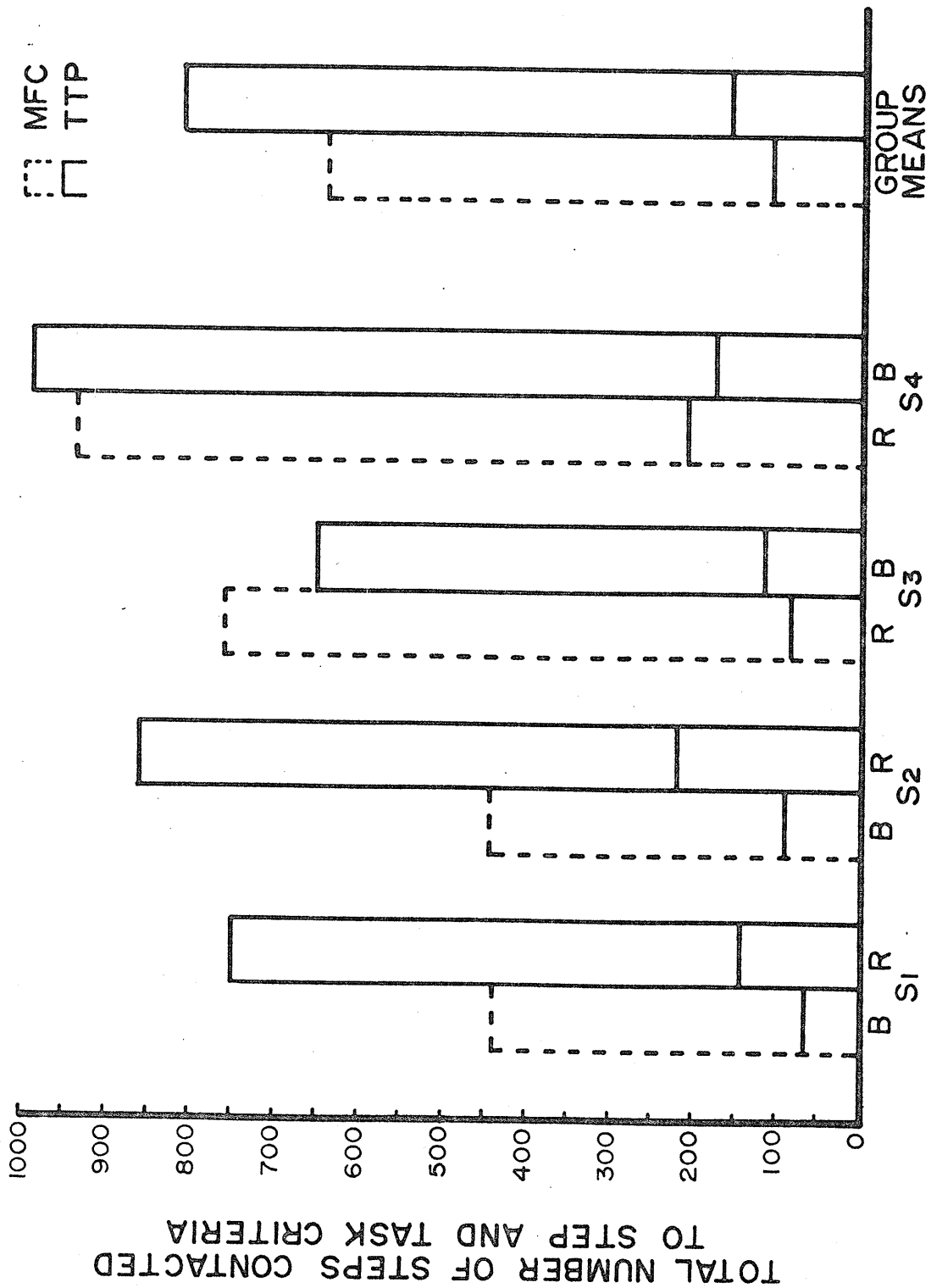


Figure 6. Total number of steps contacted for each subject and the group means for all subjects to reach task criterion (height of bar) and step criterion (indicated by horizontal line within each bar) on the brake (B) and the reel (R).

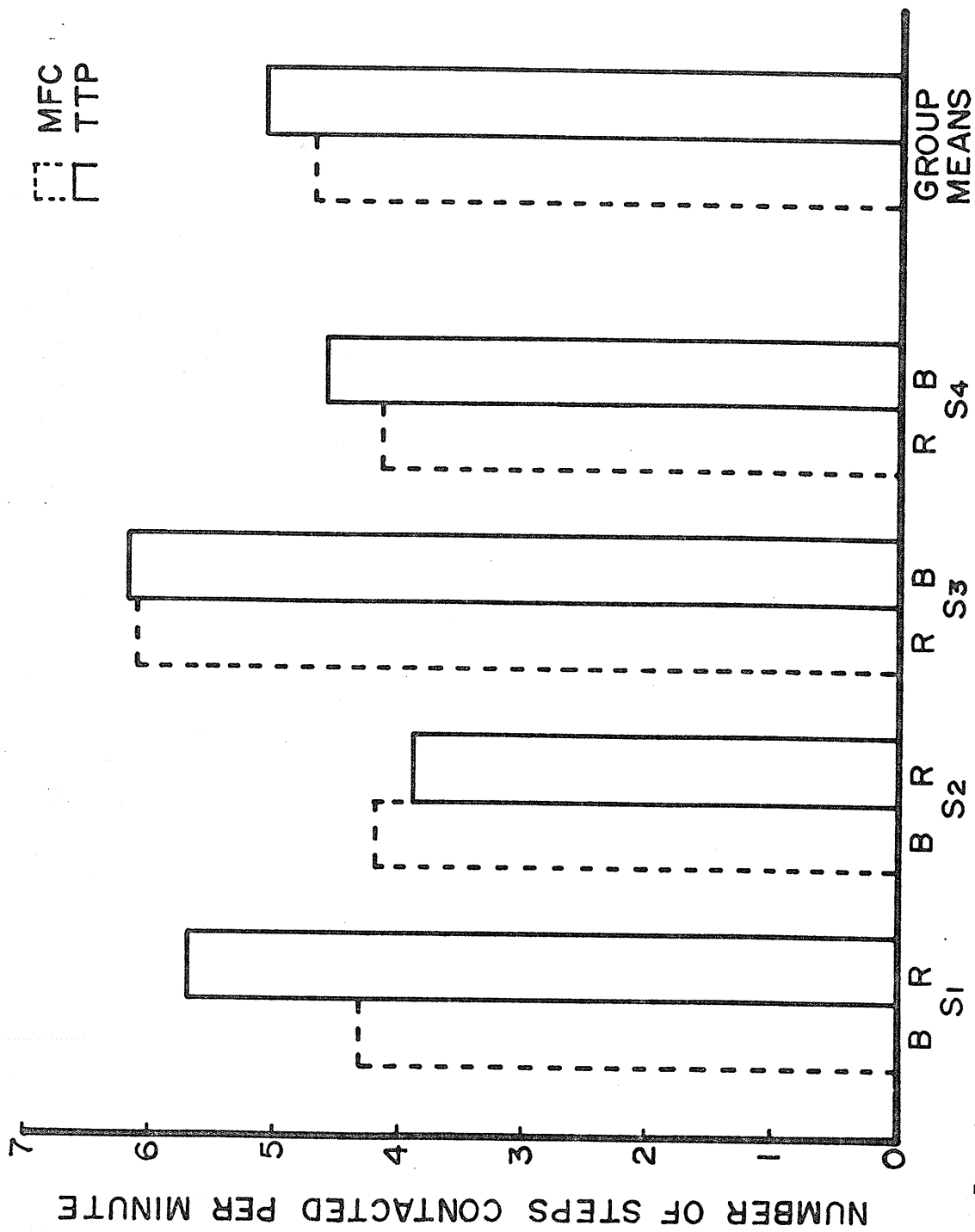


Figure 7. The average number of steps contacted per minute for each subject and the group means for all subjects on the brake (B) and the reel (R).

each subject and the group mean for each procedure. The difference within each subject was relatively small, within two steps per minute, favoring MFC only in Subject 2. The group means showed a slight advantage for TTP.

The total number of errors are shown in Figure 8. Small differences

Insert Figure 8 about here

were found in three of the subjects. The exception was Subject 3 who had considerably more errors in MFC. The group means slightly favored TTP.

Figure 9 shows Subject 1's data presented cumulatively for each step

Insert Figure 9 about here

on the number of steps contacted to initial step criterion, the number of steps contacted to task criterion, and the number of errors made during training. The steady slopes of the curves are representative for all subjects.

The total number of errors for the retention test are presented in Table 3 (Experiment I). As can be seen in the table, the task effect was

Insert Table 3 about here

apparent. Regardless of training procedures, subjects made more errors on the fishing reel task (i.e., the more difficult task) than the bicycle brake.

