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Effects of Gloves and Visual Acuity on Dexterity

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by

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Effects of Gloves and Visual Acuity on Dexterity

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ABSTRACT

Work in many environments with chemical or biological agents requires the use of personal protective equipment such as gloves and respirators. It is well established that glove thickness affects finger dexterity. There is further evidence that visual constraints (e.g., visual acuity) and gender may also impede finger dexterity. Therefore, the personal protection may place a barrier to the agent, but performance or productivity will decrease. The purpose of this study is to examine the potential effects of gloves and visual acuity as well as gender and first order interactions on task performance using standard dexterity tests.

Five men and five women volunteered as participants in the study. There were four levels of gloves: None (as control), 9 mil, 18 mil and 28 mil unlined latex gloves were used. There were five levels of visual acuity: None as a negative control, masked goggles as a positive control, and masked goggles with occlusion foils of 20/50, 20/100 and <20/300. A full factorial design was used and the combinations were randomly assigned. Three platforms were used for this study: Purdue Pegboard, Grooved Pegboard and the placing task of the Minnesota Dexterity Test.

These results showed that the main factors of Glove and Goggle were significant for all platforms and Gender was significant for the Purdue Pegboard and Grooved Pegboard. There were significant interactions among the main effects but these did not demonstrate a consistent pattern.

The largest differences in performance were associated with the gloves, even at the least thickness of 9 mil. The increased thickness to 18 and 28 mil resulted in significant and large losses of performance. It was most marked with the smaller pieces of the pegboard tasks. Generally women performed better than men for the pegboard tasks as expected and there were no differences for the larger pieces of the Minnesota tasks. Except for the greatest decrement in visual acuity, the differences among the levels of visual acuity were not significant. The expected interaction between gloves and acuity was not observed.

Effects of Gloves and Visual Acuity on Dexterity

Introduction

The problems associated with hazardous materials handling are numerous and complex. Some of these problems are associated with skin contamination by chemicals or possibly bodily fluids. Thus, for adequate protection against these harmful conditions, a person may be required to wear both gloves and respirators while having to complete tasks that require fine motor control. One must consider that hazardous materials incidents can occur at any stage of hazardous material processing, handling, transport, disposal and even storage or waste containment (NIOSH, 1984). Therefore, in most cases, wearing personal protection remains an effective practice that ensures the employees' safety.

However, an employee must efficiently complete his or her task while remaining protected as well. Using personal protective equipment might prolong the time required to perform the task. Therefore, using personal protective equipment that maintains its effectiveness as well as affecting ease of completing tasks, illustrates dilemma.

Protective Gloves

The use of hand protection, mainly in the form of protective gloves, is a common requirement for workers who are involved in handling of hazardous materials and clean ups. However, the problem of selecting the proper gloves to use for hazardous materials incidents or situations from a manual dexterity point of view has often been ignored. Furthermore, due to the nature of the chemicals agents, a single type of glove may not be adequate to provide the required degree of protection for every chemical.

To address this issue, various thickness and materials for gloves may increase the protection against chemical contamination. However, the thickness of the protective gloves may introduce problems for those who perform tasks requiring fine manual dexterity. Additionally, prolonging the time required to perform a task may compromise workers' safety and the dexterity associated with the task may be affected also.

For example, heavier gloves, although highly effective against contamination, often negatively affect the dexterity. This accepted loss of tactility and dexterity, associated with use of thicker gloves, induced investigators to determine exactly how varied glove thicknesses may affect the outcome of any dexterity task. Thus, studies involving dexterity testing of protective gloves were conducted principally to compare various types of gloves and identify those producing optimum manual performances.

Visual Acuity

Visual clarity presents another challenge when attempting to accurately perform any workplace task. This factor is significant in providing feedback about moving objects as well as the spatial characteristics of the environment (Dooly et al 1994). One parameter of visual clarity is visual acuity. This ability determines the definition of objects in one's field of view. Visual acuity consists of the ability to recognize the detail of an object (unmoving objects) and the ability to recognize the details of that subject when there is a relative motion between the subject and object.

Some tasks such as running, lifting and tasks that do not need hand eye coordination at very accurate level do not require high degrees of visual acuity. However, tasks performed at more moderate or detailed workstations usually require sharper vision.

Fine motor tasks also require a fair degree of visual response. Vision can be reduced when a person is wearing a respirator or safety goggles; thus, task performance based on fine handwork may be reduced.

Literature Review

Typical human hand performance demands include activities such as fine manipulation of objects, fast movement of an object, frequent movements between targets, forceful activities with little or moderate displacement, and forceful activities with large displacements (Chan, 2000). Previous investigators have found that gloves in general reduce performance on hand performance tasks. A survey of the literature revealed only a small selection of studies addressing visual limits (like respirator use) while performing a hand task and even fewer studies conducted on task performance while using a combination of gloves and respirators.

Gloves

Waugh and Kilduff (1984) used the performance time of completing two missile maintenance tasks to compare the difference between wearing the standard military MOPP glove and not wearing it. They concluded that using the glove increases the task time by approximately 17.6%.

Considering that desirable dexterity must be accomplished with acceptable protection and performance, two different kinds of gloves were designed by Muralidhar et al. (1998). To select a method of evaluating the gloves, performance was determined by the number of completed actions in a fixed time amount or the amount of time to complete a fixed task. The tasks were Bock Manipulation Task, Pegboard task, Assembly task, and Rope Knotting task. The Block Manipulation Task required the subject to manipulate and turn over 6 wooden cubes ranging from one-half inch on a side to 3 inches side, one cube at a time using the dominant hand. This test was scored by the time taken to turn over all the blocks. In the Pegboard Task, the subject was required to pick up 20 wooden pegs from a pegboard with non-dominant hand, turn them over and place them in another pegboard with the dominant hand. This task was performed twice and the scoring was the time to turn all the pegs. The Assembly task was a modified Pennsylvania Bimanual Work-Sample Assembly test. The subject was required to pick up and assemble small objects and place them in a container. The small objects used as the work-sample were nuts and bolts, placed in front of the subjects in separate trays. This test was scored by the number of assemblies completed in two minutes. The Rope Knotting task was a test for bimanual dexterity. The subject was required to wrap a thin flexible rope twice around a 1 in thick wooden dowel, and make two freehand knots, suspending the dowel from the rope. The task was scored as the number of seconds taken to complete the two knots.

The subjects wore four varied styles of gloves: Single Glove, Double Glove, Contour Glove (a prototype glove with two layers of protection) and Laminated Glove (a prototype glove with four layers of protection) with an ungloved hand for the control. In comparing mean number completed for these task or time to complete the task, they concluded that the heavier gloves reduced productivity by decreasing the number completed in a fixed period of time or it required additional time per unit to perform the task compared with the single glove or bare hand. Table 1 summarizes the results for the gloves tested as a percentage of bare hand performance.

