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INVESTIGATION OF THE EFFECTS OF EXTRA VEHICULAR ACTIVITY (EVA) AND LAUNCH AND ENTRY (LES) GLOVES ON PERFORMANCE

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ABSTRACT

Human capabilities such as dexterity, manipulability, and tactile perception are unique and render the hand as a very versatile, effective and a multipurpose tool. This is especially true for unknown environments such as the EVA environment. In the microgravity environment interfaces, procedures, and activities are too complex, diverse, and defy advance definition. Under these conditions hand becomes the primary means of locomotion, restraint and material handling. Facilitation of these activities, with simultaneous protection from the cruel EVA environment are the two, often conflicting, objectives of glove design. The objectives of this study was a) to assess the effects of EVA gloves at different pressures on human hand capabilities, b) to devise a protocol for evaluating EVA gloves, c) to develop force time relations for a number of EVA glove-pressure combinations, and d) to evaluate two types of launch and entry suit gloves. The objectives were achieved through three experiments. The experiments for achieving objectives a, b, and c were performed in the glove box in building 34. In experiment 1 three types of EVA gloves were tested at five pressure differentials. A number of performance measures were recorded. In experiment 2 the same gloves as in experiment 1 were evaluated in a reduced number of pressure conditions. The performance measure was endurance time. Six subjects participated in both the experiments. In experiment 3 two types of launch and entry suit gloves were evaluated using a paradigm similar to experiment 1. Currently the data is being analyzed. However for this report some summary analyses have been performed. The results indicate that a) With EVA gloves strength is reduced by nearly 50%, b) performance decrements increase with increasing pressure differential, c) TMG effects are not consistent across the three gloves tested, d) some interesting gender glove interactions were observed, some of which may have been due to the extent (or lack of) fit of the glove to the hand, and e) differences in performance exist between partial pressure suit glove and full pressure suit glove, especially in the unpressurized condition.

INTRODUCTION

Human capabilities such as dexterity, manipulability, and tactile perception are unique and render the hand as a very versatile, effective and a multipurpose tool. This is especially true for unknown environments such as the EVA environment. In the microgravity environment interfaces, procedures, and activities are too complex, diverse, and defy advance definition. Under these conditions hand becomes the primary means of locomotion, restraint and material handling. Facilitation of these activities, with simultaneous protection from the cruel EVA environment are the two, often conflicting, objectives of glove design. The conflict associated with providing hand protection while permitting adequate hand functioning has been widely recognized. Hand gloves are the primary protection device for the hands.

Numerous articles have been published in the area of the effect of gloves on task performance. Lyman and Groth (1958) reported that when gloves were worn, subjects exerted more force than when bare handed while inserting pins into a pegbox. Bradley (1969) studied the operation time of five types of control tasks with bare hand, wool gloves, and leather over wool gloves. The results of his research showed that the operation time depends on the type of gloves, the type of control operations, and the physical characteristics of the controls. Cochran et al (1986) studied grasp force degradation of some commercially available gloves. Five types of gloves and bare hand conditions were compared and the results showed that all the gloves tested reduced the maximum grasp force significantly when compared to bare hand condition. Wang et al (1987) also found similar results. The most common finding from all the published studies on gloves is that hand performance is compromised with gloves.

While most of the studies have addressed performance compromises with commercial gloves, very few studies have attempted to assess the effects of EVA gloves on basic hand capabilities (see O'Hara et., al., (1988) have provided a detailed list of the studies that have assessed the impact of EVA gloves on hand capabilities. The authors have also listed some of the non EVA pressure glove studies. The overall findings of these studies are a) gloves reduce strength capabilities, and b) gloves reduce dexterity and manipulability. The studies listed in Table 1 have each assessed certain aspects of glove effect on performance. Perhaps the most comprehensive study performed on the assessment of performance decrements with EVA gloves is the one done by O'Hara et. al. (1988). The authors had studies two levels of hand conditions (gloved and bare handed), two levels of pressure differential (0 psid, and 4.3 psid), and three levels of hand size (small, medium, and large). 11 subjects participated in an experiment where six categories of performance measures were recorded. The performance categories were 1) range of motion, 2) strength, 3) tactile perception, 4) dexterity, 5) fatigue, and 6) comfort. The salient findings were:

1) On the range of motion the glove and pressure effects were diverse and motion dependent. Effects for flexion were different from that for extension.

2) Glove reduced grip strength and pressure reduced it further. However, neither the glove nor the pressure had any effect on pinch strength.

3) The degradation in tactile perception was more with glove than with pressure.