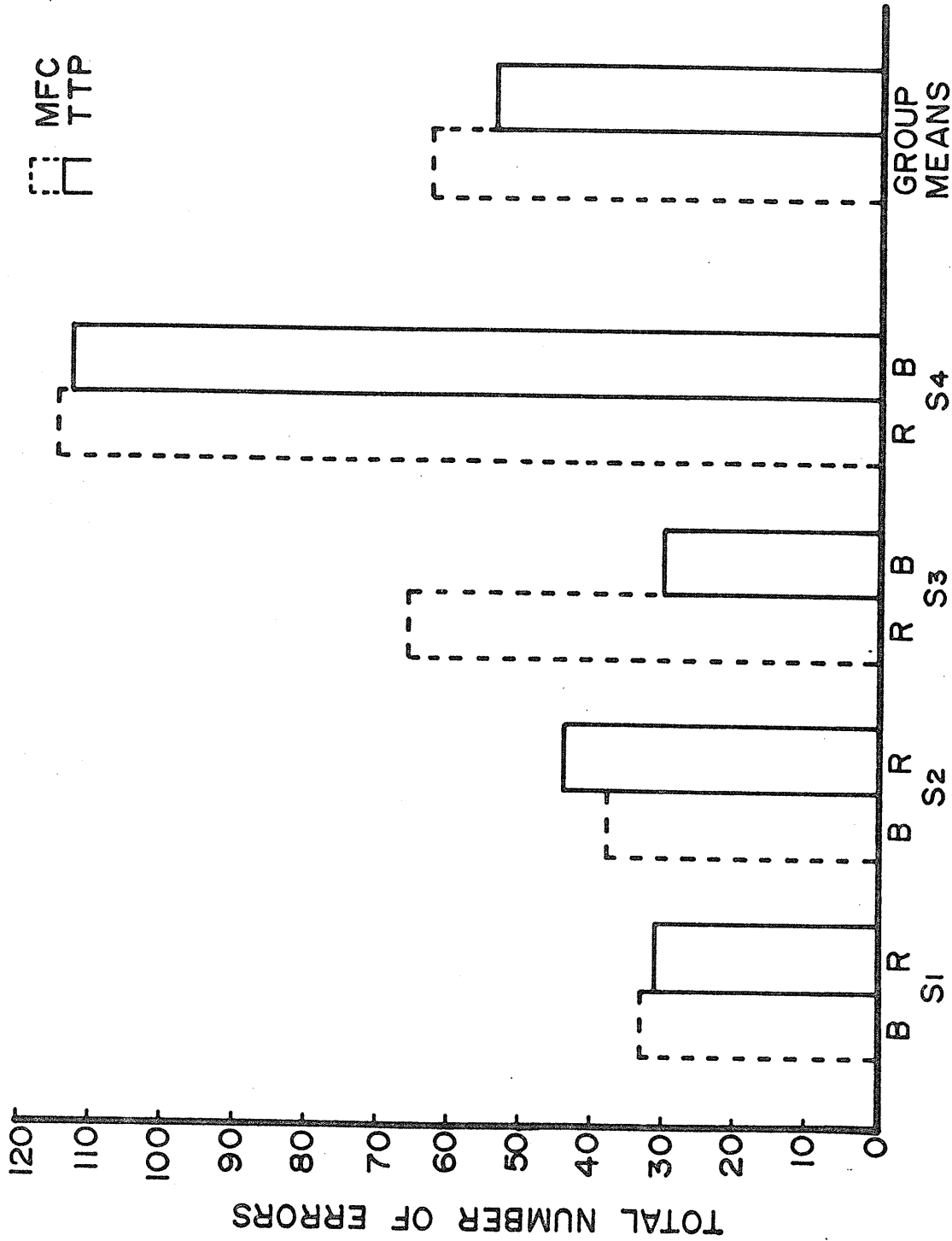


Figure 8. Total number of errors for each subject and the group means for all subjects to reach task criterion on the brake (B) and the reel (R).

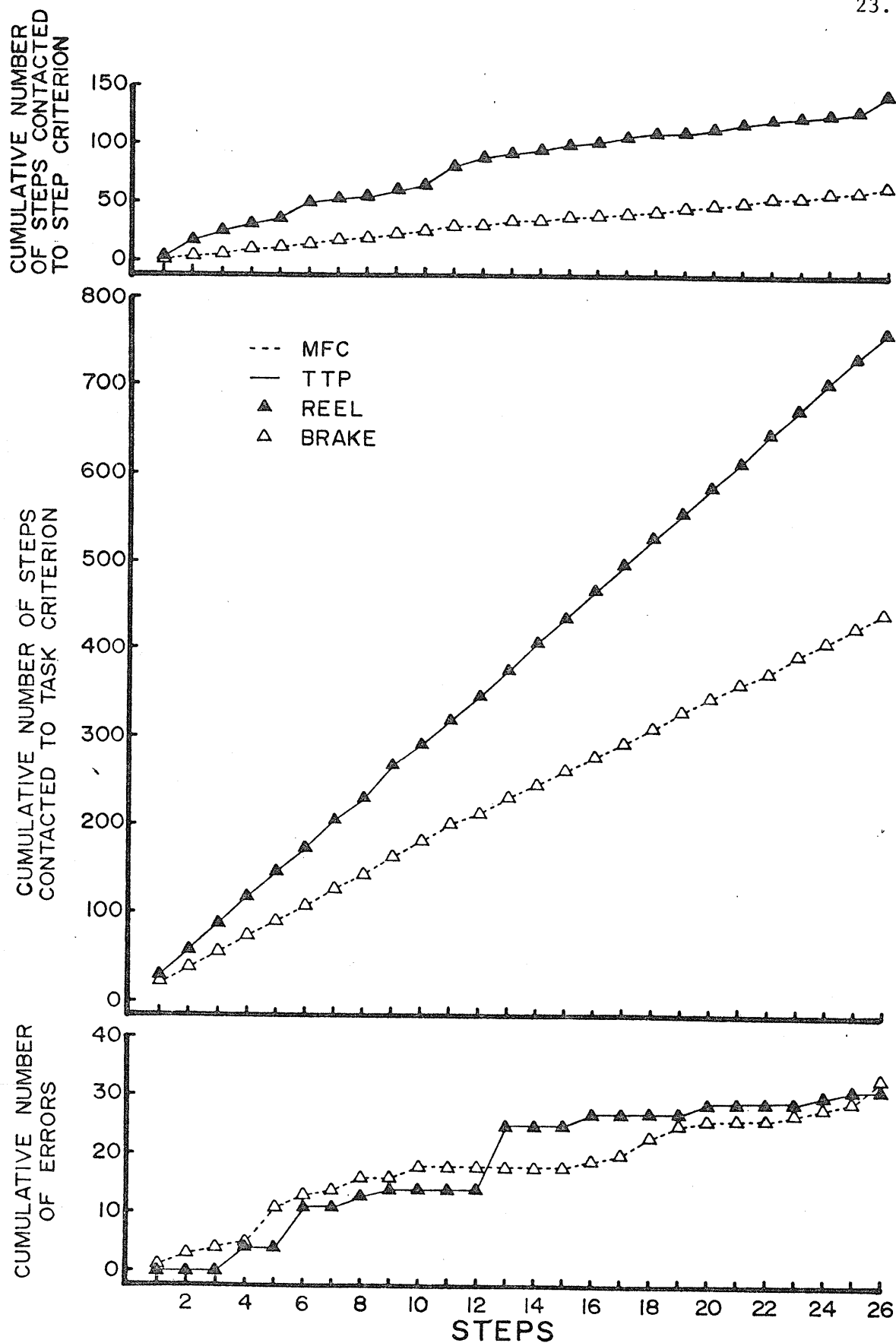


Figure 9. Cumulative presentation of Subject 1's data on the number of steps contacted to step criterion, the number of steps contacted to task criterion, and the number of errors. The steady slopes are representative for all subjects.

Table 3

Total Number of Errors Made During Retention

For Experiments I, II, and III

	Subject	Procedure-Task	Errors
Experiment I (Retention period - 6 mo)	S ₁ *	MFC - brake	-
		TTP - reel	-
	S ₂	MFC - brake	14
		TTP - reel	23
	S ₃	MFC - reel	17
		MFC - brake	15
	S ₄	MFC - reel	25
		TTP - brake	13
Experiment II (Retention period - 6 mo)	S ₁	MFC - car	1
		TTP - man	0
	S ₂	MFC - car	6
		TTP - man	7
	S ₃	MFC - man	4
		TTP - car	4
	S ₄	MFC - man	12
		TTP - car	7
Experiment III (Retention period - 3 mo)	S ₅	MFC - BW design	7
		TTP - RY design	7
	S ₆	MFC - BW design	14
		TTP - RY design	11
	S ₇	MFC - RY design	32
		TTP - BW design	33
	S ₈	MFC - RY design	15
		TTP - BW design	12

*Subject 1 was not available for retention tests on the brake and reel.

EXPERIMENT II

Due to the inconclusive findings in Experiment I and in order to assess whether there is any interaction between procedure and task complexity, Experiment II was conducted using simpler tasks. Some minor changes were made and are noted in the following section.

Method

Subjects and Setting

The same subjects were used for this experiment (see Table 1) and none of them had prior experience with the experimental tasks.

Sessions were conducted in a room measuring 6 m by 10 m, and located at the Manitoba School. There was no other activity in the same room. The experimenter and the subject were seated as in Experiment I.

Task Materials

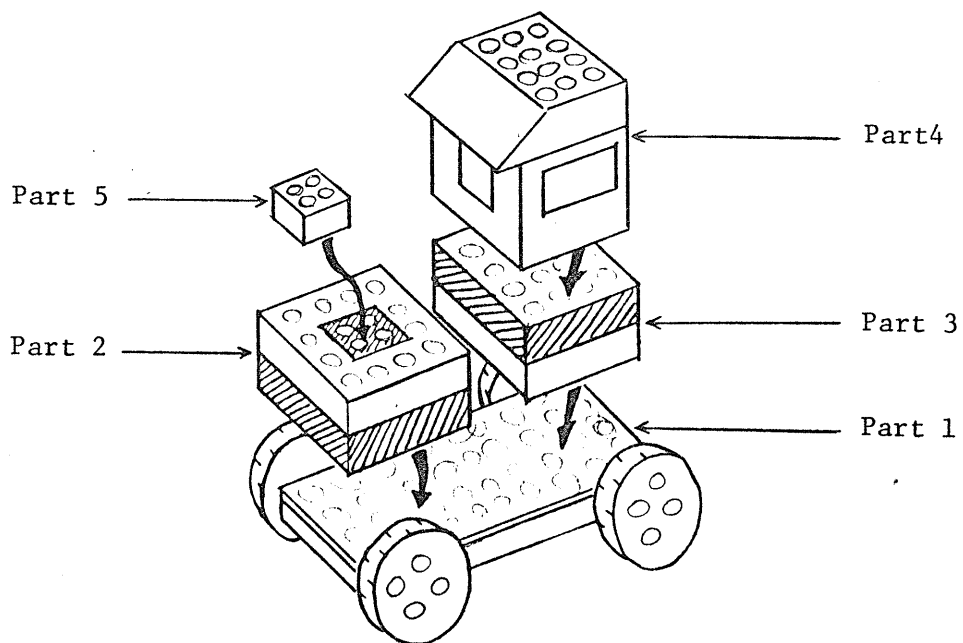
The experimental tasks were a "car" and a "man" constructed with Lego blocks. By using Lego blocks, it was hoped that task effect could be minimized because the task complexity could be manipulated more easily. Also, the movements of each response were similar in both tasks. Each task consisted of five parts and was broken down into nine steps (see Figures 10 and 11 for schematic representations and task analyses). The same

Insert Figures 10 and 11 about here

training tray was used with all but five compartments covered.