Table 1. Decrease in performance for four gloves relative to bare hands for four two-handed tasks (Muralidhar et al. 1998)

	Block Manipulation	Pegboard	Assembly	Rope Knotting
Bare Hand	100 %	100 %	100 %	100 %
Single Glove	85 %	84 %	71 %	58 %
Double Glove	76 %	80 %	67 %	48 %
Contour Glove	77 %	82 %	66 %	42 %
Laminar Glove	80 %	78 %	58 %	45 %

Plummer et al. (1985) studied the effects of gloves on dexterity. They used nine gloves—three single gloves and six double gloves—with bare hands as a control. The Bennett Hand Tool Dexterity Apparatus was used in this study. This test consisted of a U-shaped board with several holes drilled on the sides of the boards. There were three different bolts, nuts, and washers (1/2”, 5/16” and 1/4”); a screwdriver; two sizes of open-end wrenches; and an adjustable wrench. The proper bolts were inserted into their corresponding holes, and a washer and nut were positioned at each site; the subjects then tightened the bolts. The subjects were instructed to use a specific set of tools for each of the bolt sizes. This task required the subject to disassemble and assemble six bolts per glove type. The results are summarized in Table 2. Based on their analyses, using two layers of gloves generally increases the average completion time by 19% to 37%. While there was a tendency for the number of errors to increase with the double layers, the trend was not overwhelming.

Table 2. Average total time in seconds to complete a fixed set of tasks using the Bennett Hand Tool Dexterity Apparatus (Plummer et al. 1985)

Gloves	Completion Time (s)	Percent Increase
Bare Hand	67.7	0 %
Butyl	75.8	12%
Stansolv	79.7	17%
Latex / Stansolv	80.8	19%
Viton	81.9	21%
Stansolv / Butyl	84.3	24%
Latex / Stansolv	84.5	25%
Latex / Viton	87.7	29%
Stansolv / Viton	90.1	33%
Butyl / Viton	90.7	34%

McIntosh (1987) used a standardized test methodology to evaluate the manual dexterity allowed by different types and combinations of gloves. Six single gloves and three combinations of gloves were studied. The subjects were employees in a chemical plant and they performed a battery of two tests. One was the Bennett Hand Tool Dexterity Test (see the descriptions in the Plummer et al. 1985 study) and a Chlorine Cylinder Hood for Value Task Simulation, which simulated the actual emergency condition of a leaking chlorine gas valve following the Chlorine Institute Emergency Kit “A”. For the cylinder simulation task, various sections of the cylinder (hood, chain, yoke and the diamond links) were supposed to be checked for the leaking gas. This task required assembling and disassembling the hood and the chain. Specific wrenches and other tools were used for this task.

Time to complete each task and the numbers of errors committed during each task were the response variables in this study. The analyses of this study were calculated using ANOVA. The results revealed that task completion time was affected by the thickness of gloves. The gloves and combinations are displayed in Table 3 and include the average completion time for both tests as well as the performance changes. Table 3 represents the results of nine gloves and combinations, the average total completion time for each test, and the relative increase from the baseline.

Table 3. Completion time and percentage increase for Bennett Test and Cylinder Simulation task for nine gloves and combinations of gloves (McIntosh 1987)

	Bennett Test		Cylinder Simulation	
Glove	Completion Time (seconds)	Percent Increase	Completion Time (seconds)	Percent Increase
Bare Hand *	73.8	0 % (baseline)	65.4	0 % (baseline)
Butyl	80.5	9%	71.7	9%
Latex	83.4	13%	72.6	11%
Nitrile	83.6	13%	73.7	12%
Viton	88.9	20%	76.8	17%
Latex-Nitrile	89.0	15%	76.9	12%
Butyl-Viton	90.8	23%	77.2	12%
Butyl-Leather	101.1	37%	84.3	29%
PVC	101.4	37%	89.1	36%
Neoprene	115.1	56%	96.6	31%

* Estimated from Plummer et al (1985) with an adjustment multiple of 0.94 based on Butyl and Viton.

In the study of Dexterity Testing of Chemical Gloves by Robinette et al. (1986), four styles of chemical gloves were investigated to assess their dexterity. The glove types included (a) 12.5 mil Epychlorohydron / Butyl, (b) 14 mil Epychlorohydron / Butyl, (c) 14 mil Butyl, and (d) 7 mil Butyl with Nomex overglove. In their research, 15 males and 15 females were employed to perform four dexterity tests:

- Pennsylvania Bi-Manual Work sample-Assembly. The subject picked up bolts with the dominant hand and a nut with the other hand; after positioning the nuts and bolts together, the assembled unit was placed in the corresponding hole. Each board contains 10 rows of 10 holes. For this study, subjects completed one row for practice and four rows for testing.
- O'Connor Finger Dexterity Test. This includes a one-handed test. Tasks were completed by using only one hand. The subject picked up three pins at a time and

inserted them into one hole each. The test board has 5 rows; the first row is for practice and four rows are used for the actual test.

- Minnesota Rate of Manipulation Turning. This test is a two handed-test. The subject was asked to pick up, turn round blocks over, and putting them back bottom side up with the other hand in their slots.
- Crawford Small Parts Dexterity Test-Screws. This test involves use of the fingers to thread a small screw into a hole and use of a screwdriver to turn it through a board. The board contains six rows of six holes each—one row exists for practice and two rows for the actual test.

The results are summarized in Table 4.

Table 4. Time to completion and percent increase by male and female participants for four tasks and for five glove conditions (Robinette et al. 1986)

	Male		Female	
Task Platform and Hand Status	Completion Time	Percent increase	Completion Time	Percent increase
Minnesota Test				
Bare Hand	35.38	-	34.69	-
EB 12.5	41.16	16%	41.60	20%
EB 14	43.07	21%	43.89	26%
B14	43.38	22%	46.49	34%
Butyl 7/ Nomex	49.51	40%	53.04	52%
O'Connor Test				
Bare Hand	157.47	-	145.2	-
EB 12.5	191.22	21%	185.91	28%
EB 14	197.20	25%	193.04	32%
B14	206.02	31%	195.20	34%
Butyl 7/ Nomex	237.71	51%	241.67	66%
Pennsylvania Test				
Bare Hand	125.69	-	133.84	-
EB 12.5	165.56	31%	174.56	30%
EB 14	172.78	37%	178.78	33%
B14	182.87	45%	183.47	37%
Butyl 7/ Nomex	219.87	74%	243.07	81%
Crawford Test				
Bare Hand	148.73	-	178.36	-
EB 12.5	196.93	32%	231.62	30%
EB 14	193.91	31%	231.40	30%
B14	195.91	30%	233.04	31%
Butyl 7/ Nomex	230.07	54%	293.67	34%

Robinette et al stated several conclusions: (1) There was no difference by gender; (2) All the gloves decreased performance compared to bare hand performance; (3) The Butyl 7/Nomex combination was significantly worse in all tasks; (4) The performance was better with EB 12.5 gloves than with the EB 14 gloves (i.e., thicker gloves decreased performance); and (5) For the same thickness the material may make a difference (i.e., EB 14 gloves were better than B14 gloves).