4) Dexterity was reduced by both glove and pressure. Unpressurized glove reduced dexterity by 50%, while pressurizing reduced it further by 30%.

5) The fatigue effects were most uninterpretable due to complex EMG signatures at different test conditions.

6) Perceived comfort reduced by 100% with unpressurized gloved conditions. Presurizing reduced it further by 600%.

The rationale for this investigation evolved out of the above study. The O'Hara (1988) investigation used one type of glove and one pressure level. It is recognized that in EVA tasks the prebreath time before donning the suit is a function of the pressure. Greater the pressure, shorter the prebreathing time. However, the performance decrement is also a function of pressure, with larger decrements at greater pressure. An important information that is needed, and which is currently unavailable, is the pressure performance profile for the various EVA gloves. Therefore one of the objective was to develop functional relations between performance decrements and pressure differential for EVA gloves.

O'hara et. al., (1988) measured fatigue through shifts in the median frequency of the EMG power spectrum. The results were uninterpretable for a number of reasons. A number of researchers have used the functional relationship between force exerted by a muscle group and the time of endurance as a predictor of muscle fatigue (Rohmert, 1960; Monod and Scherrer, 1965). In general endurance time increases with decreasing force. Bishu et. al. (1989) have used endurance time for evaluating container handles. The second objective was to develop force time relationships for a variety of EVA glove - pressure combinations.

A third objective for this study evolved out of the reasoning that while some research existed on the effects of EVA gloves on performance, none existed for the effects of launch and entry suit (LES) gloves.

OBJECTIVES

1. To assess the effects of EVA gloves at different pressures on human hand capabilities.

2. To devise a protocol for evaluating EVA gloves.

3. To develop force time relations for a number of EVA glove-pressure combinations.

4. To evaluate two types of launch and entry suit gloves.

The objectives were achieved through three experiments described below.

EXPERIMENT 1

Objective:
To assess the effects of eva gloves at different pressures on human hand capabilities.

Subjects:
Six subjects (three males and three females) participated in this experiment. Their participation was voluntary.

Independent variables:
The independent variables tested in this experiment were gender, glove type, pressure differential, and glove make. The six subjects were equally split between two genders to provide the gender differences. Two types of glove assembly were used namely, with and without thermal meteorite garment (TMG). An EVA glove is an assemblage of two major units-an inner pressurizing glove, and an outer TMG glove. One of the objective was to assess the exact effect of TMG on performance. Current shuttle gloves operate at 4.3 psid. Certain developmental gloves are being designed to operate at 8.3 psid. The rationale being at higher pressure differentials the prebreathing time is reduced considerably. Five levels of pressure differentials were used in this experiment ie., 0 psid, 3.2 psid, 4.3 psid, 6.3 psid, and 8.3 psid. The intent was to develop a pressure-performance decrement profile. Three different gloves were tested here, namely current shuttle gloves (referred to hereafter as GLOVE C), and two developmental gloves (referred to hereafter as GLOVES A and B). To summarize the independent variables with their respective levels were:

1. Gender	male and female.
2. Glove type	with and without TMG
3. Pressure	0, 3.2, 4.3, 6.3, 8.3
4. Glove make	A, B, and C.

Performance measures:
The performance measures were selected based on the O'Hara (1988) study, and comprised two strength measures (grip and pulp pinch strength), two dexterity measures (nuts-bolts test, and rope tying test), and a tactility measure (two point discrimination test). The criteria for selection of performance measures were a) they should be generic, and hence repeatable, and b) they should be reasonably representative of the EVA

activities. Grip and pinch strengths measure a person's force capabilities, while the two point discrimination test provides a valid measure for tactility. Dexterity and manipulability were measured by the the rope tying test, and the nuts-bolts test.

Glove box:

The testing was done in Advanced Suit Laboratory in Building 34. The actual tests were conducted inside a glove box. The glove box is cylindrical in shape, approximately 2 ft in diameter and 4 ft in length with an internal volume of 13 ft^3. On either sides of the glove box were two end caps, made of plexiglass and bolted through 8 bolts. About midway along the axis of the glove box were 2 six in. circular openings in the cylinder wall, placed shoulder width apart, which provided access and attachment points for the EVA glove and arm assemblies. The glove box was connected to a vacuum pump and could be evacuated to any desired pressure level. There was a gauge on the outer cylinder wall calibrated to read the pressure differential inside.

Procedure:

The levels of independent variables were factorially combined to yield 26 experimental conditions. There were 26 experimental conditions in this experiment (see table 1). The order of presentation of these was randomized for each subjects.

