TECHNICAL REPORT

73-35-PR

DEXTERITY AFFORDED by CB PROTECTIVE GLOVES

by

John M. McGinnis

Carolyn K. Bensel

John M. Lockhart

March 1973

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UNITED STATES ARMY
NATICK LABORATORIES
Natick, Massachusetts 01760

Pioneering Research Laboratory

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Foreword

The study reported here was conducted by the Human Factors Group, Behavioral Sciences Division, Pioneering Research Laboratory, at the request of the Clothing and Personal Life Support Equipment Laboratory. This work was done as part of Project 1J664713DL40, Clothing and Equipment, and of Task 02 under Project 1T062106A121, Human Factors Analysis and Design Guidance in Support of Materiel Research and Development.

Acknowledgments

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Abstract

Three chemical and biological (CB) protective gloves were evaluated and compared to bare hands with regard to their effects on the performance of five manual tasks during 14 daily sessions. One task measured the angular force which could be exerted on a cylindrical handle. Four tasks measured finger or hand dexterity. One of these included the use of wrenches and screwdrivers. On the Torque Test, scores were highest when the butyl rubber CB protective glove was worn and lowest (only 1/3 as large) with the standard cotton CB protective glove. Performances with bare hands and with butyl gloves worn under the leather glove were between the two extremes and were approximately equal. On all four dexterity tasks, bare hand performance was best and performance was worst when the butyl glove was worn under the leather glove. On these tasks, performances with the cotton glove and the butyl glove were very similar and differed significantly from the two extreme conditions. Because of the great impairment on manual dexterity, it was recommended that the butyl and leather glove combination be given no further consideration for use as the Army CB protective glove.

Introduction

The purpose of this study was to evaluate three types of chemical and biological (CB) protective gloves with regard to their effects on manual performance. The particular operational characteristics addressed in this study were: "The improved CB protective glove will provide significantly improved tactile sensitivity as compared to that afforded by the present impregnated cotton gloves. The improved CB protective gloves will be so designed that they present a minimum of interference with finger dexterity required in the performance of military duties, to include operation and adjustment of small devices and instruments, handling materiel, and the loading and firing of weapons". (Ref 1, Para 24).

The handwear systems investigated in this study are pictured in Appendix A. These were:

a. the bare hand

b. a chemically-impregnated cotton, five-finger glove which is the present standard CB protective handwear

c. a butyl rubber, five-finger, "relaxed hand" glove which is impermeable and is being considered to replace the present CB protective glove

d. the butyl glove worn under the standard, five-finger leather glove.

Thus, there were three glove conditions and a bare hand condition. The latter was included for the purpose of a more complete data analysis.

The effects of handwear on manual performance were determined for five different manual tasks, which had been used previously to study the dexterity afforded by cold-wet gloves (Ref 2). One task was assumed to be related to firmness of grasp. Three other tasks were assumed to measure varying degress of manual, finger, or fine finger dexterity. The fifth was a measure of proficiency in the use of wrenches and screwdrivers.

Method

Subjects – Thirteen men participated as subjects in the present investigation. Six were volunteer enlisted men assigned to the Climatic Research Laboratory Test Subject Platoon. They ranged in age from 20 to 25 years and, with one exception, they had had previous training in the performance of some or all manual tasks used here. The remaining seven subjects were civilian and military personnel in the Clothing and Life Support Equipment Laboratory, NLABS. They ranged in age from 25 to 45 years and had had no previous exposure to the manual tasks used in this study.

Apparatus and Tasks – A battery of tests was assembled which was considered suitable for measuring important aspects of manual dexterity and the effects of handwear on manual performance. The following tasks, numbered in the order performed, were included:

1. Torque Test – a test designed to measure the amount of angular force which can be applied to a 0.75-in. diameter brass cylinder when it is grasped in one hand (Ref. 2). It is assumed that this task is closely related to the ability to hold onto objects and has little other relation to dextrous manipulation. One trial on the task consisted of two successive tries. The higher of the two scores, in inch-pounds, was used in subsequent analyses.

2. Minnesota Two-Hand Turning Test – a widely-used test designed to measure manual dexterity (Ref. 3). The subject, starting at the upper right-hand corner of the form board containing 60, 1.5-in. diameter and 7/8-in. thick blocks, picks up each block with the lead hand, turns it over, and places it down with the following hand until all blocks have been turned.

3. O'Connor Fine Finger Dexterity Test – a test widely used for measuring fine finger dexterity and aptitude for assembling small mechanical parts. In the shortened form used in this study, the subject was required to pick up and place three pins in each of 20 holes.

4. Cord Manipulation and Cylinder Stringing Test – a test designed by McGinnis to measure proficiency in handling soft, flexible materials

(Ref. 2). It consists of 10 large and one small loop of 3/32-in., woven nylon cord attached at equal intervals to a flexible webbing base with a hook at the far end, and of 10, 1/2-in., plastic cylinders with a 3/8-in. bore. The nearest loop is elongated until the sides are brought together, the doubled end is inserted through a cylinder, and the distal end is opened to form a smaller loop. The next loop is then elongated, passed through the first loop and through a cylinder. This procedure continues until the 10 loops form a chain with one cylinder mounted on each link. The smaller final loop is inserted through the tenth and placed over the hook to complete the task.