Experimental Design

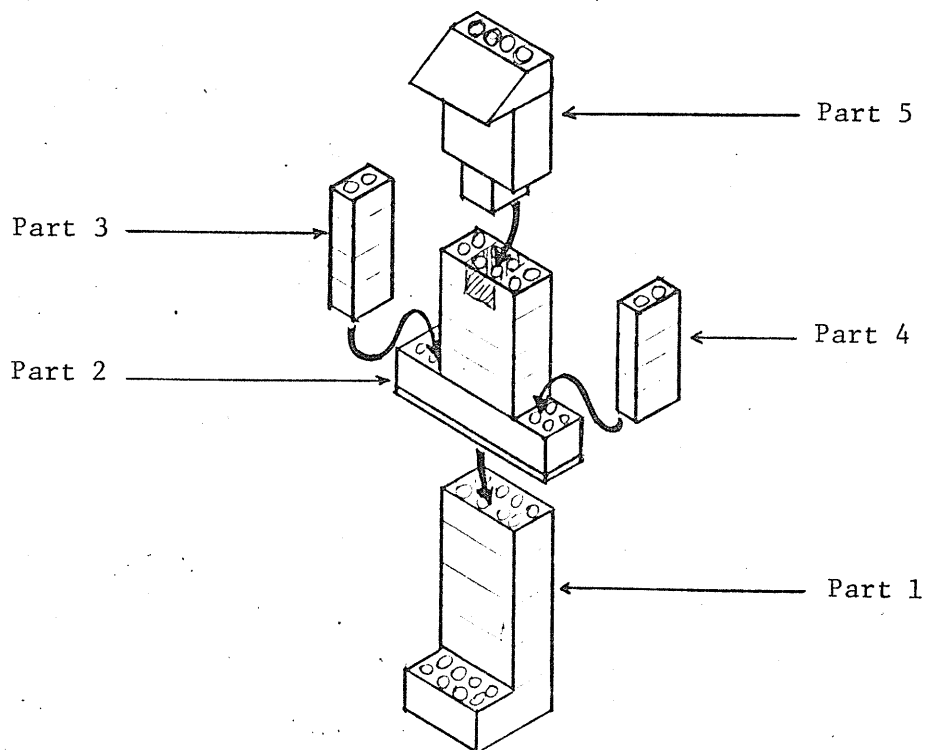
The multi-element baseline design was also used for Experiment II.



Task analysis:

1. Pick up part 1.
2. Pick up part 2.
3. Attach part 2 onto either end of part 1.
4. Pick up part 3.
5. Attach part 3 onto the remaining end of part 1.
6. Pick up part 4.
7. Attach part 4 onto part 3.
8. Pick up part 5.
9. Attach part 5 onto the center of part 2.

Figure 10. Schematic representation and task analysis of the Lego car.



Task analysis:

1. Pick up part 1.
2. Pick up part 2.
3. Attach part 2 onto part 1.
4. Pick up part 3.
5. Attach part 3 onto either side of part 2.
6. Pick up part 4.
7. Attach part 4 onto the remaining side of part 2.
8. Pick up part 5.
9. Attach part 5 onto the center of part 2.

Figure 11. Schematic representation and task analysis of the Lego man.

[see Figure 3 (Experiment II)]:

Modified Forward Chaining and Total Task Presentation

Both procedures were the same as in Experiment I.

Prompting and Fading Procedures

These procedures were the same as in Experiment I.

Interobserver Reliability

The reliability assessment procedure was the same as in Experiment I and the results are presented in Table 2 (Experiment II).

Consequence Management

Consequence management procedures were the same as in Experiment I.

Baseline Procedure

Each subject was tested on task assembly using the first baseline procedure of Experiment I. The second baseline measure of Experiment I, in which each step was individually tested, was not taken for Experiment II in order to avoid possible learning effects during baseline due to the simplicity of the tasks.

Dependent Variables

The six dependent measures of Experiment I were also taken in this experiment.

Retention

A retention test was conducted six months after the completion of training. The procedures and dependent measure were the same as in the previous experiment.

Results

None of the subjects could assemble the whole task during baseline. Figure 12 shows the TOT and TST required to learn the tasks to criterion.

Insert Figure 12 about here

Once more, a task effect was present; the car was more difficult to learn than the man. Regardless of procedures, the man required less time to learn. This resulted in the reversal of effects when the tasks were counterbalanced across subjects. The difference between TOT and TST (shaded area in Figure 12) was proportionally greater in MFC for all subjects with the exception of Subject 4. The average TOT and TST across subjects showed almost no difference between the two procedures.

A greater number of steps were contacted in learning the car (i.e., the more difficult task) to task criterion. This occurred in all subjects regardless of training procedures (see Figure 13). However, three of the

Insert Figure 13 about here

subjects (Subjects 2, 3, and 4) learned all steps to initial step criterion with fewer steps contacted in MFC, while Subject 1 showed no differences (indicated by the horizontal line within each bar in Figure 13). The group average favored MFC slightly both in terms of the number of steps contacted to reach initial step criterion, and the task criterion.

Figure 14 shows Subject 2's data presented cumulatively for each

Insert Figure 14 about here

step on the number of steps contacted to initial step criterion, and the number of steps contacted to task criterion. The steady slopes of the

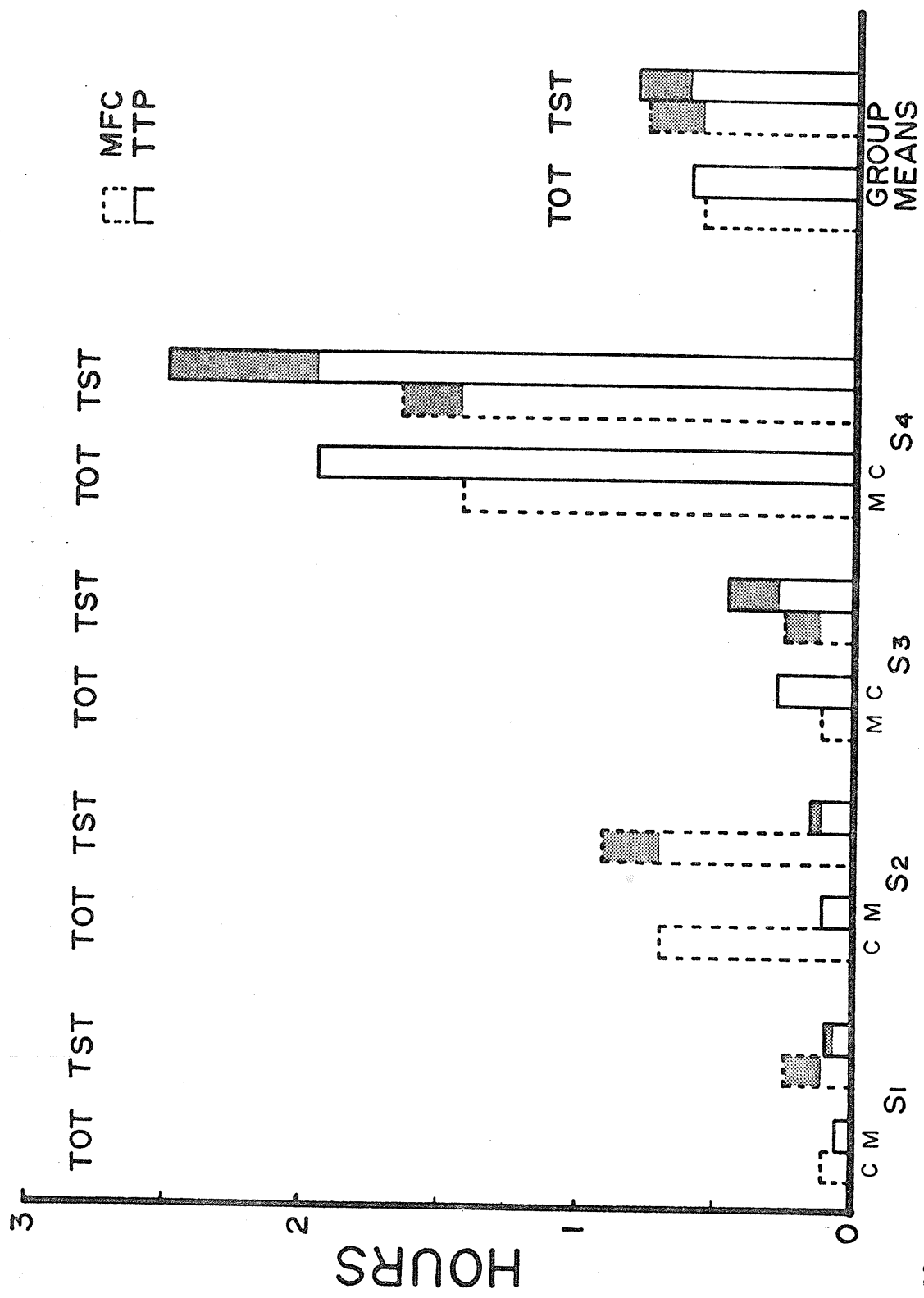


Figure 12. Total time on task (TOT) and total session time (TST) for each subject and the group means for all subjects to reach task criterion on the Lego car (C) and the Lego man (M).