Table 1: Experimental design

GLOVE CONDITIONS

PRESSUR	A	A with TMG	B	B with TMG	C	C with TMG
0 psi						
3.2 psi						
4.3 psi						
6.3 psi					na	na
8.3 psi					na	na

In addition all the subjects performed a 'Bare handed' condition on the last day. Within a condition the order of presentation of the five tasks (grip, pinch, nuts-bolts, rope tying, and 2PD test) was also randomized for each subject. As stated earlier six subjects participated in this study. Gender was a between subject factor. Each subject performed one condition per day, resulting in 26 days of experimentation in all. A trial consisted of the following steps.

1. The glove box was pressurized to the required level.
2. The subject donned a pair of comfort gloves and the gloves for that day's trial.

3. Grip strength was recorded through a Jamar Hand Dynamometer connected to a digital read out, and to a Teac Recorder.
4. Pulp pinch strength was measured following a 2 minute rest period using a pinch gauge.
5. For the nuts-bolts test, three pairs of nuts and bolts (large medium and small size) were mounted on a wooden panel. The task involved removing the nut from its respective bolt, and mounting the nut back again. The time for this activity was recorded with a stop watch.
6. The rope tying test consisted of tying a simple shoe lace knot on the same wooden panel that had the nuts and bolts. Three sizes of ropes (small, medium, and large) were used and the time to tie was recorded with a stop watch.
7. 2 PD test consisted of the subjects sliding their right index finger along the edges of the 'V block'. The distance of the point at which they felt two edges from their staring point was recorded as their tactility score. In order to keep the force at the point of contact constant the 'V block' had a balancing weight on the other side (see Figure 1).

Figure 1 shows the sketch of the experimental set up with nuts-bolts panel, and the 2PD test. Figure 2 shows the sketch of the three gloves tested. A trial lasted for about 20 minutes. Figure 3 shows a sample data collection sheet.

Results:

As of writing this report the data is in a raw form and will be analyzed in the academic year 1992-1993. The complete results are expected to be written up as a NASA Technical Paper in that period.

EXPERIMENT 2

Objective:

To develop force time relations for a number of EVA glove-pressure combinations.

Subjects:

Six subjects (three males and three females) participated in this experiment. Their participation was voluntary.

Independent variables:

The independent variables tested in this experiment were gender, glove make, pressure differential, and level of exertion. The six subjects were equally split between two genders to provide the gender differences. Three levels of pressure differentials were used in this experiment ie., 0 psid, 4.3 psid, and 8.3 psid. The intent was to develop a pressure-performance decrement profile. Three different gloves were tested here, namely current shuttle gloves (referred to hereafter as GLOVE C), and two developmental gloves (referred to hereafter as GLOVES A