5. Bennett Hand Tool Dexterity Test — a test which measures proficiency in the use of wrenches and screwdrivers (Ref. 4). Two open-end wrenches, one large crescent wrench, and a screwdriver are used to relocate six bolt, nut, and washer combinations of three different sizes.

The score for each of the last four tests was the time required to complete the given number of components on the task, recorded to the nearest 0.01 minutes.

Testing was conducted in a laboratory maintained at 70° to 75°F with minimal windspeed. The enlisted men who served as subjects were outfitted in fatigues, wool socks, and leather combat boots. The remaining test subjects wore shirts, slacks, and civilian dress shoes.

Procedure — Before testing began, each subject was fitted for and issued one, appropriately-sized pair of the following types of gloves which were used only by that subject throughout the study: the standard cotton CB protective glove, the butyl rubber CB protective glove, and the standard leather glove. All gloves were new and had not been previously worn. The butyl glove was tested alone and when worn under the standard leather glove, while the cotton glove was only tested alone. These three glove configurations plus the bare hand condition comprised the four levels of the handwear variable.

Subjects were generally run in pairs for the 14 sessions comprising this study. During the first session, the subjects were instructed and performed the five manual tasks in order,

first barehanded and then while wearing the standard CB protective glove, the butyl CB protective glove, and the butyl glove under the leather glove, in that order. During each of the 13 subsequent sessions, the order of presentation of handwear conditions was random for each pair of subjects. Subjects participated in only one experimental session per day and performed the manual tasks in the order specified above. They were given one trial on each test with one of the four handwear conditions before moving to the next handwear condition.

The data from each task were subjected to separate analyses of variance. In addition, the first seven sessions and the last seven sessions were analyzed separately for each task. The experimental design used in the analyses was a factorial one of the form: Subjects (1–13) by Handwear Condition (Bare hands and three glove types) by Sessions (1–7 or 8–14).

Results

Each analysis of variance performed on the task data yielded a significant main effect of handwear. In the analysis of sessions 1 through 7, the main effect of sessions was also found to be significant on all tasks. In the analysis of sessions 8 through 14, the sessions effect was significant only for the Minnesota Two-Hand Turning Test and the Bennett Hand Tool Dexterity Test. The results of the analysis of variance performed on sessions 1 through 7 for each task are presented in Tables 1, 3, 5, 7, and 9. The same information for sessions 8 through 14 is presented in Tables 2, 4, 6, 8, and 10. Additional analyses, in the form of Newman-Keuls multiple comparisons tests, were performed on the significant handwear effect for each task. The results of these tests and the mean for each handwear condition are presented in Table 11.

On the Torque Test, the performance level was highest when the butyl glove was worn and lowest with the cotton glove. Performance with the bare hand and with the butyl glove worn under the leather glove fell between these two extremes. During the first seven sessions, scores achieved with the bare hand were significantly higher than those achieved when the butyl glove was worn under the leather glove, while the difference between these two handwear conditions was not significant during the last seven sessions (Table 11).

Mean Torque Test performance for each session and handwear condition is plotted in Figure 1 revealing the extent of the differences among types of handwear. Performance was relatively constant during the last seven sessions, regardless of the handwear worn, while performance level was generally increasing over the first seven sessions. The increase was greatest with the butyl gloves and when the butyl glove was worn under the leather glove. This resulted in the significant interaction between handwear and sessions during the first seven sessions (Table 1).

The results of the analyses of the four manual dexterity tasks are similar to each other (Tables 3–10). Performance was significantly better with the bare hand than when any of the three types of gloves were worn. The worst performance occurred when the butyl glove was worn under the leather glove. Performance with the cotton glove and the butyl glove differed significantly from these two extremes (Table 11).

Mean Two-Hand Turning Test scores for each session and handwear condition are presented in Figure 2. Performance level was improving over all 14 sessions on this task, yielding decreasing time scores and the significant main effect of sessions (Tables 3 and 4). For the first seven sessions, there was also a significant interaction between handwear condition and sessions attributable to the greater change in performance with the butyl glove worn under the leather glove compared to the other three handwear conditions. There was no significant difference between the cotton and the butyl gloves for either sessions 1–7 to 8–14 (Table 11).

On the O'Connor Fine Finger Dexterity Task, performance with the butyl glove was superior to that with the cotton glove during the first seven sessions only. During the last seven sessions, performance with these two types of gloves did not differ significantly (Table 11). In Figure 3, it can be seen that performance on this test under all handwear conditions improved during the first seven sessions and remained relatively constant during the last seven. This was reflected in a significant main effect of sessions in the analysis of variance of the data from the first seven sessions (Table 5). In addition, there was a significant interaction between handwear and sessions during the first seven sessions (Table 5). As with the Two-Hand Turning Test results, this interaction would seem to be attributable to the relatively greater performance improvement with the butyl glove under the leather glove than with the other three handwear conditions, particularly with the bare hand condition (Figure 3).