Bensel (1993) conducted a study to determine the effect of the thickness of gloves on manual dexterity. She performed five dexterity tasks with three gloves that differed by thickness with a bare hand condition as control. The glove thicknesses were 7mil, 14mil, and 25mil. Bensel compared the mean time to completion over 14 sessions based on five alternate platforms. The platforms were:

- Minnesota Dexterity Test. It involved both finger and whole-hand dexterity. It required that cylindrical block removed with one hand turned over and placed by the other hand.
- O'Connor Finger Dexterity Test. Pure test of finger dexterity. It required picking up three pins at a time and placing them in a hole using only the preferred hand.
- Cord and Cylinder Manipulation test. It is a two-hand test involving alternately stringing small cylinders on cord loops attached to a flexible base and intertwining the loops to form a chain with one cylinder mounted on each of 10 links.
- Bennett Hand Tool Test. It is a measure of the proficiency in the use of tools. In this test they used wrenches and screwdriver to open the nuts and bolts and relocate and tightening them
- Rifle Disassembly/Assembly test. This is a test of assembling and reassembling of an Army M16A1 rifle.

Each subject participated in 14 testing sessions. In this study, the main results of the study over different sessions and time are reported. Table 5 presents the mean time to completion versus thickness of gloves as average over six sessions selected over a total of 14 sessions.

Table 5. Completion time (in seconds) for each of four dexterity tests and for each glove condition as a mean of all subjects across six sessions (2, 4, 7, 9, 12 and 14) representing the range of sessions and the percent increase from the bare hand (no glove) condition (Bensel 1993).

Hand Status	Completion Time (s)	Percent Increase
Minnesota		
Bare Hand	31.36	-
7mil glove	33.87	8 %
14mil glove	36.58	16%
25mil glove	40.63	29%
O'Connor		
Bare Hand	77.74	_
7mil glove	86.70	11.5%
14mil glove	90.18	16%
25mil glove	98.85	27.1%
Cord and Cylinder		
Bare Hand	46.10	-
7mil glove	54.32	17.8%
14mil glove	64.04	38.9%
25mil glove	74.32	61.2%
Bennett		
Bare Hand	124.28	-
7mil glove	129.84	4.4%
14mil glove	130.87	5.3%
25mil glove	144.38	16.1%
Rifle Assembly/Disassembly		
Bare Hand	55.86	-
7mil glove	59.68	6%
14mil glove	63.56	13%
25mil glove	69.33	24%

For all of the tasks, there was an increase in performance time as glove thickness increased. The changes depended on the task.

Other factors may influence performance. One of these is size. Both Plumber et al. (1985) and McIntosh (1987) reported statistically significant effects due to bolt size in the Bennett test. The findings summarized in Table 6 suggested that the subjects experienced increasing difficulty in handling the parts as part size decreased.

Table 6. Comparison of total completion time for three bolt sizes in Bennett test

Bolt Category	Bolt Diameter	Plummer et al (1985)	McIntosh (1987)
Large	1/2 inch diameter	81.9	84.1
Medium	5/16 inch diameter	84.4	97.5
Small	1/4 inch diameter	91.4	not used

Another factor is gender. Robinette et al. (1986) studied four styles of chemical protective gloves to assess their dexterity. He grouped the subjects in two groups: male and female. His results revealed no significant variation between the male and the female performance during specific tasks. The normative data from standard dexterity tests report gender differences. For instance, there was a difference between male and female in performing tasks for all tasks of Pegboard platform and Grooved Board platform. In all tasks, the average performance for female is better than male. Table 7 reports the difference between male and female for both test platforms.

Table 7. Gender differences in performance based on normative data for the Purdue Pegboard and the Grooved Pegboard platforms

Purdue Pegboard				Grooved Pegboard			
	Male	Female	Percent Increase for female over male		Male	Female	Percent Increase for female over male
Right Hand	13.59	15.18	11%	Dominant Hand	87.1	83.5	4%
Left Hand	13.18	14.49	9%	Non Dominant Hand	93.1	90.5	3%
Both Hands	10.81	12.24	13%				
Assembly	27.86	36.19	30%				

Bensel (1993) found that performance improved for five tasks over 14 sessions. That is, there appears to be a significant and continuing learning effect.

The overall conclusions on gloves are that (1) gloves impede performance when compared to bare hand, (2) part size may effect performance, (3) gender may affect performance and (4) task complexity is a factor.

Respirator Masks and Visual Acuity

A respirator mask may reduce visual performance and reveal an indirect effect on hand performance. Johnson et al (1994) suggested that the accuracy of hand operations remains directly dependent on an individual's visual activity. Thus, wearing respirators while performing various tasks might reduces productivity and performance. They attributed visual limitations in task performance while wearing respirators to the following conditions:

- Moisture condensation while cooling the environment
- Deposition of fines particles outside the mask
- Scratched lenses
- Wearing eyeglasses under a respiratory mask

Waugh and Kilduff (1984) used the performance time of completing two missile maintenance tasks to compare the difference between wearing the standard military respirator (a mask/hood) and not wearing it. They concluded that using mask/hood combinations increases the task time about 18%.

Johnson et al (1994) employed 46 subjects to perform a console monitoring and two hand-eye coordination tasks while wearing military respiratory protection masks with degraded lenses to provide seven levels of specified visual acuity: 20/25, 20/30, 20/40, 20/50, 20/70, 20/100 and the respirator mask alone (no change in the lens). There was a no-mask control. They measured the actual visual acuity as a mean of Snellen Line Scores.

There were three tests used in this study: two hand-eye tests (Tracking and Random) and the Saccadics test. For the Random Hand-Eye Coordination test, specific squares were lit in completely random patterns. Correct scores were obtained when the subject touched the square while it was lit. For the Tracking Hand Eye Coordination test, the squares lit one at a time in serpentine patterns (particular order) on a board. Squares were lit only for 0.7 seconds each. Correct scores were obtained by touching the square while it was lit. For both tests, the number of correct responses was automatically scored (Johnson et al., 1994). For the Saccadics test, performance tests demonstrated an easily quantifiable example and represented varied visual abilities. Additionally, it represented console monitoring, based on a computer program displayed on a monitor. The two letters, "A" or "C," randomly appeared on the monitor and the subject was required to press the right key on the keyboard within 0.67 seconds: the faster and more accurate the response, the higher the maximum score. Test results provided in Table 8 revealed that impaired visual acuity could reduce the score by 35% for hand-eye coordination tasks, and by 50% for monitoring tasks (Saccadics test).