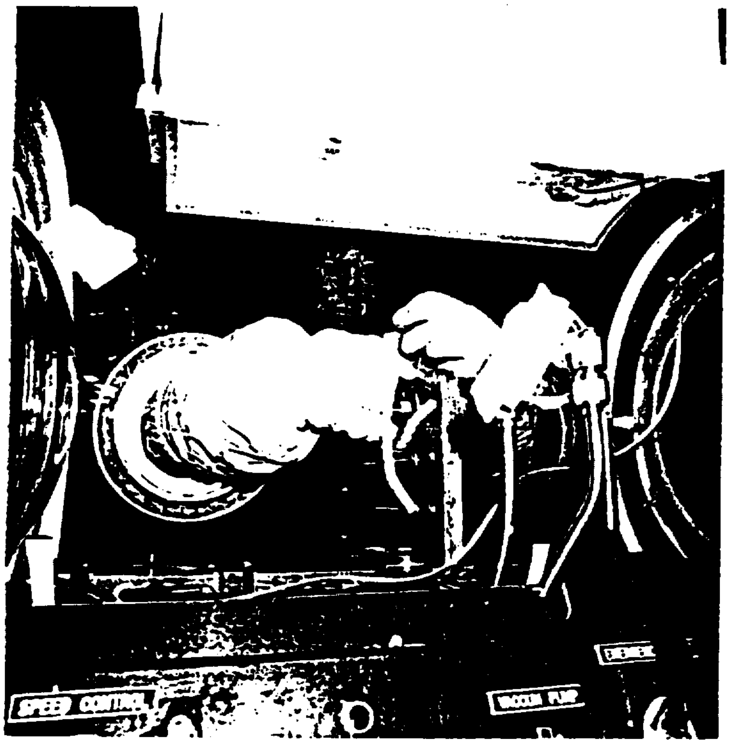

Figure 1: Nuts & Bolts Test: Experiment 1

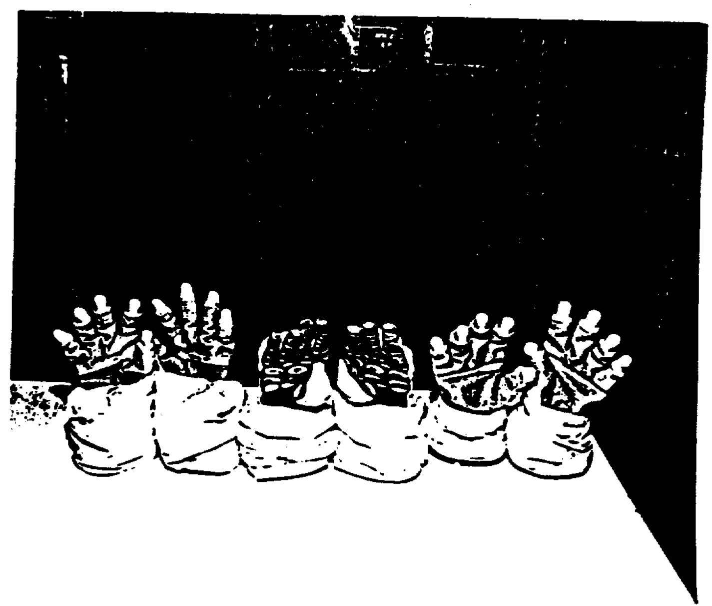

Figure 2: EVA Gloves: Experiments 1 & 2

Figure 3: Launch and Entry Suit Gloves

and B). Four levels of exertion,i.e., 100%, 75%, 50%, and 25% of maximal voluntary contraction were used here. The performance measure was the time to quit. To summarize the independent variables with their respective levels were:

1. Gender male and female.
2. Pressure 0, 4.3, 8.3
3. Glove condition A, B, C, and Bare hand
4. Level of exertion 100%, 75%, 50%, and 25%.

Procedure:

There were 36 different treatment conditions in this experiment. The order of presentation of the 36 conditions was randomized for each subject. Table 2 shows experimental design for this study.

Table 2: Experimental design for Experiment 2:

PRS	A 100%	A 75%	A 50%	A 25%	B 100%	B 75%	B 50%	B 25%	C 100%	C 75%	C 50%	C 25%
O PSI												
4.3 PSI												
8.3 PSI									*	*	*	*

* Bare handed condition at 100, 75, 50, and 25% MVC.

Initially the maximum voluntary contraction (MVC) for each glove-pressure combination was measured using a Jamar hand dynamometer. The dynamometer was wired to a TEAC recorder. The four levels of exertion at any glove-pressure combination was computed with respect to the MVC at that glove-pressure. A trial consisted of the following steps.

1. The exertion level for the'condition of the day' was first calculated.
2. The subject then exerted to the computed level on the Jamar hand dynamometer.
3. The subject maintained the level of exertion for as long as he/she could, before quitting voluntarily.
4. The endurance time was recorded through the TEAC recorder and a stop watch.

A 24 hour rest period was followed between trials. As a result the subjects performed one trial per day for 36 consecutive days.

Results:

As of writing this report the data is in a raw form and will be analyzed in the academic year 1992-1993. The complete results are expected to be written up as a NASA Technical Paper in that period.

EXPERIMENT 3

Objective:

To evaluate two types of launch and entry suit gloves.

Subjects:

Ten subjects (five males and five females) participated in this experiment. Their participation was voluntary.

Independent variables:

The independent variables tested in this experiment were gender, and glove type. There were four glove conditions, namely unpressurized partial pressure glove (LES unpressurized), pressurized partial pressure glove (LES pressurized), unpressurized full pressure glove (ACES), and bare handed condition. Figure 3 shows the sketch of the gloves used in this experiment.

Performance measures:

The performance measures were selected based on the O'Hara (1988) study, and were similar to the ones used in Experiment 1 above. The measures comprised two strength measures (grip and pulp pinch strength), two dexterity measures (panel test, and rope tying test), and a tactility measure (two point discrimination test).

Procedure:

There were four treatment conditions in this experiment. The order pf presentation of these was randomized across each subject. Within a treatment condition the order of presentation of the tasks (grip strength, pinch strength, panel test, rope tying, and 2PD test) was also randomized. A trial consisted of the following steps.