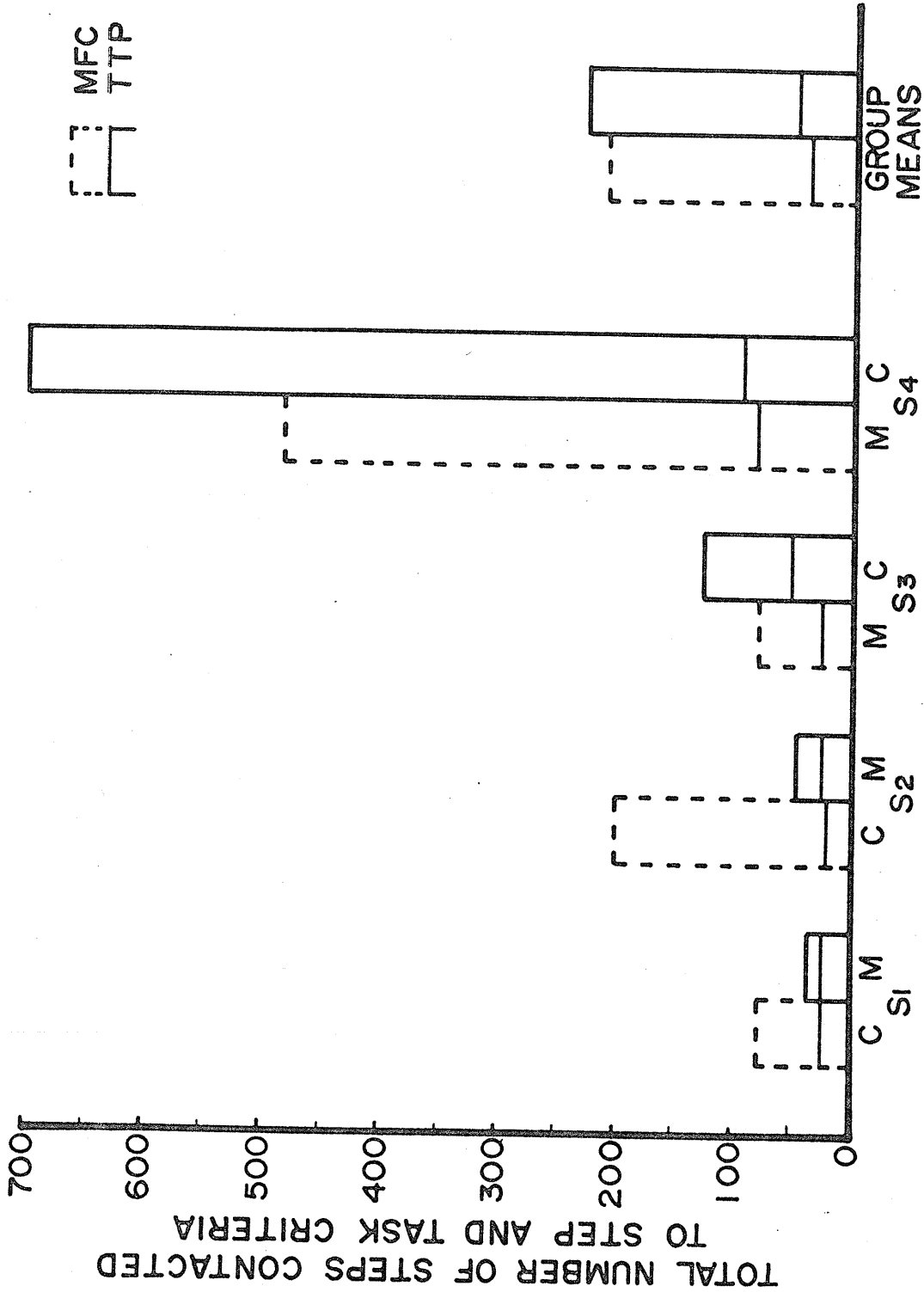


Figure 13. Total number of steps contacted for each subject and the group means for all subjects to reach task criterion (height of bar) and step criterion (indicated by horizontal line within each bar) on the Lego car (C) and the Lego man (M).

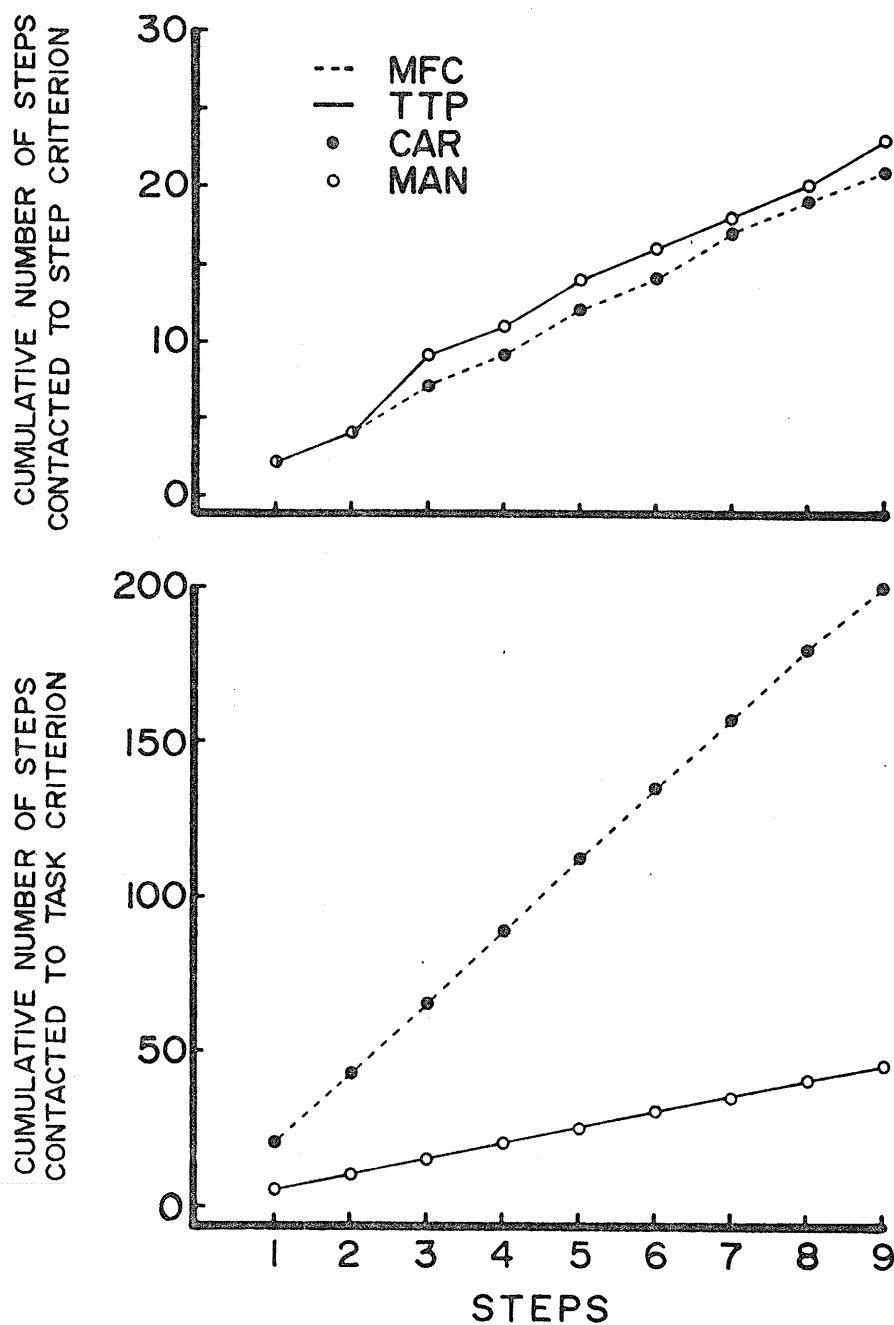


Figure 14. Cumulative presentation of Subject 2's data for each step on the number of steps contacted to step criterion, the number of steps contacted to task criterion. The steady slopes are representative for all subjects.

curves are representative for all subjects.

Figure 15 shows the average number of steps contacted per minute.

Insert Figure 15 about here

As can be seen in the figure, the task effect was also apparent. All subjects contacted fewer steps per minute in learning to assemble the car. A small difference of less than one step contacted per minute was reflected by the group averages favoring TTP.

The cumulative number of errors incurred during training for each subject, and the group means across all subjects are shown in Figure 16.

Insert Figure 16 about here

When the car (i.e., the more difficult task) was taught by MFC and the man by TTP, more errors occurred in MFC while no errors occurred with TTP. When the tasks were counterbalanced for Subjects 3 and 4, approximately the same number of errors were made in the two procedures. The group averages also showed a slight advantage for TTP.

The total number of errors made during retention are presented in Table 3 (Experiment II). No apparent differences were found between the two procedures.

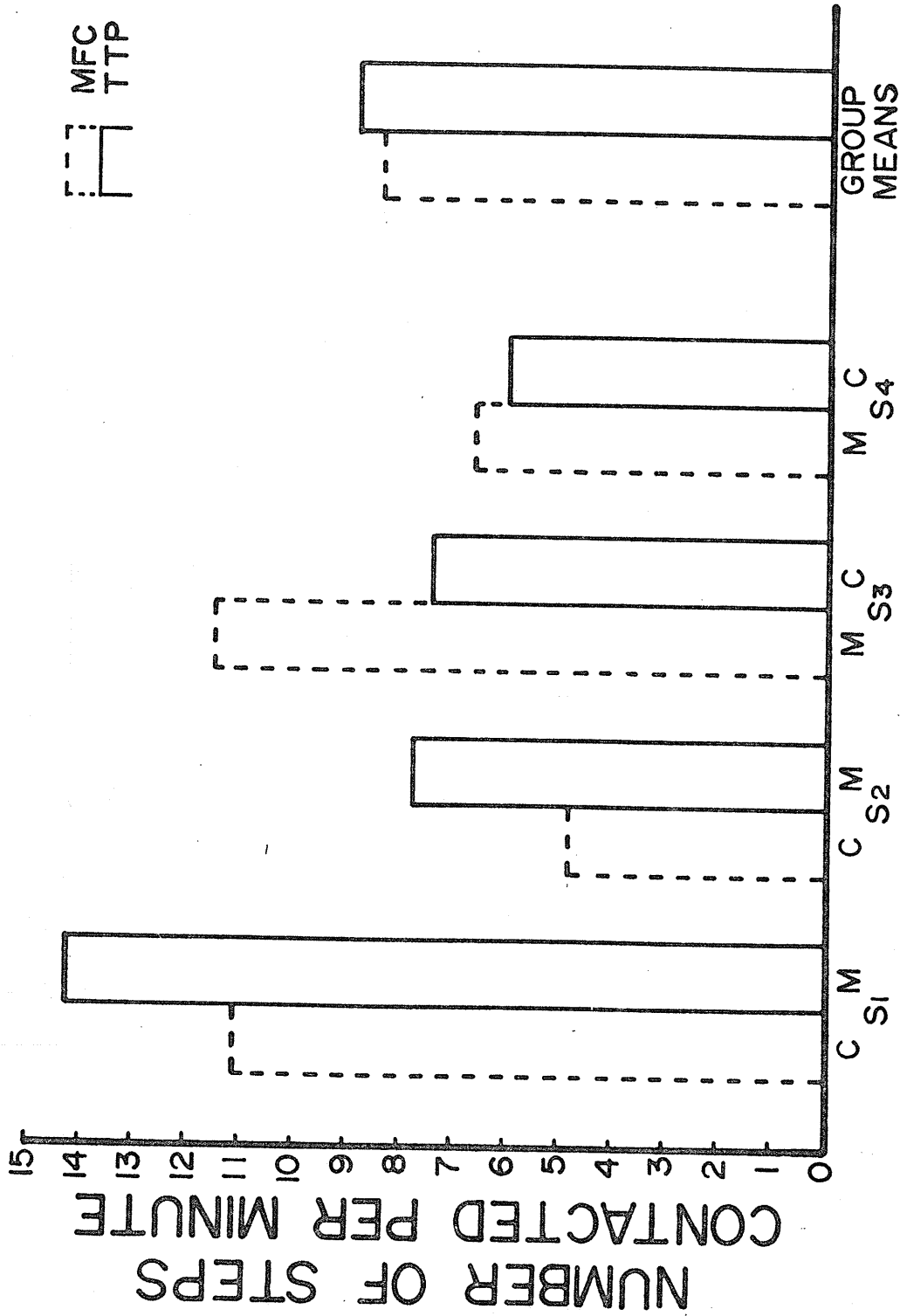


Figure 15. The average number of steps contacted per minute for each subject and the group means for all subjects on the Lego car (C) and the Lego man (M).