Table 8. The specified visual acuity and actual visual acuity and the decrements in performance for three tasks requiring eye-hand coordination (Johnson et al 1994)

	Control	*Mask*	*20/25*	*20/30*	*20/40*	*20/50*	*20/70*	*20/100*
Actual Acuity	20/14	20/15	20/20	20/23	20/28	20/30	20/36	20/5
Hand-eye Decrement	0	15%	21%	23%	26%	28%	34%	36%
Tracking Decrement	0	6.1%	8.5%	11.6%	10.1%	9.7%	13.9%	15.1%
Saccades Decrement	0	1.5%	4%	11%	20%	29%	34%	50%

In another study addressing altered vision, Dooly et al. (1994) repeated Johnson's study. They used scratched lenses with specified acuity of 20/25, 20/30, 20/40, 20/50, 20/70 and 20/100 as a result of multiple pilot-testing on ten subjects. Actual visual acuity was determined by a Snellen chart similar to Johnson et al. (1994). Table 9 represents the results of their study.

Table 9. The specified visual acuity and actual visual acuity and the decrements in performance for three tasks requiring eye-hand coordination (Dooly et al 1994)

	Control	Mask	20/25	20/30	20/40	20/50	20/70	20/100
Actual Acuity	20/15	20/15	20/20	20/23	20/28	20/34	20/38	20/64
Hand-eye Decrement	0	15.3%	20.3%	24.7%	26.3%	28.1%	34.4%	37.1%
Tracking Decrement	0	7.4%	9.2%	11.5%	11.1%	11.4%	14.9%	17.2%
Saccades Decrement	0	1.6%	5.9%	11.8%	21.4%	29.6%	35.3%	50.8%

Combination of Masks and Gloves

Wang and Kilduff (1984) compared performance time between a standard uniform and the MOPP-4 configuration with a mask/hood respirator and gloves. The two tasks were TOW self-test and Dragon test. The TOW self-test was a simple repair test. The Dragon test was more difficult and required assembly of a missile part. The experiment was organized as a pair of two-way designs with replications. Each task had three replications and it was based on random assignment.

Comparing the mean values between the performance of the uniform and MOPP-4, they found that the MOPP-4 caused an overall increase of 45.3%. This was greater than the combined increases due to gloves and to mask (35.2%)

Hypotheses

Based on the literature review, it is clear that gloves and visual acuity may reduce performance. Furthermore, only one study investigated the interaction of both gloves and vision, and they discovered a significant interaction.

For this study, the Null Hypothesis is that there is no effect of using gloves and reduced visual acuity on dexterity. The Alternative Hypothesis is that there is an effect of gloves and acuity on dexterity and an interaction effect between gloves and acuity.

Methods

The purpose of this project was to examine the effects of gloves and visual acuity on finger dexterity with considerations of gender and part size. To this end, a laboratory experimental design was developed.

Participants

The entrance criteria were normal vision or corrected vision with contact lenses. There was no test of visual acuity for the subjects. As this study involved human subjects, each subject was required to provide consent per IRB protocol.

Ten participants, five men and five women, at the University of South Florida were recruited to participate in this study. All participants were right hand dominant.

Dexterity Test Platforms

Three platforms were used to simulate finger dexterity and hand motions. Each platform included different tasks that used each hand separately or together

Purdue Pegboard Test.

Joseph Tiffen developed the Purdue Pegboard Test in 1948. This device is used extensively to aid in the selection of employees for jobs that require fine and gross motor dexterity and coordination. It involves gross movements of hands, fingers and arm, and fingertip dexterity. The pegboard is complete with pins, collars, washers, and an examiner's manual with norms.

Figure 1. Photograph of Purdue Pegboard Test

There are two columns of small holes in which the pins can be mounted. Pins, collars, and washers are located in four cups mounted on the top of the board. The board is placed squarely in front of the subject, parallel to the edge of the table. At the far right side and far left side are cups designed for the pins. The washers and collars are placed in the other two cups between those containing the pins.

If the subject is right handed, collars are in the immediate cup to the left of the right cup with the pins, and if the subject is left handed, the collars are placed in the immediate cup to the right of the left cup containing the pins. The cups containing pins are filled with 25 pins. Then the immediate cup to the right side of that is filled with 20 collars and the cups immediate to the left side of the board contain 40 washers. In the case of left-handed subject, the placement of collars and washers are reversed.

The test starts with the dominant hand.

Evaluation is based on four separate scores:

1. Right Hand (Dominant Hand) (number placed in 30 seconds)
2. Left Hand (Non-Dominant Hand) (number placed in 30 seconds)
3. Both Hands (number placed in 30 seconds)
4. Assembly using Both Hands (number of assemblies in 60 seconds)

The subject performs the sequence of tasks three times in one session.

Grooved Pegboard Test.

The Grooved Pegboard Test is a manipulative dexterity test consisting of 25 holes with randomly positioned slots. Pegs with a key along one side must be rotated to match the hole before they can be inserted. This test requires more complex visual-motor coordination than typical pegboard tests. Some common uses are student labs, screening procedures in industry, and evaluating lateralized brain damage.

Figure 2. Photograph of Grooved Pegboard Test

The score reflects the time required to place all 25 pegs into slots. First, the dominant hand is used, then the non dominant hand and finally both hands are used. The subject performs the three tasks three times in one session.

Minnesota Dexterity Test.

The Minnesota Dexterity Test is a frequently administered, standardized test for the evaluation of a subject's ability to move small objects various distances. The complete test consists of three varied sections: Placing Test, Turning Test and Displacing Test. The Placing task was the one used in this study. The disk-shaped pieces are arranged above the board. The participant moves then into a template closer to the body.

The scores are based on the total time required to complete an entire task. The test starts with the dominant hand and then proceeds to non dominant hand and lastly, both hands. Each task was repeated three times in one session.

Figure 3. Photograph of Minnesota Dexterity Test

Visual Acuity

The study is based on controlling visual acuity. The Stealth Goggles were in this study as the vehicle to control acuity through occlusion foils. The foils with specified acuities of 20/50 (0.4 occlusion), 20/100 (0.2 occlusion) and <20/300 (<0.1 occlusion) were mounted inside separate sets of goggles. The occlusion foils were masked around the edges to direct the subjects view only through the foils. These are shown in Figure 4.

Five levels of acuity/goggles were employed in this study:

1. No goggle (Bare Face) as Negative Control
2. Only Goggle as Positive Control
3. 0.4 Occlusion = 20/50 Visual Acuity
4. 0.2 Occlusion = 20/100 Visual Acuity
5. <0.1 Occlusion = 20/300 Visual Acuity

Figure 4. Photograph of Stealth Goggles with occlusion foils and masking.

Gloves

Three thicknesses of unlined latex gloves were included in this study plus a control for four levels of gloves.