As on the O'Connor Test, performance on the Cord and Cylinder Test improved during the first seven sessions and remained relatively constant during the last seven yielding a significant main effect of sessions in the analysis of variance performed on sessions 1–7. There was also a significant interaction between handwear condition and sessions in the analysis of variance based on the first seven sessions (Table 7). This again reflected the relatively greater improvement in performance with the butyl glove under the leather glove than with the other three glove conditions (Figure 4). As was the case with the Two-Hand Turning Test, no significant difference was found between the butyl and the cotton gloves throughout all sessions.

The results of the Bennett Hand Tool Dexterity Test differed from those of the other three dexterity tasks insofar as there was no significant interaction between handwear

condition and sessions in the analysis of the former (Tables 9 and 10). It can be seen in Figure 5 that the performance changes over sessions for each handwear condition were essentially parallel on the Bennett Test. Also, the significant main effect of sessions in the analyses of both the first and the last seven sessions is attributable to a decrease in time scores over all sessions (Tables 9 and 10). As on the Two-Hand Turning and the Cord and Cylinder Tests, there was no significant difference in performance between the cotton and the butyl gloves for the first or last seven sessions (Table 11).

Discussion

While the results of this study indicated that the wearing of gloves produced a significant impairment in manual performance, the extent to which gloves impaired performance differed with the type of glove worn and the tasks performed. Insofar as the ability to apply angular force is concerned, as reflected by the Torque Test, the butyl glove was significantly superior to the cotton glove and to the other two handwear conditions investigated. The handwear differences on the Torque Test are of such magnitudes as to be practically important. Torque scores with the butyl glove were approximately 3.0 times greater than those for the cotton glove, 1.3 times greater than bare hand scores, and slightly more than 1.3 times greater than the scores for the butyl and leather glove combination. With the cotton glove, torque scores were approximately 43% of bare hand scores, 33.3% of the butyl glove scores, and 47% of the butyl and leather glove combination scores.

On the four remaining tasks, dexterity performance with the butyl glove differed significantly from that with the cotton glove only on the O'Connor Fine Finger Dexterity Test and this difference occurred only during sessions 1–7. The butyl and leather glove condition resulted in far greater impairment of manual performance than did any other handwear condition. Based upon the results of the present study, it is recommended that the butyl and leather glove combination be given no further consideration for use as the Army CB protective glove.

The extensive performance impairment when the butyl glove was worn under the leather glove occurred throughout the study even though there was a relatively greater lowering of time scores over sessions with this glove combination. This finding indicated that more learning was required on the part of the wearer to use these gloves with any degree of manipulative skill than was required to use the butyl or the cotton glove or the bare hand. The practical significance of this finding is the possibility that, because of the frustrations introduced by the butyl and leather glove combination during initial practice on a task under non-toxic conditions, the wearer may more readily discard these gloves than he would the others tested here and not practice sufficiently to become even minimally adept in their use. For the same reasons, during practice under toxic conditions, the wearer may more readily discard the outer leather glove of this combination and use only the butyl glove. Again, the wearer would not achieve the level of performance with the butyl and leather glove combination which would have been possible with additional practice.

Conclusions

1. On the Torque Test, scores were highest when the butyl glove was worn and lowest with the cotton glove. Performance levels with the bare hand and with the butyl and leather glove combination were between these two extremes and were approximately equal.

2. On the four dexterity tasks, bare hand performance was fastest and the slowest scores occurred when the butyl and leather glove combination was worn. Performance levels with the cotton glove and with the butyl glove differed significantly from these two extremes. However, for seven out of eight comparisons, the scores achieved with the cotton and with the butyl gloves did not differ significantly from each other.

3. The butyl and leather glove combination resulted in far greater impairment of manual performance on the four dexterity tasks than did any other handwear condition.