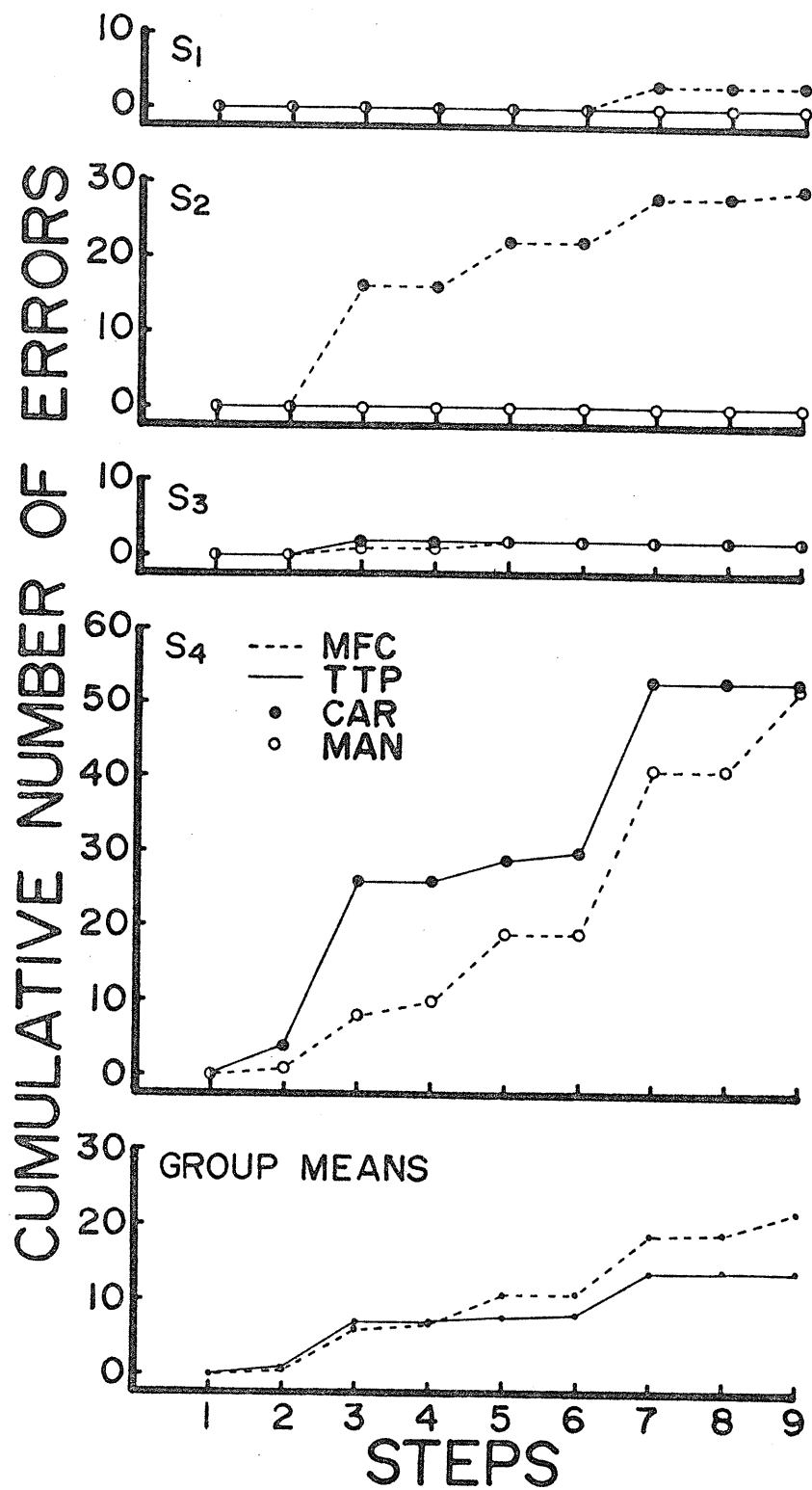


Figure 16. Cumulative number of errors for each subject and the group means for all subjects to reach task criterion on the Lego car (C) and the Lego man (M).

EXPERIMENT III

A third replication of Experiment I was conducted using more complex tasks (i.e., long, repetitive chains). Changes that were made are noted in the following section.

Method

Subjects and Setting

Only Subject 3 from the previous experiments continued to participate in Experiment III. Three new subjects were selected and all four subjects had no prior experience with the experimental tasks (see Table 1 for description of subjects). Sessions were conducted in the same setting as Experiment II.

Task Materials

The experimental tasks were two abstract designs constructed with Lego blocks. Each task consisted of a Lego base board, cut to 19 cm by 20 cm, to which Lego blocks could be attached. There were 20 Lego blocks in each task which consisted of eight pieces measuring 32 mm by 15 mm by 10 mm, seven pieces measuring 16 mm by 16 mm by 10 mm, four pieces measuring 16 mm by 8 mm by 10 mm, and one piece measuring 24 mm by 16 mm by 10 mm. The subjects were to attach the blocks one by one to the base board following a pre-specified sequence. The position of each block was cued by one or two white dots, painted on the base board, depending on the size of the block. One design was made up of blue and white blocks, and the other of red and yellow blocks. The color alternated from one block to the next within each design. Figure 17 shows the schematic represen-

Insert Figure 17 about here

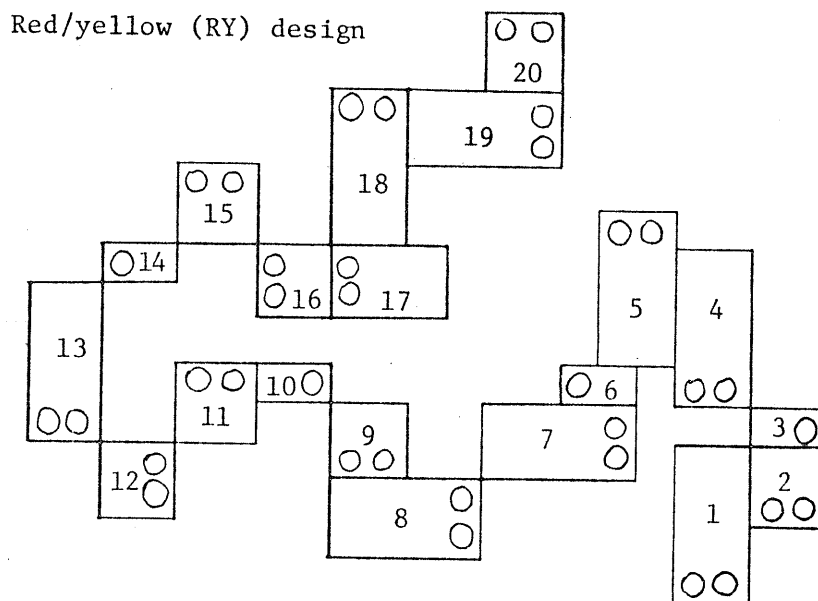
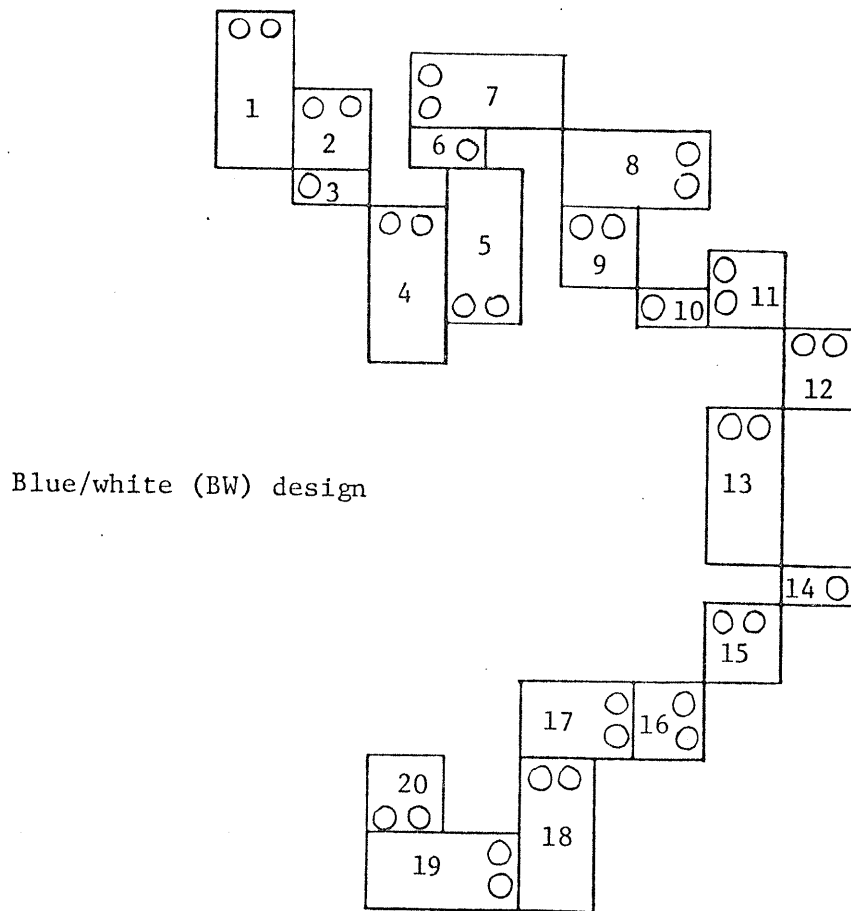


Figure 17. Schematic representation of the blue/white design and the red/yellow design. The circles represent white dots painted on the base board.

tations of the two designs. Each task was broken down into 40 steps and a task analysis is shown in Figure 18. Since the steps in both tasks

Insert Figure 18 about here

were identical except for the positioning of the blocks, the steps are listed for only one task.

No training tray was used in this experiment. The blocks were arranged from left to right in the correct sequence in front of the subject.

Experimental Design

The experimental design was the same as in the previous experiments [see Figure 3 (Experiment III)].

Modified Froward Chaining and Total Task Presentation

Both procedures were the same as in the previous experiments, except that all parts were exposed throughout training.

Prompting and Fading Procedures

The procedures were the same as in previous experiments with the exceptions of Subjects 7 and 8. Half-way through the experiment, these subjects became very dependent on the prompts in that they continued to perform at either Level 2 or 3 on many of the steps. Thus, the usual time limit (10 to 15 seconds) was decreased to about two or three seconds. Furthermore, if the subject did not initiate responding within that period, physical guidance (Level 1) with no verbal prompts was given to perform that step. This was done to minimize the possible reinforcing effects of prompting. Physical guidance was faded out as the subject began to initiate responding within the brief time limit. These changes were implemented in both training procedures after the same number of sessions.