1. Grip strength was recorded through a Jamar Hand Dynamometer connected to a digital read out, and to a Teac Recorder.
2. Pulp pinch strength was measured following a 2 minute rest period using a pinch gauge.
3. The panel test consisted of flipping a number of toggle switches, and unscrewing/screwing a number of bulbs mounted on a panel. A panel with a large number of toggle switches, screwed bulbs was used in the test. The time for this activity was recorded with a stop watch.
4. The rope tying test consisted of tying a simple shoe lace knot on the same wooden panel that had the nuts and bolts. Three sizes of ropes (small, medium, and large) were used and the time to tie was recorded with a stop watch.

5. 2 PD test consisted of the subjects sliding their right index finger along the edges of the 'V block'. The distance of the point at which they felt two edges from their staring point was recorded as their tactility score. In order to keep the force at the point of contact constant the 'V block' had a balancing weight on the other side (see Figure 1).

Results:

As of writing this report the data is in a raw form and will be analyzed in the academic year 1992-1993. The complete results are expected to be written up as a NASA Technical Paper in that period.

OVERALL DISCUSSION

The data for all the experiments described above are, currently, in a raw unanalyzed form. It is expected that they will be analyzed in the following months, and will be output as distinct NASA Technical Papers. However, in order to make this report complete, some rough summary analyses have been performed, and are described in this section. Figure 4 shows the plot of Glove effect on grip strength. It is seen that a) a significant gender effect exists, and b) Glove B, and C exhibit greater grip strength. The most glaring finding is that donning gloves reduces strength by nearly 50%. Figure 5 shows a plot of the pressure differential effect. As expected performance reduces with increasing pressure differential. It appears that there are two levels of performance decrements with pressure. Performance at 3.2 and 4.3 psi look similar while performance at 6.3 and 8.3 psi appear similar, and worse than other pressure differentials. Figure 6 shows the plot of TMG effect on grip strength. A Gender Tmg interaction appears to exist, with the female strength reducing with TMG, while the male strength increasing with TMG. Size and extent of fit may be causing this result. Figure 7 shows the plot of the TMG * Glove interaction. Glove C seems to stand out from the other two. TMG seems to reduce strength on Glove C, while opposite effect is observed on gloves A, and B.

Figures 8 through to 12 deal with dexterity as measured by the total time taken on the Nuts and Bolts test. Figure 8 shows Glove effect. Two findings are interesting: a) there is a five fold decrease in dexterity when gloves are donned(60 seconds to 300 seconds), and b) male subjects' performance improves in the order A, B, and C; while female subjects' performance improves in the opposite order C, B, and A. Figure 9 shows the Pressure effect on dexterity, and as expected, performance is seen to decrease with increasing pressure. Figure 10 shows the TMG effect on dexterity. Again performance with TMG is superior to that without TMG. This was expected. However, what was not expected is shown in Figure 11. TMG * Glove interaction on dexterity is shown in Figure 11. The TMG of glove B appears to be the best, while that of glove C is the worst. The results suggest that in case of glove C TMG does not change the performance level, while it does offer the needed protection.