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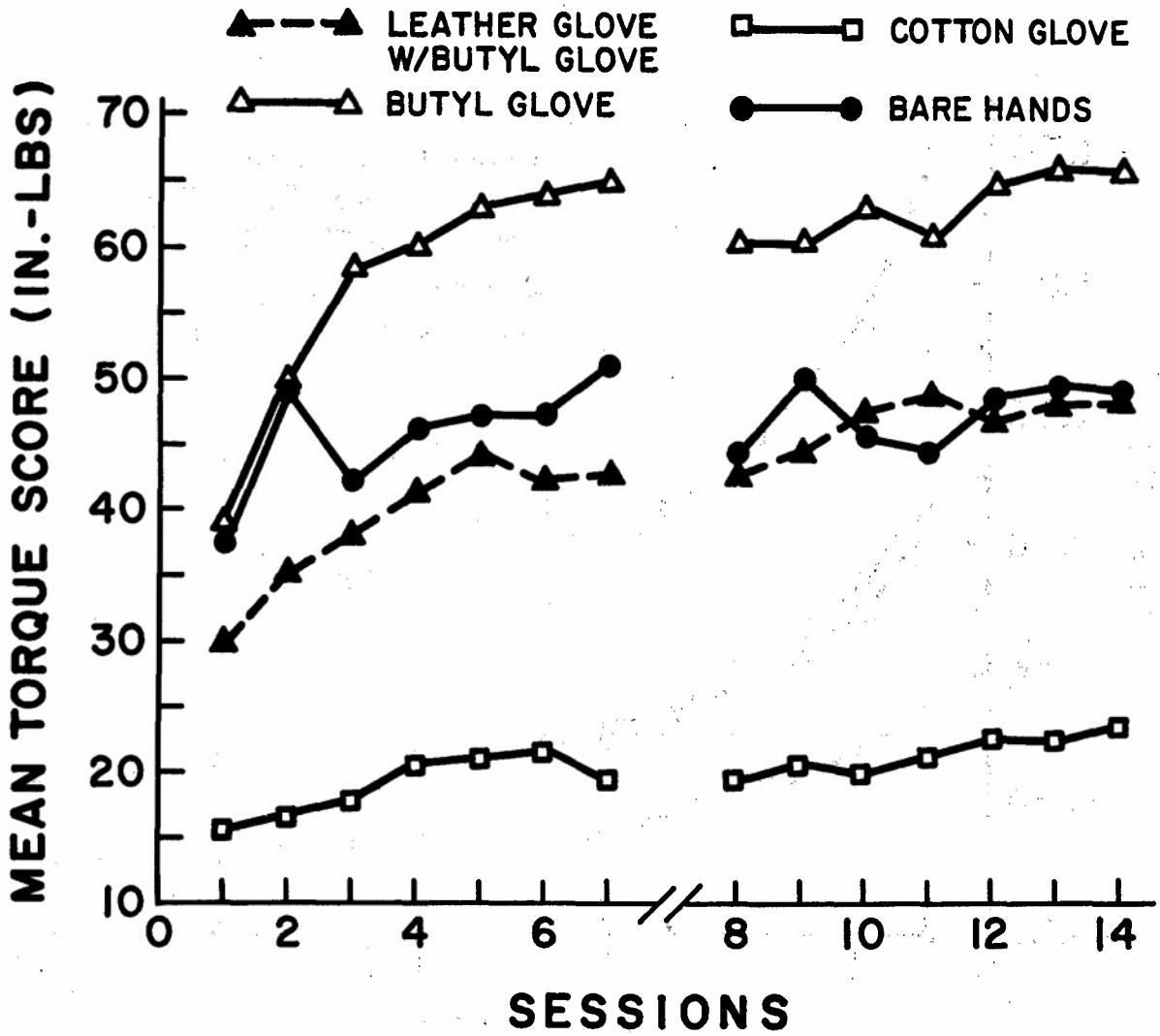

Figure 1. Mean Torque Test scores for each session and handwear condition.