1. Pick up block 1.
2. Attach block 1 to the correct position.
3. Pick up block 2.
4. Attach block 2 to the correct position.
5. Pick up block 3.
6. Attach block 3 to the correct position.
7. Pick up block 4.
8. Attach block 4 to the correct position.
9. Pick up block 5.
10. Attach block 5 to the correct position.
11. Pick up block 6.
12. Attach block 6 to the correct position.
13. Pick up block 7.
14. Attach block 7 to the correct position.
15. Pick up block 8.
16. Attach block 8 to the correct position.
17. Pick up block 9.
18. Attach block 9 to the correct position.
19. Pick up block 10.
20. Attach block 10 to the correct position.
21. Pick up block 11.
22. Attach block 11 to the correct position.
23. Pick up block 12.
24. Attach block 12 to the correct position.
25. Pick up block 13.
26. Attach block 13 to the correct position.
27. Pick up block 14.
28. Attach block 14 to the correct position.
29. Pick up block 15.
30. Attach block 15 to the correct position.
31. Pick up block 16.
32. Attach block 16 to the correct position.
33. Pick up block 17.
34. Attach block 17 to the correct position.
35. Pick up block 18.
36. Attach block 18 to the correct position.
37. Pick up block 19.
38. Attach block 19 to the correct position.
39. Pick up block 20.
40. Attach block 20 to the correct position.

Figure 18. Task analysis for the blue/white and red/yellow designs.

Interobserver Reliability

The reliability assessment procedure was the same as in the previous experiments and results are presented in Table 2 (Experiment III).

Consequence Management

Consequence management procedures were the same as in the previous experiments with one exception. In the previous experiments, the subject did not receive social approval for correct performance of a step after it had reached step criterion. In the present experiment, due to the length of the chain and the number of trials required to reach task criterion after all steps reached step criterion, two or three brief instances of verbal approval were given randomly during a trial for correct performance of steps that were already at step criterion. These were faded out as errors decreased until task criterion was reached.

Baseline Procedure

Since the whole sequence of the parts could be seen from the completed product, a match-to-sample baseline was taken. An alternate Lego design was used for baseline to avoid possible learning effects. The alternate design was constructed with 25 Lego blocks which formed the shape of a guitar. The subject was presented with the base board and the necessary blocks arranged in sequence in front of him/her. A completed design of the task was also shown in front of the subject throughout baseline. The subject was given a general command to attach the blocks to the base board matching the completed design presented. One minute was allowed for the subject to initiate responding. If the subject responded within a minute, the experimenter recorded the steps performed until all parts were used or until the subject stopped responding for one minute. It was assumed

that the subject could not perform the experimental task if they did not emit match-to-sample skills on the related baseline task.

Dependent Variables

The dependent variables were the same as in the previous experiments.

Retention

A retention test was conducted three months after the completion of training. The procedures and dependent measure were the same as in the previous experiments.

Results

None of the subjects were able to match the sample during baseline. In fact, no correct attachments of any blocks were made.

Figure 19 shows the time required to learn the tasks to criterion.

 Insert Figure 19 about here

All subjects required less TOT when the tasks were trained by the MFC procedure. However, the difference between TOT and TST (see shaded area in Figure 19) was greater for MFC in each subject. This resulted in slightly more TST for MFC in three of the subjects. The group means showed an advantage for MFC in TOT but a slight advantage for TTP in TST.

Consistent across all four subjects, tasks taught by MFC required fewer steps contacted to reach both initial step criterion and task criterion (see Figure 20).

 Insert Figure 20 about here

Minimal difference was noted in the number of steps contacted per

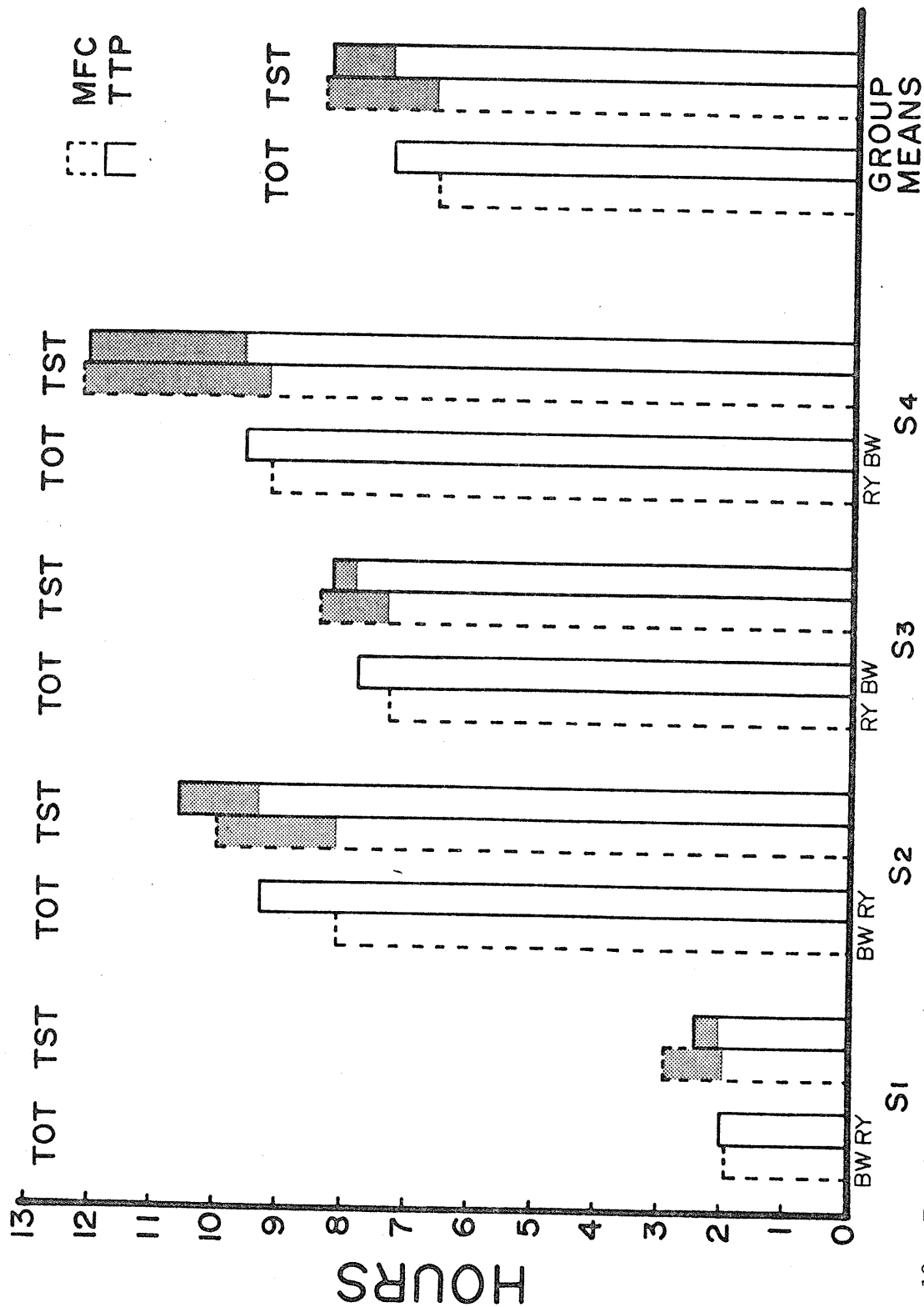


Figure 19. Total time on task (TOT) and total session time (TST) for each subject and the group means for all subjects to reach task criterion on the blue/white design (BW) and the red/yellow design (RY).



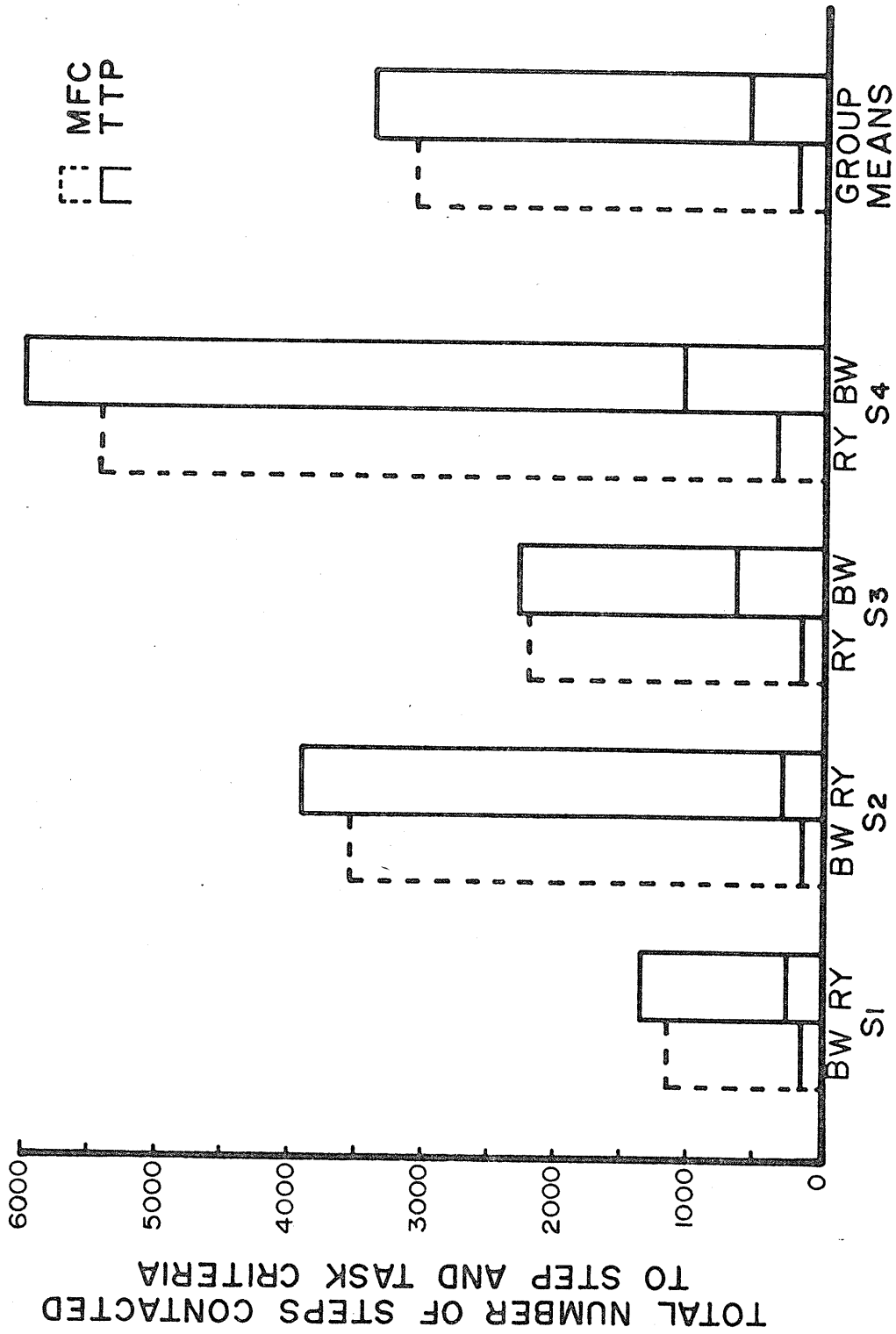


Figure 20. Total number of steps contacted for each subject and the group means for all subjects to reach task criterion (height of bar) and step criterion (indicated by horizontal line within each bar) on the blue/white (BW) and the red/yellow (RY) designs.

minute for each subject (see Figure 21), that is, the subjects worked at

Insert Figure 21 about here

about the same rate in both procedures.