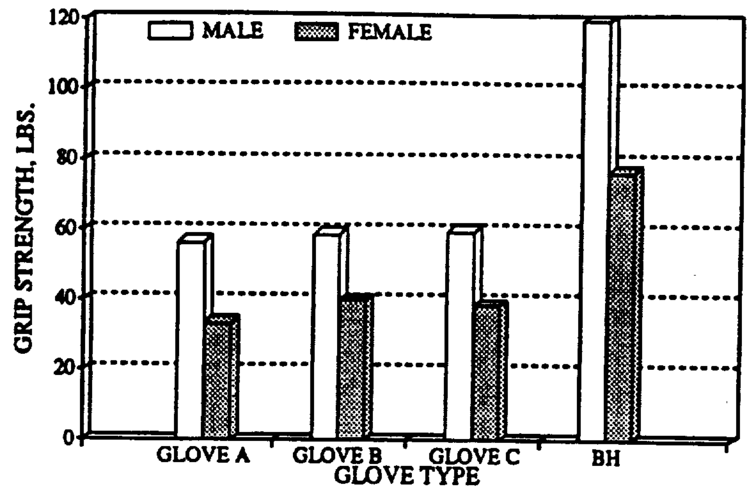

Figure 4: Glove Effect

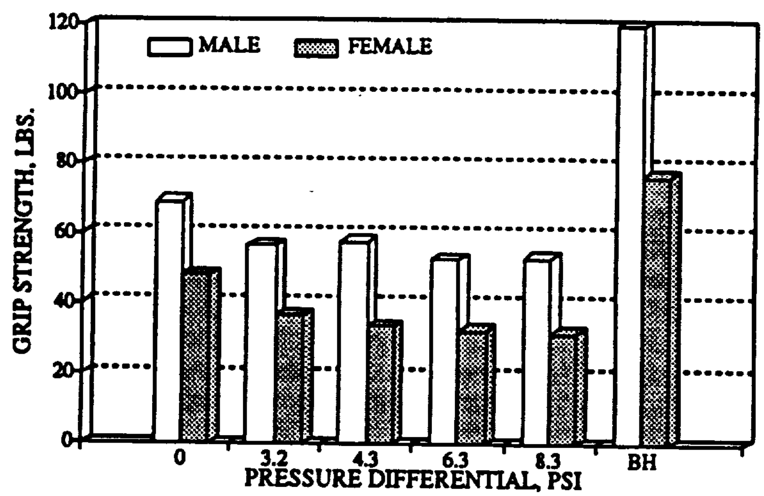

Figure 5: Pressure Effect

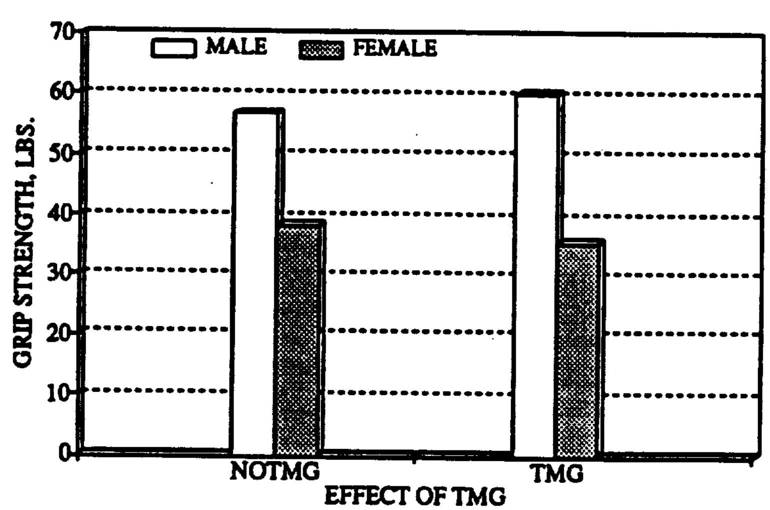

Figure 6: TMG Effect

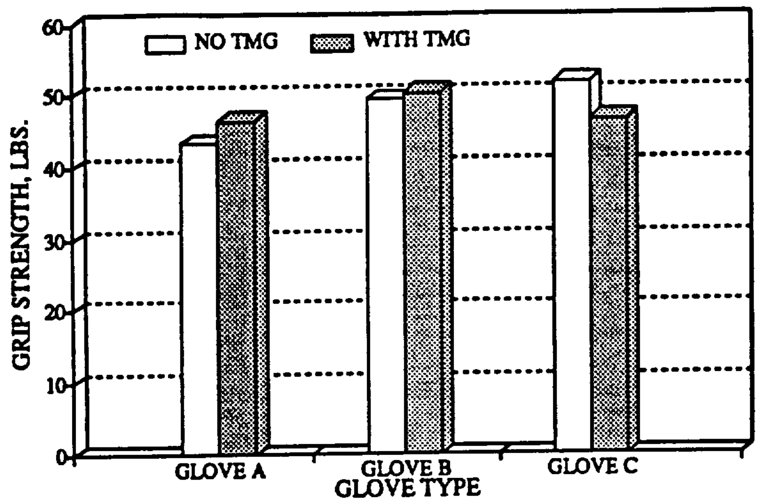

Figure 7: Glove x TMG Interaction

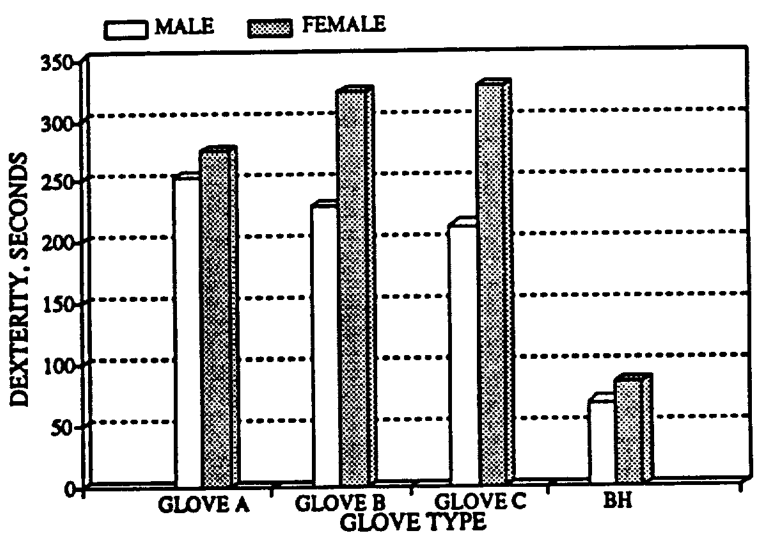

Figure 8: Glove Effect

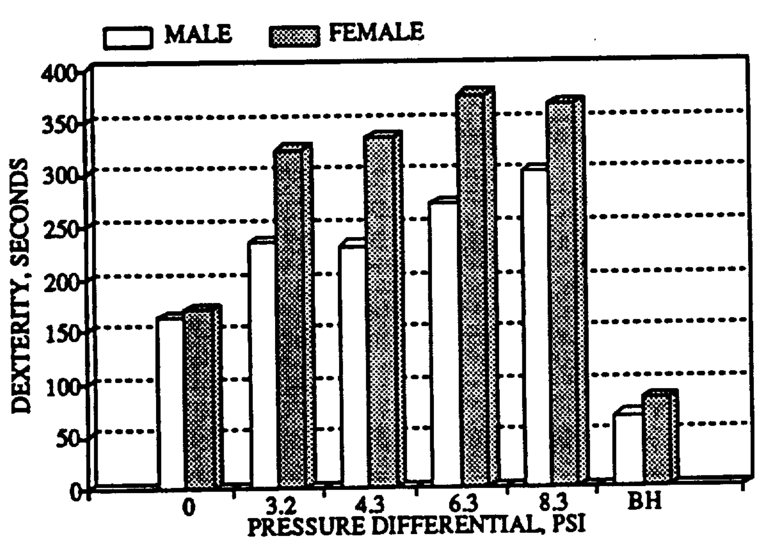

Figure 9: Pressure Effect

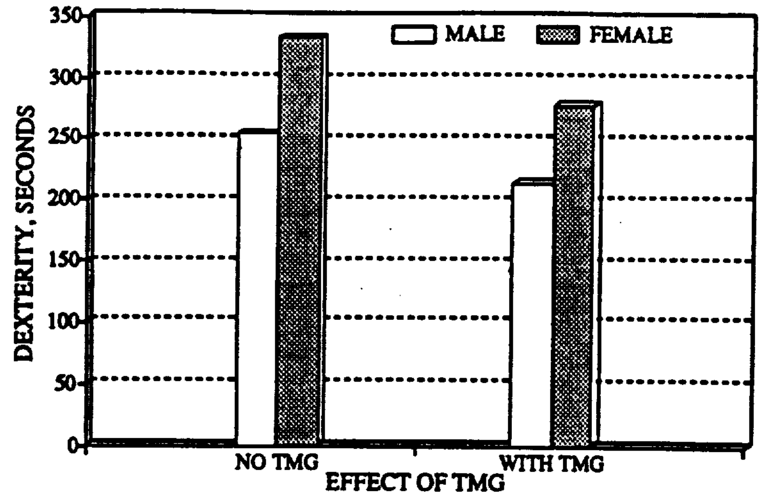

Figure 10: TMG Effect

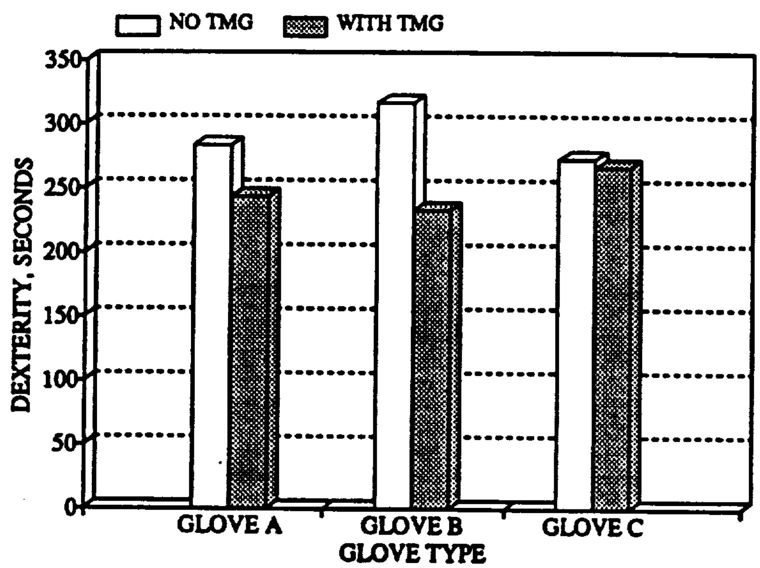

Figure 11: TMG Glove Interaction

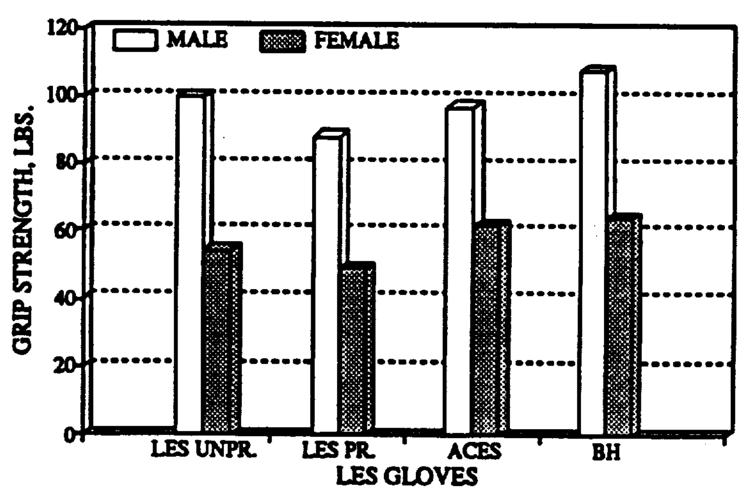

Figure 12: Glove Effect: Experiment 3

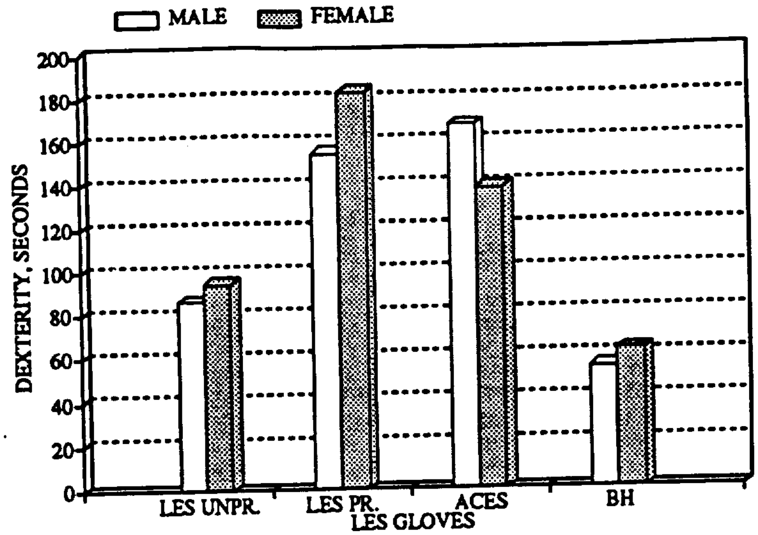

Figure 13: Glove Effect: Experiment 3

The TMG of glove B, and A in addition to the providing protection against environment seem to improve performance as well.

Figures 12 and 13 deal with the summary analysis of experiment 3 described above. Figure 12 shows the plot of Glove effect. The strength decrement is largest in case of LES glove pressurized to 2.8 psi (approximately 80% of the bare handed strength). The full pressure gloves (ACES) and partial pressure gloves seem to have similar performance in the unpressurized condition. Figure 13 shows the plot of Glove effect on dexterity, as measured by the total time taken on the panel test. The full pressure suit glove appears to be worse in performance than the partial pressure suit glove in the unpressurized condition.

CONCLUSIONS

Although the detailed analyses is still to be done, the summary analysis described above reiterates the fact that gloves do reduce hand capabilities. The findings can be summarized as follows:

1. Strength is reduced by nearly 50%.
2. Performance decrements increase with increasing pressure differential.
3. TMG effects are not consistent across the three gloves tested. More research is needed.
4. Some interesting gender glove interactions were observed. Some of these may have been due to the extent (or lack of) fit of the glove to the hand.
5. Differences in performance exist between partial pressure suit glove and full pressure suit glove, especially in the unpressurized condition.

REFERENCES

A complete list of references on this report will be published along with the detailed analysis through the NASA Technical Papers to be published at a future date. Meanwhile interested persons can contact the author for a detailed reference list.