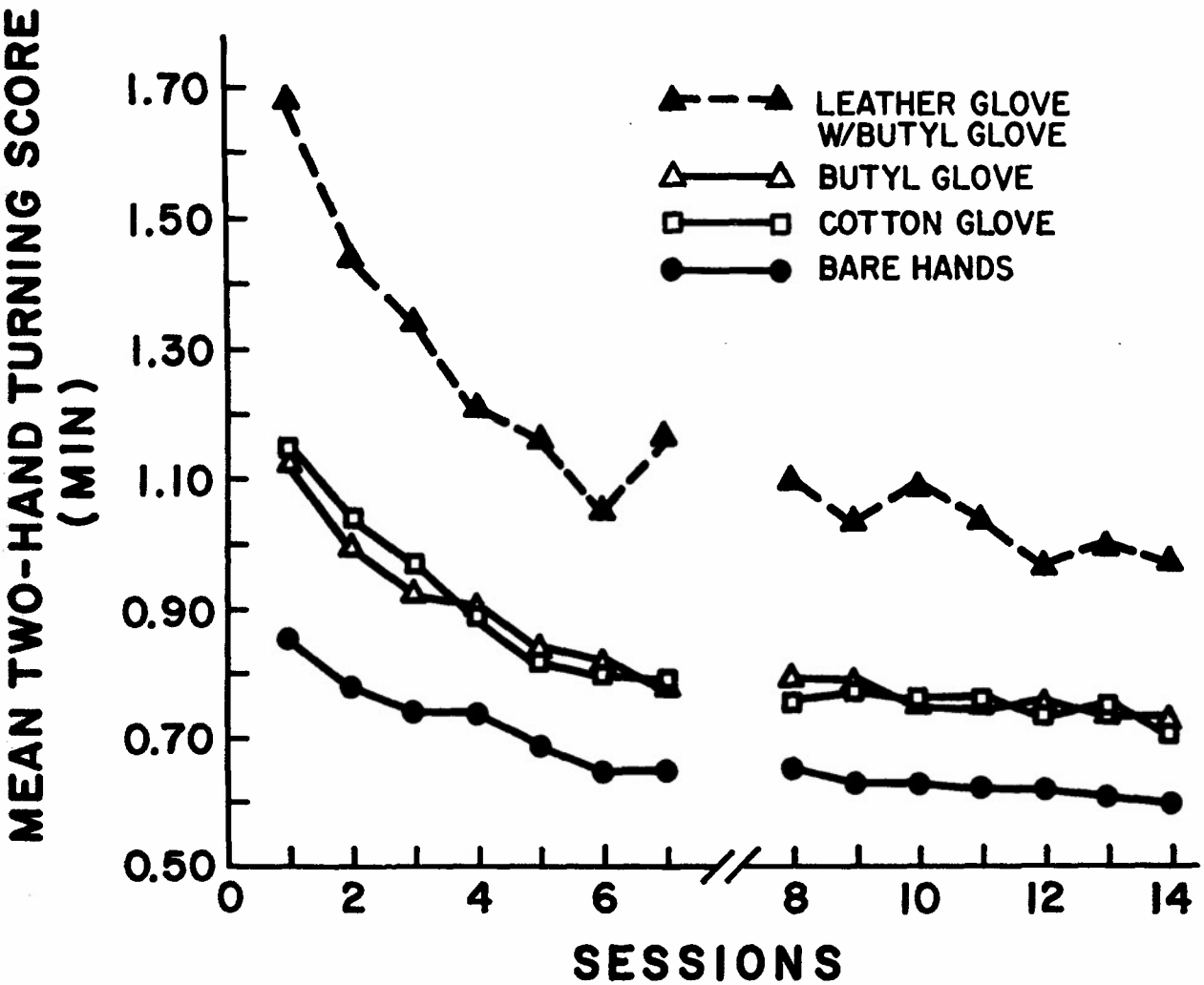

Figure 2. Mean Two-Hand Turning Test scores for each session and handwear condition.

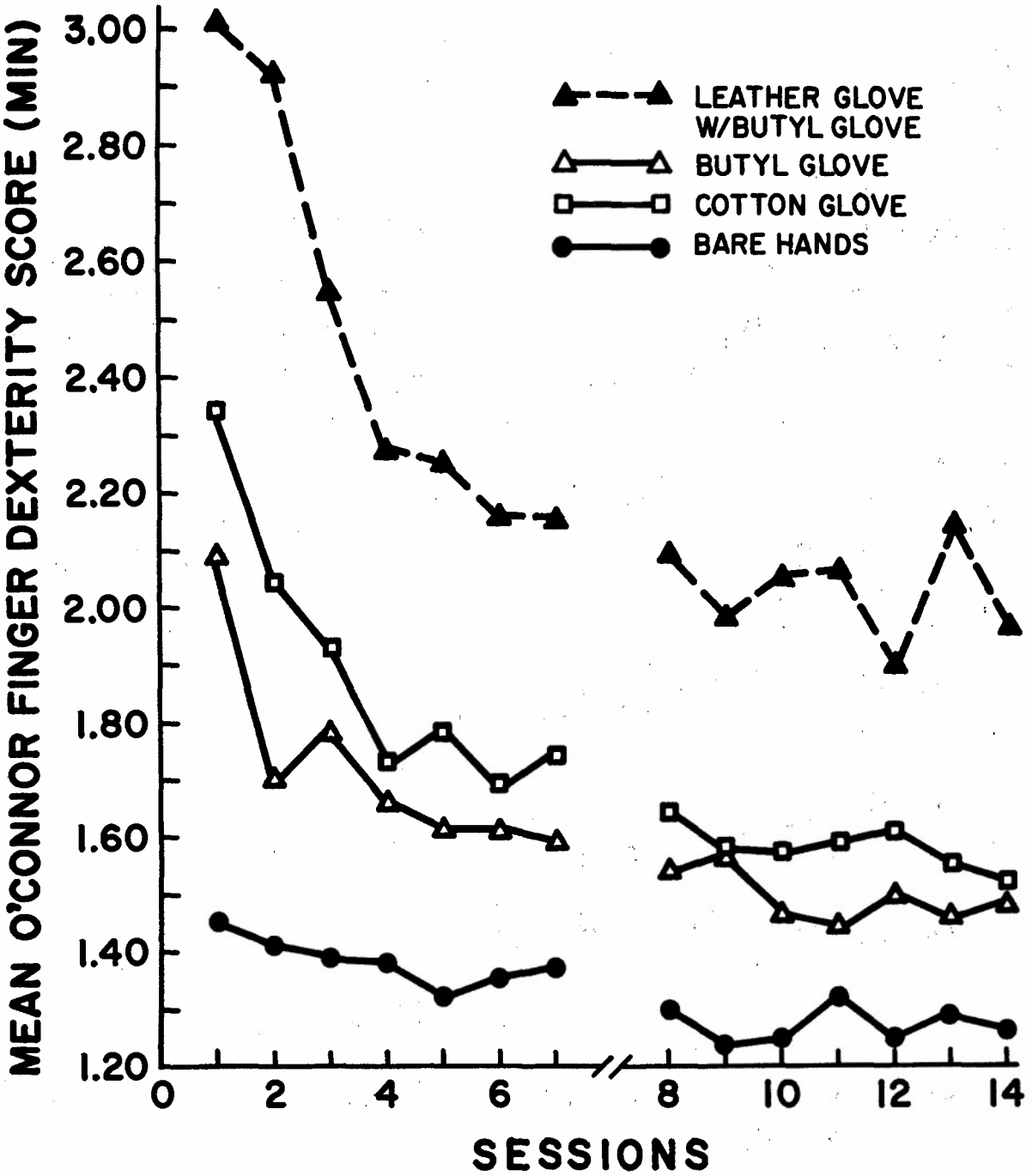

Figure 3. Mean O'Connor Fine Finger Dexterity Test scores for each session and handwear condition.