Figure 22 shows the total number of errors for each subject. All

Insert Figure 22 about here

subjects were found to have fewer errors in the TTP procedure.

Subject 5's data, on the number of steps contacted to initial step criterion and task criterion, are presented cumulatively for each step in Figure 23, and are generally representative for all subjects.

Insert Figure 23 about here

Figure 24 shows Subject 5's data presented cumulatively for each step

Insert Figure 24 about here

on the number of errors made. This is also generally representative for all subjects.

Although no task effect was observed, no apparent difference was revealed between the procedures in the retention test. The total number of errors are presented in Table 3 (Experiment III).

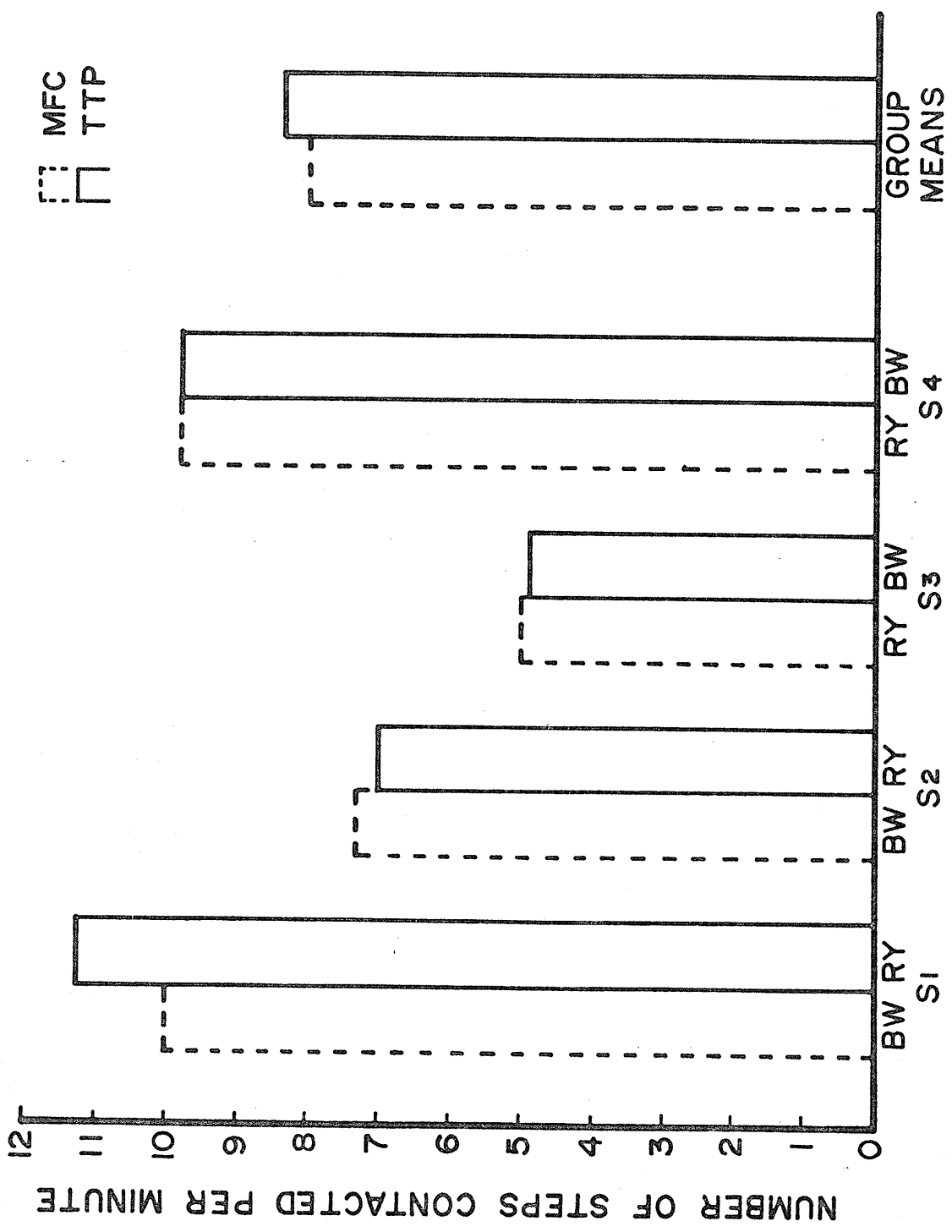


Figure 21. The average number of steps contacted per minute for each subject and the group means for all subjects on the blue/white (BW) and red/yellow (RY) designs.

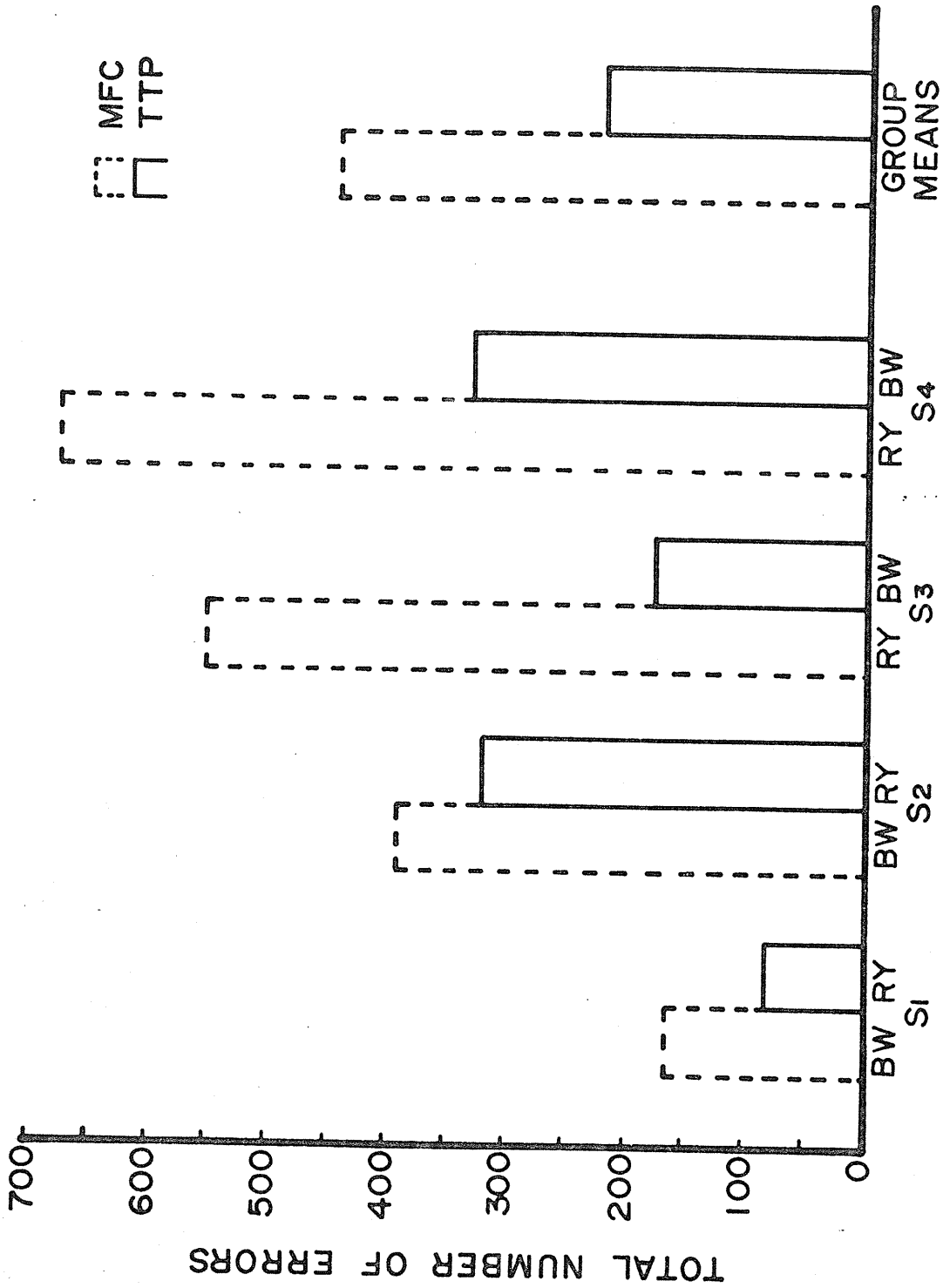


Figure 22. The total number of errors for each subject and the group means for all subjects to reach task criterion on the blue/white (BW) and the red/yellow (RY) designs.