1. No Glove (Bare Hand) as a Control
2. Unlined Latex Glove 9 mil
3. Unlined Latex Glove 18 mil
4. Unlined Latex Glove 28 mil

Experimental Conditions

The experiment was designed as a complete factorial so that participants act as their own controls and could be compared to all combinations of experimental treatments. The treatments were gloves and goggles. Table 10 illustrates the combinations of gloves and goggles.

Table 10. Combinations of gloves and goggles in the factorial design with letter codes for each cell.

Glove\Goggle	No Goggle	Simple Goggle	20/50 Goggle	20/100 Goggle	<20/300 Goggle
No Glove	A	B	C	D	E
9 mil	F	G	H	I	J
18 mil	K	L	M	N	O
28 mil	P	Q	R	S	T

All combinations were performed on different days following a pre-assigned random sequence of sessions for each participant. This minimized the effects of learning, which could affect the results. Further, the sequence of platforms within a session was randomized to minimize the effect of order.

Experimental Sessions

All the subjects were directed to perform their tasks according to a pre-determined, randomized schedule. The schedule had the following characteristics.

- There were three platforms: Pegboard, Grooved Board, and Minnesota Board.
- Each platform had specific tasks that followed a prescribed order: Right hand, Left hand, Both hands
- Each task was completed once in the specified order and the order was repeated three times
- All three platforms were randomly assigned for each trial

Analyses of the Results

Data were analyzed by SAS statistical packages. The main effects and interactions among individuals, gloves, and goggles were examined by ANOVA.

For the Pegboard test, the number of pegs placed in the holes for a fixed interval was the dependent variable. For the Grooved Board and Minnesota Board, the time required to perform the task was the dependent variable.

Results

Laboratory tests were performed to examine the role of gloves and vision on dexterity. There were four levels of gloves and five levels of vision in a complete factorial design and participants were nested by gender. The study design called for each participant to complete 10 tasks three times for each combination of glove and goggle, where the tasks were distributed among three platforms. Ten participants were recruited and completed all experimental protocols, and two other participants completed only one or two sessions. A univariate analysis was used to review the distributions of study variables. This was followed by an analysis variance to explore main effects and two-way interactions. A multiple comparisons test targeted areas where significant differences occurred in the main effects.

Data Set and Univariate Distributions

During the individual sessions, data were recorded manually on worksheets designed for data collection. The data were then transferred to a spreadsheet in preparation for analysis.

The data were organized into five groups of columns as follows:

- The first group was the organizational information. They included the participant identifier (ID), gender, level of vision (Goggles), level of gloves, and the order number (the first, second or third trial in a session defined by Goggles and Gloves). For Goggles the levels were: None (Bare Face), Standard (Only Goggle), 20/50 Visual Acuity (L1), 20/100 Visual Acuity (L2) and <20/300 Visual Acuity (L3). For Gloves, the levels were: None (Bare Hand), Unlined Latex glove 9 mil (G1), Unlined Latex glove 18 mil (G2), Unlined Latex glove 28 mil (G3).
- The second group was the data from the Purdue Pegboard platform. These were the number of pegs inserted into holes in 30 seconds with the right hand (DR), left hand (DL), both hands (DBoth) and the computed sum of these three values

(DRHBoth). The fifth value is the number of assemblies completed in 60 seconds (DAss).

- The third group was the data from the Grooved Board. The values were the total time in seconds to complete the assigned task for the right hand (also dominant) (GDTT) and for the left hand (non-dominant) (GNonTT).
- The fourth group was the data from the Minnesota Board that included the right (dominant) hand (MR), the left (non-dominant) hand (ML) and both hands working together (MBoth).

The distributions of the data were examined with a univariate analysis of the data in JMP v5.1. It was clear that the distributions of time to completion for the Grooved Board and Minnesota Board for a predetermined number of efforts were skewed toward higher times. To bring in those values, a logarithmic transformation was applied to those times by taking the base-10 logarithm (log) of each individual time. The log-transformed data were subsequently used in the analysis of variance and multiple comparisons. The last group of data was the log-transformed values: lnGDTT for GDTT, lnGNonTT for GNonTT, lnMR for MR, lnML for ML and lnMBoth for MBoth.

Analysis of Variance

The principal goal of the research was to examine the effects of gloves and vision on manual dexterity. Other factors that may influence the results were gender and experience with the manual activity of the test platforms.

A complete factorial design was selected for the experiments, which lent itself to an analysis of variance to determine statistical significance. As a learning effect was expected, the design called for a randomization of participant assignment to treatment groups. To examine whether there was a change in performance from the first to the third repetition of the test within a session, a 4-way ANOVA for main effects was run. The main effects were participant ID, Glove, Goggle, and Order. For the most part, there were no significant effects for Order except for the Minnesota Board for the right and left hands alone. The significant effects were present for both the time values and the log-transformed times, and in all cases, there was a monotonic improvement in mean performance from the first to the third repetition. Using Tukey's Honestly Significant Difference (hsd) as computed by JMP on the least squares means, the significant difference was between the first and third repetition with the second repetition resembling the first and the third. The effect of Order was not considered further in the analyses.

The next step was considering more fully the main effects and first order interactions. To accomplish this, Goggle, based on five levels (None, Standard, L1, L2 and L3); Gloves, based on four levels (None, G1, G2, and G3); and Gender were treated as main effects. Participants were nested under Gender. The dependent variables were the right and left hands, both hands, and the assembly tasks for the Pegboard; the right and left hands for the Grooved Board; and right, left and both hands for the Minnesota Board. The results by level of significance are presented in Table 11.

Table 11. Statistical significance for main effects of Gender, Glove and Goggle, and for the first level interactions.

	Gender	Glove	Goggle	Glove x Goggle	Gender x Glove	Gender x Goggle
Pegboard						
Right Hand	***	***	***	*	-	**
Left Hand	***	***	***	*	***	-
Both Hands	***	***	***	-	***	***
Assembly	***	***	***	*	***	***
Grooved Board						
Right Hand	***	***	***	-	-	***
Left Hand	***	***	***	***	***	***
Minnesota Board						
Right Hand	-	***	***	***	-	***
Left Hand	-	***	***	**	-	***
Both Hands	-	***	**	-	-	***

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

Gender was significant for the two platforms that required manipulation of the small pieces (i.e., Pegboard and Grooved Board), but not for the Minnesota Board, which had larger pieces to manipulate. There were significant effects for Gloves and for Goggles among all the tests.

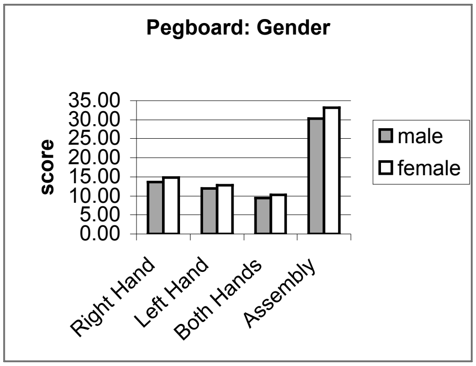
Among the interactions, the interaction of Glove x Goggle and Gender x Goggle existed among most of the tasks. There were significant interactions of Gender x Glove for only the tasks with small pieces that did not involve the dominant hand.