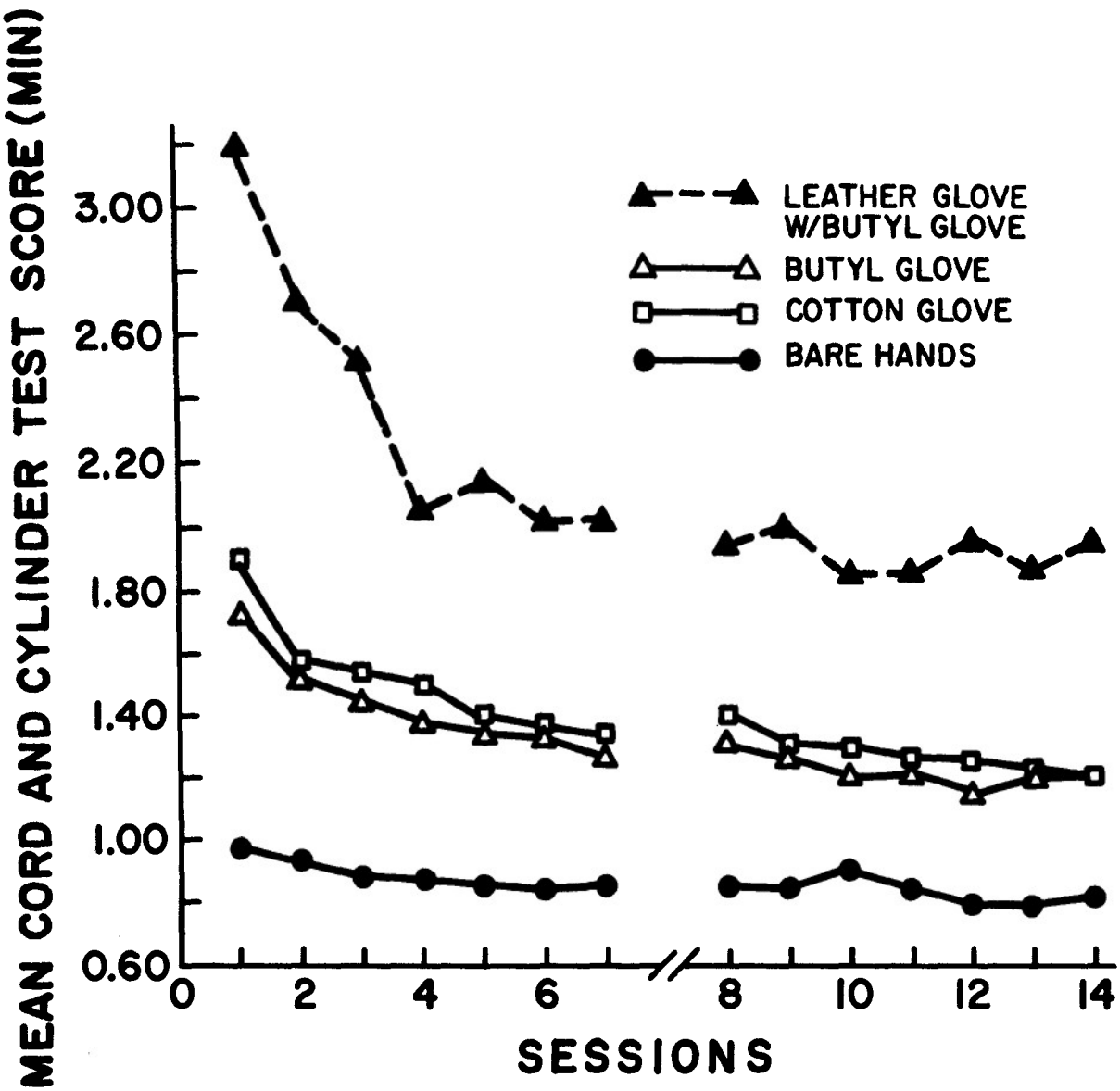

Figure 4. Mean Cord and Cylinder Manipulation Test scores for each session and handwear condition.