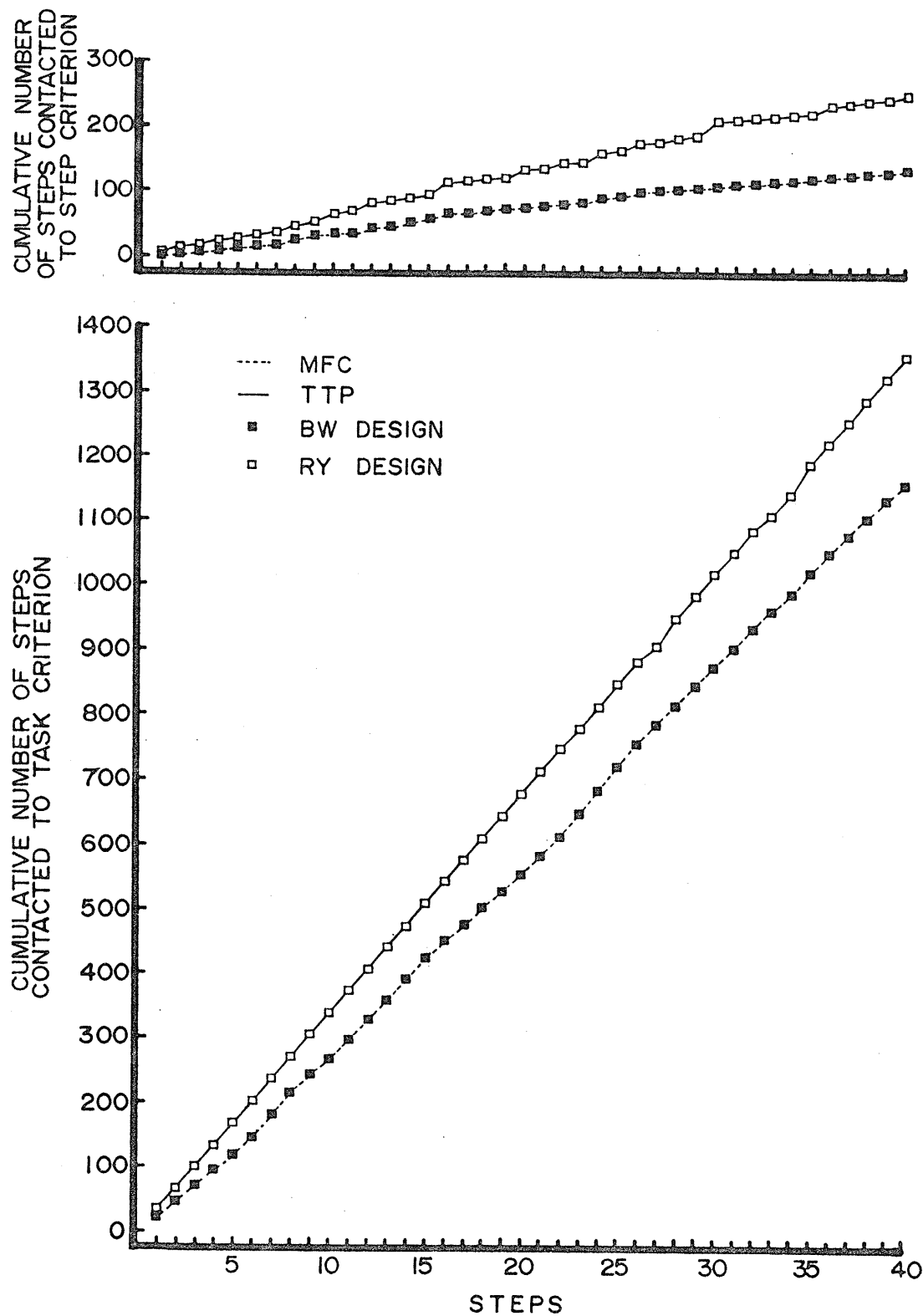


Figure 23. Cumulative presentation of Subject 5's data for each step on the number of steps contacted to step criterion and the number of steps contacted to task criterion. This is representative for all subjects.

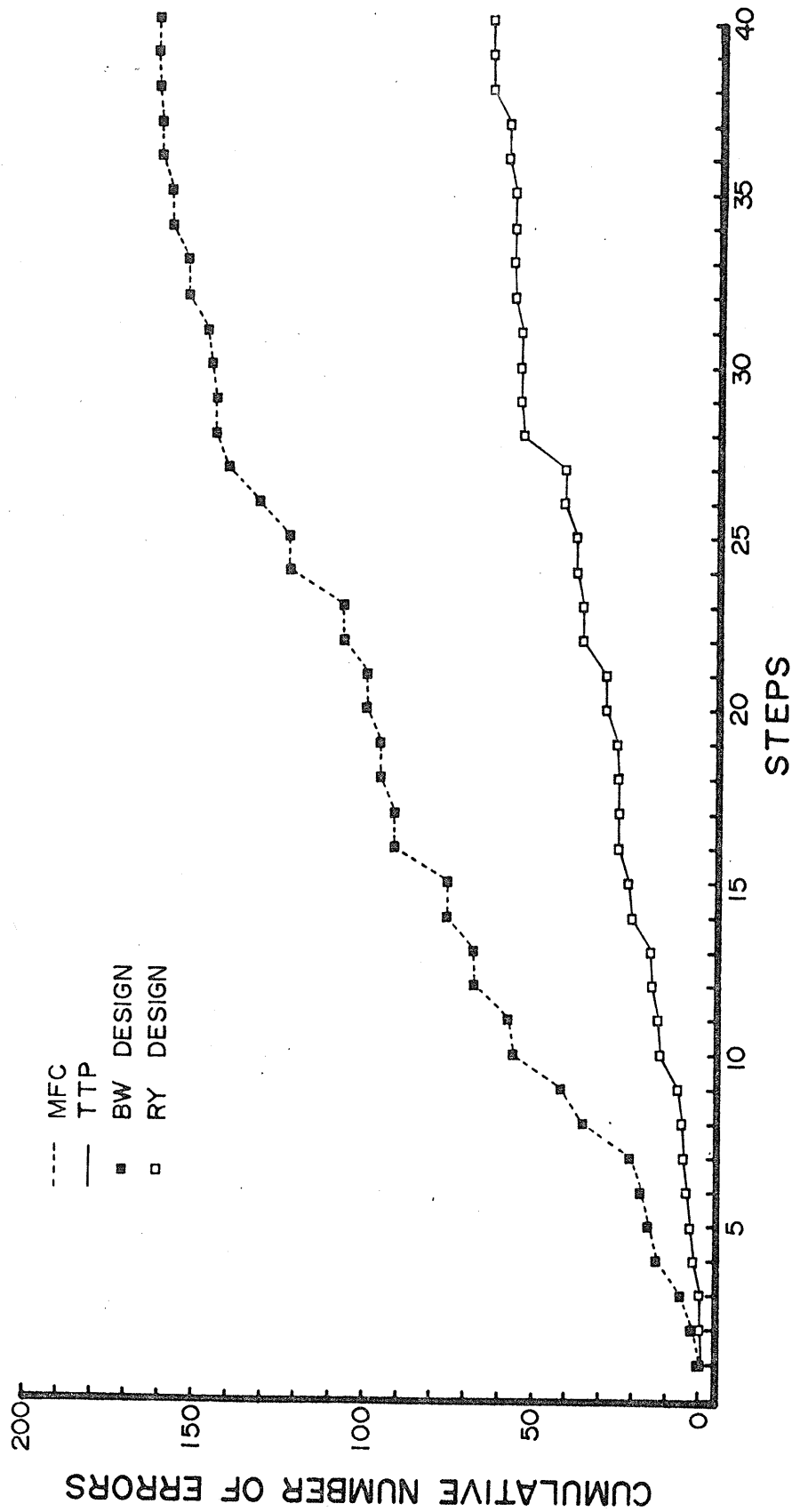


Figure 24. Cumulative presentation of Subject 5's data for each step on the number of errors made. This is representative for all subjects.

Discussion

In spite of the task effects in Experiments I and II, MFC showed substantial superiority over TTP in training steps to the initial step criterion with fewer steps contacted. Only one negative instance (Subject 4 in Experiment I) occurred across all three experiments. The results also showed that MFC had an advantage over TTP in having fewer steps contacted to reach task criterion, although the differences were smaller than for step criterion. This was supported by all subjects in Experiment III and the group means of Experiments I and II. There were three negative instances (Subject 3 in Experiment I, and Subjects 1 and 2 in Experiment II), and in each of them, the more difficult task was being trained by MFC. However, MFC produced relatively poor generalization over time during training. This was reflected by the greater number of errors (errors were defined as performing a step below Level 4 after step criterion had been reached) in MFC in all three experiments. There were a few exceptions (Subject 2 in Experiment I, and Subjects 3 and 4 in Experiment II), but the differences were minimal in those cases. In terms of TOT, all subjects in Experiment III and the group means of Experiments I and II indicated a slight advantage favoring MFC. However, more time was required in applying the MFC procedure as indicated in all subjects (with the exception of Subject 4 in Experiment II). Because of this, the initial advantage in TOT held by MFC was greatly minimized when TST was concerned. The group means in all experiments showed minimal differences in TST between the procedures. The data also revealed no apparent difference in the number of steps contacted per minute between the procedures. That is, subjects worked at about the same rate during training in both procedures. Procedure and task complexity interactions

were not evident across the three experiments. In view of the task effects in the first two experiments, such interactions, if they existed, could have been confounded and precluded. Finally, no apparent difference was found in retention between the two procedures.

Yu et al. (Note 4) suggested that the traditional FC procedure resembled a gradual increase of a fixed ratio reinforcement schedule and that this may have been partially responsible for the faster work rate relative to TTP that they observed. It was also suggested that the traditional FC procedure required that more time be spent in repeating learned steps, thus minimizing its efficiency in total training time. In this study, the MFC procedure was an attempt to improve training time by eliminating some repetition of learned steps. As the results indicated, subjects on the MFC procedure not only failed to improve TST, they also failed to maintain the faster work rate and lower error rate (in percentage) found in the previous study by Yu et al.

Two factors might be responsible for this failure. First, one aspect of the MFC procedure lacked the gradual transition of response requirement as in the traditional FC procedure. In the MFC procedure, before all the steps reached criterion, the subject was seldom required (thus reinforced) to perform more than a two-step link except during a probe trial which occurred once every session. After all the steps reached step criterion, the chain was extended to its full length. This abrupt change of reinforcement contingency, which represented an increase in response requirement and a decrease in reinforcement density, might account for the deterioration in both the work rate and the error rate. A second factor was the amount of time required in applying the procedure. In spite of the work rate and error rate, MFC showed a slight advantage in TOT compared to TTP. However, this advantage disappeared when the time spent by the

trainer was included. This extra training time typically involved rearranging task materials in between trials, some recording, and reinforcement time. This was higher in MFC because a greater number of trials were performed each session (due to the length of each trial) than in TTP, before all steps reached step criterion.

For the practitioner, an effective training procedure would include minimal total training time as an important feature. The present study suggests that the total training time is a function of a number of variables that are inter-related, and a strategy to maximize the effectiveness of one may detract from the other. Therefore, an effective training procedure probably will represent an effective combination of strategies. In view of the problems identified in the MFC procedure examined in this study, it would seem reasonable to make the MFC procedure more similar to the traditional FC procedure for additional examination. This may have the effect of increasing the amount of repetition on learned steps and arranging the trials in such a way as to provide a gradual transition of response requirements for reinforcement. Such modifications should bring about a faster work rate, a lower error rate, and less trainer response time. If such modifications are found to be effective, they should be extended to backward chaining for further study.

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