Main Effects

Significant main effects occurred with Gender, Glove and Goggle. To visualize these effects, histograms were prepared for each main effect by platform. Tukey's hsd was used to determine where the differences occurred. For the time data associated with the Grooved Board and Minnesota Board, which were log-transformed for the analysis, the mean values of time are the geometric mean time rather than the arithmetic mean time.

Gender

The effects of gender on performance for the three platforms are illustrated in Figure 5. Figure 5a displays the score for four tests on the Pegboard, where the higher score indicates more items completed in the allotted time. In all cases, the women scored somewhat higher than the men, and all the differences were statistically significant. In Figure 5b, the geometric mean performance results for the same work were less for the women than the men, which indicates improved performance. Figure 5c compares the men and women for three tasks on the Minnesota Board. There were no differences in the geometric mean time to complete the three tests. A major difference between the Minnesota Board and the other two platforms (Pegboard and Grooved Board) was the size of the pieces handled.



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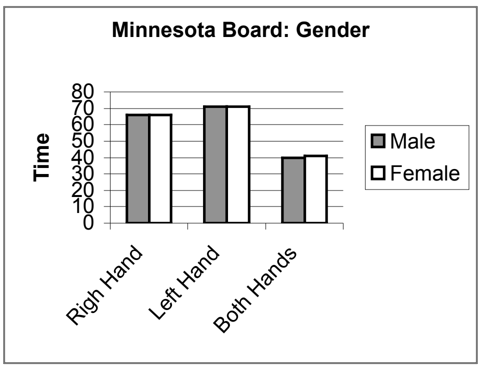

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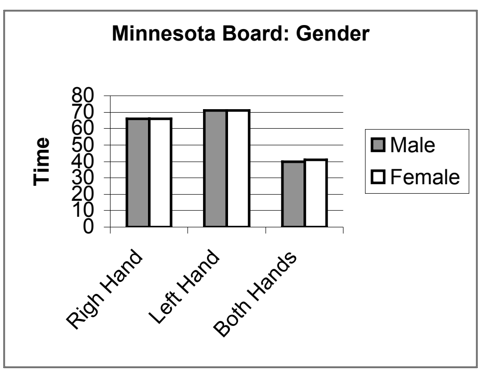
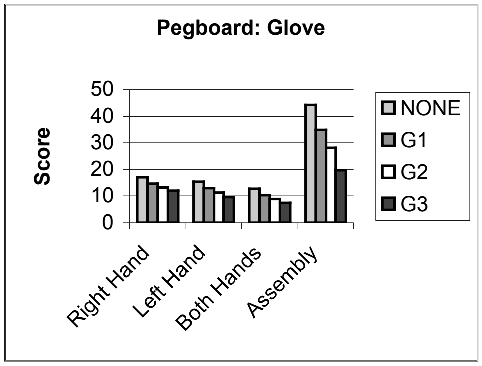


c.

Figure 5. Test performance by Gender: (a) as score for Pegboard, (b) as geometric mean time in seconds for the Grooved Board, and (c) as geometric mean time in seconds for the Minnesota Board.

Gloves

The performance by Glove level for each of the platforms and tasks is pictured in Figure 6. The presumed order of performance was no gloves (None) followed in order of decreasing performance by glove thicknesses of 9 mil (G1), 18 mil (G2) and 28 mil (G3). As expected, the number completed (Score) in Figure 6a decreased with Glove level and the geometric mean time to competition in Figures 6b and 6c increased. In most cases, the multiple comparison test indicated that all Glove levels were different from each other. The three exceptions were all in the Minnesota Board for Right Hand Left Hand and Both Hands, where the difference between the 8mil and 18mil gloves was not significantly different. Again, it was the larger pieces that failed to yield a difference where the smaller pieces revealed a variance.



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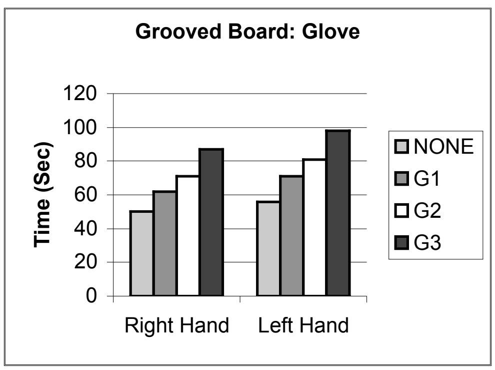

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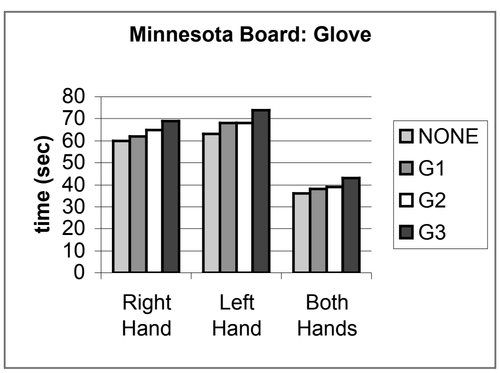
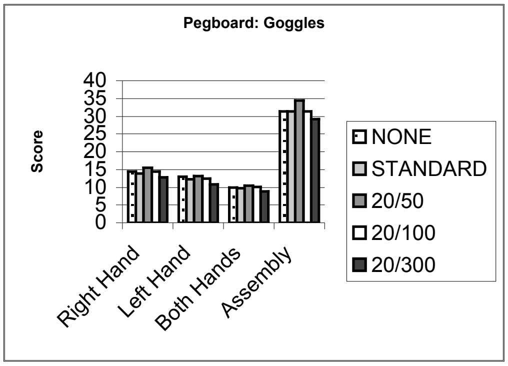


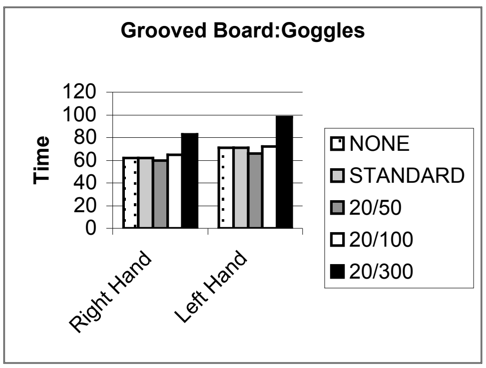
c.

Figure 6. Test performance by Glove: (a) as score for Pegboard, (b) as geometric mean time in seconds for the Grooved Board, and (c) as geometric mean time in seconds for the Minnesota Board.