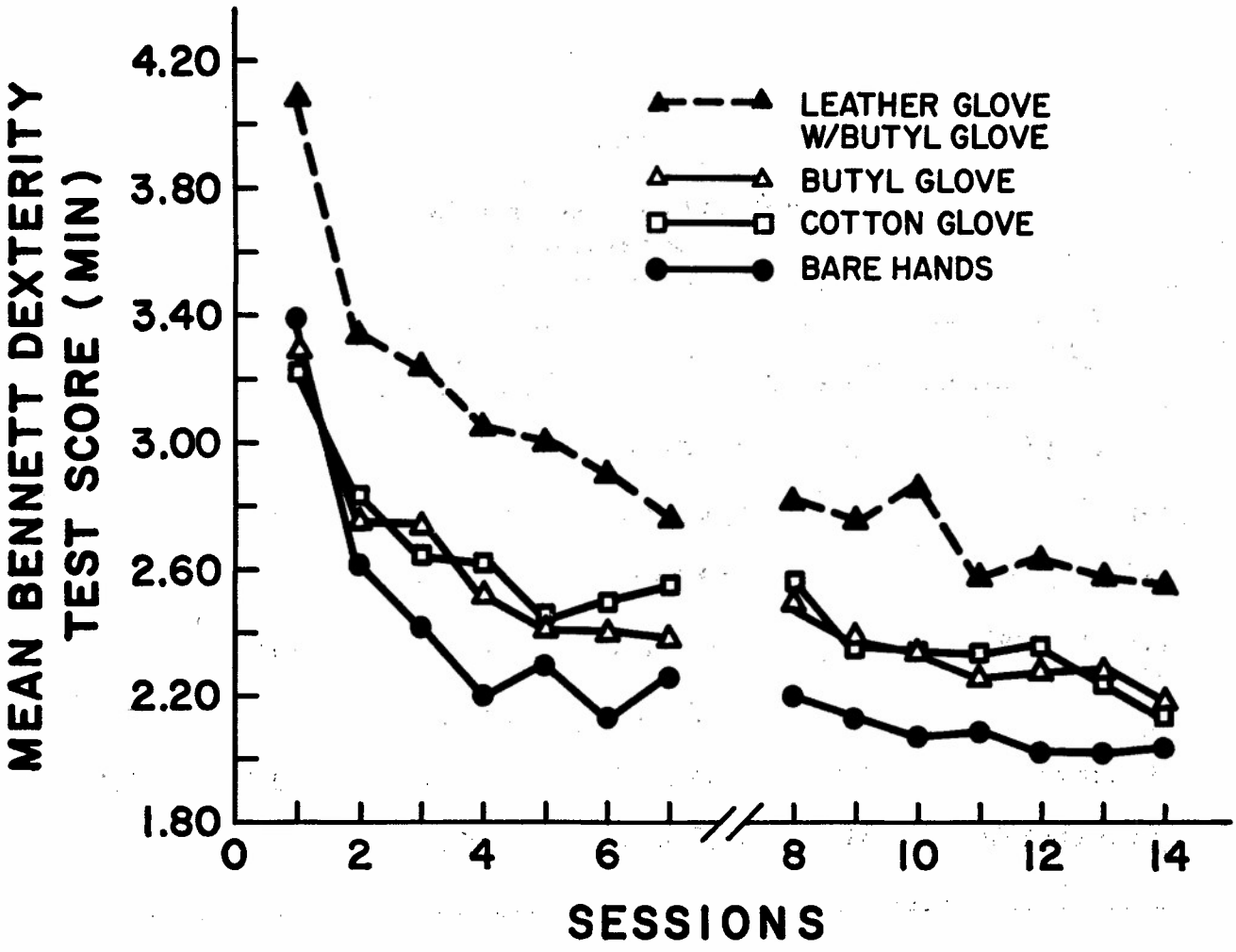

Figure 5. Mean Bennett Hand Tool Dexterity Test scores for each session and and handwear condition.

Table 1

Analysis of Variance of Torque Test Performance Data (Sessions 1–7)

SV	df	SS	MS	F-ratio	p
Subjects (Ss)	12	16867.330	1405.611	-	
Sessions	6	7902.308	1317.051	14.889	.001
Ss x Sessions	72	6368.978	88.458		
Handwear (H)	3	70334.363	23444.788	71.976	.001
Ss x H	36	11726.208	325.728	-	
H x Sessions	18	3301.253	183.403	3.093	.001
Ss x H x Sessions	216	12807.176	59.292	-	

Table 2

Analysis of Variance of Torque Test Performance Data (Sessions 8–14)

SV	df	SS	MS	F-ratio	p
Subjects (Ss)	12	28950.116	2412.510	--	
Sessions	6	919.808	153.301	2.137	
Ss x Sessions	72	5164.192	71.725		
Handwear (H)	3	79847.527	26615.842	59.163	.001
Ss x H	36	16195.400	449.872	--	
H x Sessions	18	585.973	32.554	<1.000	
Ss x H x Sessions	216	10980.600	50.836	--	

Table 3

Analysis of Variance of Two-Hand Turning
Test Performance Data
(Sessions 1–7)

SV	df	SS	MS	F-ratio	p
Subjects (Ss)	12	11.732	0.978	--	
Sessions	6	5.618	0.936	32.289	.001
Ss x Sessions	72	2.090	0.029	--	
Handwear (H)	3	15.359	5.120	61.983	.001
Ss x H	36	2.974	0.083	--	
H x Sessions	18	0.899	0.050	4.940	.001
Ss x H x Sessions	216	2.188	0.010	--	

Table 4

Analysis of Variance of Two-Hand Turning Test Performance Data (Sessions 8–14)

SV	df	SS	MS	F-ratio	p
Subjects (Ss)	12	8.411	0.701	—	
Sessions	6	0.208	0.035	5.833	.001
Ss x Sessions	72	0.414	0.006	—	
Handwear (H)	3	8.143	2.714	38.771	.001
Ss x H	36	2.521	0.070	—	
H x Sessions	18	0.095	0.005	1.250	
Ss x H x Sessions	216	0.992	0.004	—	

Table 5

Analysis of Variance of O'Connor Finger Dexterity Test Performance Data (Sessions 1–7)

SV	df	SS	MS	F-ratio	p
Subjects (Ss)	12	35.077	2.983	—	
Sessions	6	11.896	1.923	17.180	.001
Ss x Sessions	72	8.307	0.115	—	
Handwear (H)	3	56.767	18.922	70.109	.001
Ss x H	36	9.715	0.270	—	
H x Sessions	18	5.009	0.283	3.912	.001
Ss x H x Sessions	216	15.635	0.072	—	