Goggles

The performance by Goggle level for each of the platforms and tasks is pictured in Figure 7. The presumed order of performance was no goggles (None), followed in order of decreasing performance by clear goggles (Standard), specified acuity of 20/50 (L1), specified acuity of 20/100 (L2) and specified acuity of < 20/300 (L3). The overall pattern of performance was not expected. First for the expected, the performance for the lenses with a specified acuity of less than (<) 20/300 was the worst in all tests; this was statistically significant from all other levels except Assembly in the Pegboard and the three tests associated with the Minnesota Board with the larger pieces. The most striking unexpected outcome was the observation that the best performance across all tests on all platforms was the Goggle level with a specified acuity of 20/50. However, it was not usually statistically significantly different from the negative baseline of no goggles or the positive baseline of standard goggles. The performance among None, Standard and specified acuity of 20/100 were about the same.





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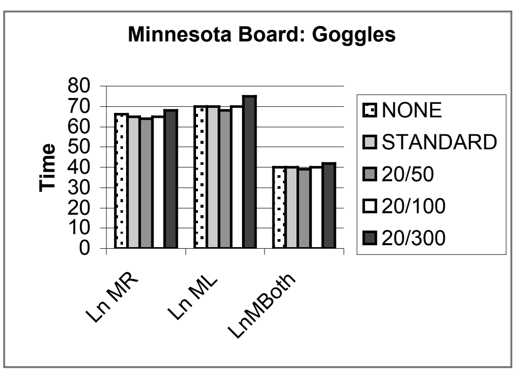

c.

Figure 7. Test performance by Goggles: (a) as score for Pegboard, (b) as geometric mean time in seconds for the Grooved Board, and (c) as geometric mean time in seconds for the Minnesota Board.

First Order Interactions

First order interactions were tested in the ANOVA described above. There were significant interactions for Glove x Goggle as expected. There were also interactions of Glove and Goggle with Gender.

Glove by Goggle Interactions.

Significant Glove x Goggle interactions were found across six of the nine tasks. Two of the non-significant interactions were the two tasks that involved both hands performing the same activity: Both Hands on the Pegboard and the Minnesota Board. The third non-significant interaction was the dominant hand on the Grooved Board, and that interaction had a p-value less than 0.06. There was no consistent pattern of interaction among the tasks and most were characterized by a random weaving of the relationships.

Gender by Glove Interactions.

Significant Gender x Glove interactions occurred in four tasks. All of the significant interactions were associated with the tasks employing small pieces (Pegboard and Grooved Board). When the dominant hand (right hand) was used alone or there were large pieces (Minnesota Board), the interactions were not significant. Again the interactions appeared to represent a random exchanging of relative positions.

Gender by Goggle Interactions.

Significant interactions of Gender x Goggles were observed for eight of the nine tasks. The characteristic pattern for these interactions was a weaving of the lines indicating that the relative performance of the men and women toggled among the different levels of Goggles and that the outcome was probably more random than systematic.

Discussion

Gloves have been shown to effect finger dexterity on standard tasks and gender was a recognized confounder for some of the tasks. Further, there was some evidence that vision might affect eye-hand coordination. The hypothesis of this study is that there are no differences within gender, over a range of common gloves or over a range of visual acuity and there are no interactions among these main effects. The results of the investigation into effects of gloves, visual acuity and gender on tasks requiring finger dexterity indicated significant main effects as well as first order interactions.

Comparisons with Normative Data

Three platforms were employed in this study of finger dexterity. The standard platforms were the Purdue Pegboard available from Lafayette Instrument Company (called Pegboard), Grooved Pegboard available from Lafayette Instrument Company (called Grooved Board), and the Complete Minnesota Dexterity Test available from Lafayette Instrument Company (called Minnesota Board). Each of these platforms has been used extensively for employee screening and diagnosis of disorders and have normative data associated with them. To compare the participants in this study to the normative data, the average values among participants separated by gender as appropriate for each task during which the participant did not wear either gloves or goggles were used to determine the percentile from the normative data. The results are shown in Table 12.

Table 12. Average Task Score for Males and Females on the Pegboard and Grooved Board and for All on the Minnesota Board and the Percentile from the Normative Data.

Task	Male		Female		All	
	Average Score	Percentile	Average Score	Percentile	Total Score	Percentile
Pegboard						
Right Hand	17.6	85	18.9	75	18.2	35
Left Hand	16.3	81	17.8	74	17.0	15
Both Hands	13.6	81	14.1	95	13.8	87
Assembly	44.3	50	46.7	72	45.4	58
Grooved Board						
Right Hand (Dominate)	47	96	47	96	46	97
Left Hand (Non-Dom)	51	66	55	55	59	64
Minnesota Board						
Right Hand	59	53	60	52	60	52
Left Hand	59	53	63	58	63	58
Both Hands	35	78	36	81	35	80

It is clear that the average values were generally above the 50th percentile indicating that the participants performed better than a larger population.

Gender

The normative data for the two platforms that were based on small parts (i.e., Pegboard and Grooved Board) separated the data for males and females, and the female data indicated better performance. Significant differences were also found in this study between genders. Figure 5a and 5b illustrate the changes in performance between genders across the experimental conditions of gloves and goggles. Based on the normative data, the average differences in performance (either increased number completed or decreased time) ranged from 4 to 10% on the Pegboard compared to 2 to 7% in this study; and about 3.2% the Grooved Board compared to 8 to 10% in this study. The Minnesota Board did not have distinguishable differences between gender in its normative data and no significant differences were found in this study, suggesting that the larger parts reduced the gender effect.

Robinette (1986) used several platforms to evaluate the effect of glove thickness on the performance and he also considered gender. He found no differences between genders. For three of the four platforms, the parts were larger than the Pegboard and Grooved Board of this study and required more complex motions. These features make the comparison less direct and may explain the lack of difference. The O'Connor test, however, was similar to the smaller parts handling of this study, yet no difference was found.

Glove Thickness

All of those who investigated the thickness of gloves on dexterity performance found that adding gloves compared to no gloves, using thicker gloves compared to thinner ones, and / or using multiple layers decreased performance, Plummer et al. (1985) and McIntosh (1987). The general trend of increasing thickness of a single glove decreasing performance was confirmed in this study. The range of performance decrements for the three gloves were from 3% LnMR (Minnesota Board Dominant hand) to 74% LnGTT (for Grooved Board Dominant Hand).

Only two studies reported the thickness of single gloves (Robinette et al. 1986 and Bensel 1993). Bensel (1993) used gloves of 7, 14 and 25 mil over four dexterity test platforms. While the percent decrements increased with glove thickness, the magnitude of decrement varied over the platforms. For the similar Minnesota Board and O'Connor tests, she saw decrements of 8 and 11% for the 7 mil gloves, respectively, 16 % for the 14 mil and about 28% for the 25 mil gloves, regardless of the platform. This compares with decrements of 14% for the 9 mil gloves, 22 % for the 18 mil and about 36% for the 28 mil gloves, regardless of the platform for this study. The other study was Robinette et al (1986), where there were three gloves of similar thickness at 12.5 to 14 mil. Across four platforms, these gloves had similar decrements between 20 and 40% as compared to two gloves of this study which were 18 to 22% for the 9 mil and 23 to 35% for the 18 mil.