Table 6

Analysis of Variance of O'Connor Finger Dexterity Test Performance Data (Sessions 8–14)

SV	df	SS	MS	F-ratio	p
Subjects (Ss)	12	26.329	2.194	—	
Sessions	6	0.284	0.047	1.068	
Ss x Sessions	72	3.166	0.044	—	
Handwear (H)	3	27.549	9.183	67.522	.001
Ss x H	36	4.908	0.136	—	
H x Sessions	18	0.630	0.035	1.400	
Ss x H x Sessions	216	5.368	0.025	—	

Table 7

Analysis of Variance of Cord and Cylinder Test Performance Data (Sessions 1–7)

SV	df	SS	MS	F-ratio	p
Subjects (Ss)	12	19.977	1.655	—	
Sessions	6	13.507	2.251	28.316	.001
Ss x Sessions	72	5.726	0.079	—	
Handwear (H)	3	105.267	35.089	165.047	.001
Ss x H	36	7.652	0.212	—	
H x Sessions	18	7.016	0.390	10.918	.001
Ss x H x Sessions	216	7.714	0.036	—	

Table 8

Analysis of Variance of Cord and Cylinder Test Performance Data (Sessions 8–14)

SV	df	SS	MS	F-ratio	p
Subjects (Ss)	12	21.465	1.789	—	
Sessions	6	1.407	0.234	<1.000	
Ss x Sessions	72	18.645	0.259	—	
Handwear	3	48.605	16.202	37.944	.001
Ss x H	36	15.377	0.427	—	
H x Sessions	18	4.692	0.261	1.040	
Ss x H x Sessions	216	54.248	0.251	—	

Table 9

Analysis of Variance of Bennett Hand Tool Dexterity Test Performance Data (Sessions 1–7)

SV	df	SS	MS	F-ratio	p
Subjects (Ss)	12	63.083	5.257	--	
Sessions	6	40.978	6.830	21.309	.001
Ss x Sessions	72	23.073	0.320	--	
Handwear (H)	3	26.172	8.724	65.644	.001
Ss x H	36	4.783	0.133	--	
H x Sessions	18	27.001	0.150	1.412	
Ss x H x Sessions	216	22.938	0.106	--	

Table 10

Analysis of Variance of Bennett Hand Tool Dexterity Test Performance Data (Sessions 8–14)

SV	df	SS	MS	F-ratio	p
Subjects (Ss)	12	40.690	3.391	—	
Sessions	6	2.894	0.482	3.766	.005
Ss x Sessions	72	9.206	0.128		
Handwear (H)	3	16.923	5.641	55.852	.001
Ss x H	36	3.643	0.101		
H x Sessions	18	0.737	0.041	1.000	
Ss x H x Sessions	216	11.719	0.054	—	

Table 11

Mean Score for Each Task under Each Handwear Condition

Task	Handwear			
Sessions 1–7				
Torque Test	C 57.16	A 45.80	D 39.19	B 18.92
Two-Hand Turning Test	A 0.73	C 0.91	B 0.92	D 1.29
O'Connor Fine Finger Dexterity Test	A 1.38	C 1.72	B 1.89	D 2.47
Cord and Cylinder Test	A 0.88	C 1.42	B 1.52	D 2.38
Bennett Hand Tool Dexterity Test	A 2.47	C 2.64	B 2.69	D 3.19
Sessions 8–14				
Torque Test	C 63.24	A 47.38	D 46.47	B 21.82
Two-Hand Turning Test	A 0.62	B 0.752	C 0.753	D 1.03
O'Connor Fine Finger Dexterity Test	A 1.27	C 1.49	B 1.58	D 2.03
Cord and Cylinder Test	A 0.91	C 1.22	B 1.27	D 1.92
Bennett Hand Tool Dexterity Test	A 2.08	C 2.31	B 2.33	D 2.69

Note: A=Bare Hands, B=Cotton Glove, C=Butyl Glove, D=Leather Glove w/Butyl Glove. Handwear not connected by same line are significantly different ($p<.05$).

APPENDIX A

Photographs of Handwear Conditions

A1. Cotton CB Protective Glove

A2. Butyl CB Protective Glove

A3. Leather Glove with Butyl CB Protective Glove

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13. ABSTRACT

Three chemical and biological (CB) protective gloves were evaluated and compared to bare hands with regard to their effects on the performance of five manual tasks during 14 daily sessions. One task measured the angular force which could be exerted on a cylindrical handle. Four tasks measured finger or hand dexterity. One of these included the use of wrenches and screwdrivers. On the Torque Test, scores were highest when the butyl rubber CB protective glove was worn and lowest (only 1/3 as large) with the standard cotton CB protective glove. Performances with bare hands and with butyl gloves worn under the leather glove were between the two extremes and were approximately equal. On all four dexterity tasks, bare hand performance was best and performance was worst when the butyl glove was worn under the leather glove. On these tasks, performances with the cotton glove and the butyl glove were very similar and differed significantly from the two extreme conditions. Because of the great impairment on manual dexterity, the butyl and leather glove combination was judged unacceptable.

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