The Figure 8 represents the effect of Glove on all the dexterity tasks of this study. The relative relationships are clear and statistically significant.

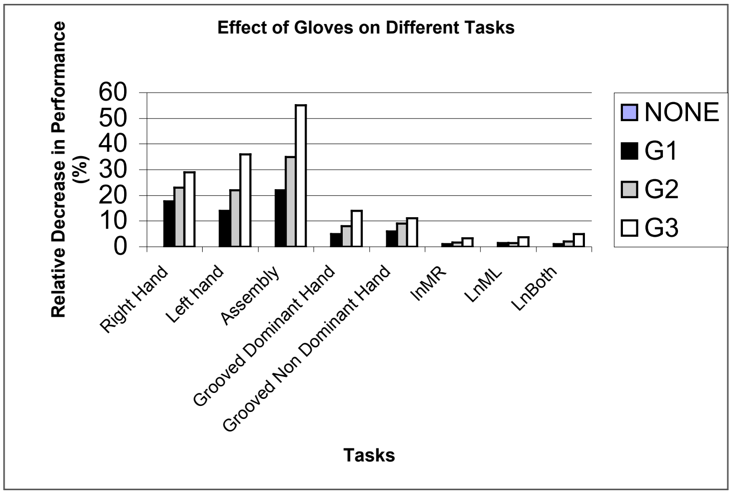

Figure 8. Relative decrease in performance for the three levels of gloves expressed as a percent from the bare hand control.

Goggle and Visual Acuity

Because the actual visual acuity was not assessed for the participants in this study, the data of Johnson et al. (1994) and Dooly et al. (1994) were used to estimate the actual (versus specified) acuity in this study. Table 13 provides the estimated values. For the foils with specified acuities of 20/50 and 20/100, the estimates were based on the average values of the previous investigators. The estimation for <20/300 of <20/160 was based on a linear extrapolation of the combined data from both studies.

Table 13. Specified and Estimated Acuity Levels.

Specified Acuity Level	No Goggle	Standard Goggle	Lenses with 20/50 acuity	Lenses with 20/100 acuity	Lenses with < 20/300 acuity
Estimated Acuity Level	20/15	20/15	20/32	20/59	< 20/160

All three different lenses were utilized for our three different dexterity boards. Figure 9 shows the values of different acuity levels on task performance.

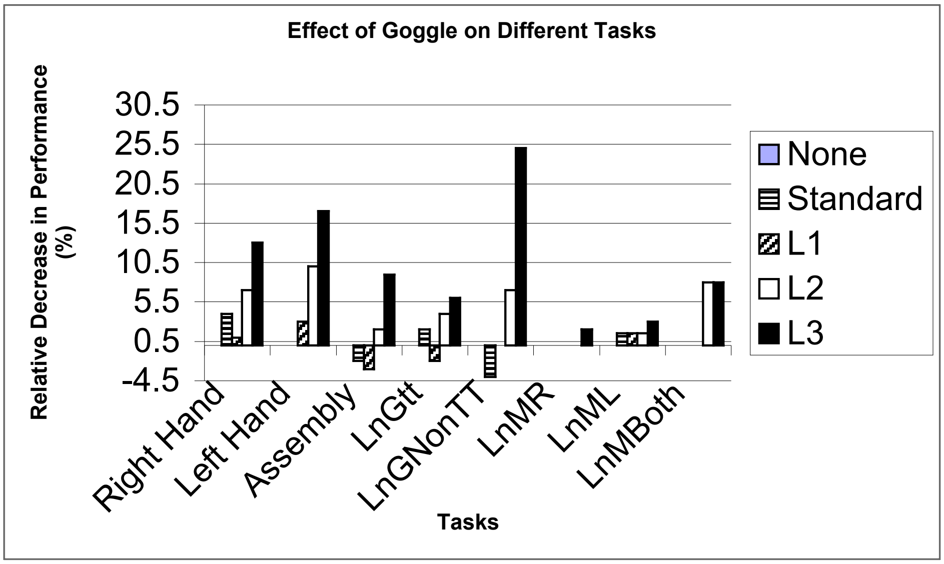

Figure 9. Relative decrease in performance for the four levels of goggles expressed as a percent from the No Goggle control.

The data show that the acuity level of 20/300 (20/160) has the largest effect on performance and it was significant from the negative and positive controls (No Goggles and Standard Goggles) for all the tasks. A strange outcome was the apparent improved performance seen with the visual acuity slightly reduced.

Combination of Gloves and Visual Acuity

Waugh and Klilduff (1984) concluded that wearing heavy gloves and a full mask/hood respirator decreases performance by 45% versus the sum of loss due to gloves alone and respirator alone of 35%. That is, there was a significant interaction. While the current study did not find a consistent pattern of interaction between gloves and goggles, the potential was explored for a special case. The comparison of interest is the bare hands and no goggles condition versus the heaviest glove (28 mil) and the visual acuity of 20/100. The Assembly task of the Pegboard was chosen as the representative task. The task performance for the glove alone, the goggle alone and the combination are provided in Table 14.

Table 14. Performance time for Pegboard Assembly task as the mean number completed and the percent decrement from the control condition.

Assembly Task (Both Hands)	No Goggle	Specified Acuity of 20/100
No Glove	45.2 / 0%	44.3 / 2%
28 mil Glove	20.5 / 54%	19.0 / 58%

Clearly the interaction decrement of 58% is close to the sum of the glove alone (54%) and the acuity level (2%) of 56%. This re-enforces the conclusion that there is no interaction. The loss of interaction, however, may be due to a much more restricted field of view of some other feature of the military mask/hood combination.

Size of Parts

The performance decrements were greatest for the Pegboard, which used small pieces followed by the Grooved Board also with small pieces that required more manipulation. The least effect was seen for the Minnesota Board with larger pieces. Plummer et al. (1985) also studied the effect of glove on dexterity with the Bennett test using bolt and nut assembly and disassembly test. They concluded that the size of the bolts and nuts has direct effect on performance outcome. They concluded that for smaller sizes of bolts and nuts, performance decreases. This observation was confirmed by McIntosh (1987).

Bensel (1993) reported decreases in performance with increasing glove thickness. It was more difficult to see a pattern associated with part size, although the Minnesota Board and O'Connor tasks were similar to the Minnesota Board and Pegboard tasks of this study. In this pair, she did not demonstrate much difference in performance between the platforms. Therefore the effects of part size is still speculative.

Conclusions and Recommendations

The purpose of this study was to explore the expected effects of gloves, the suspected effects of visual acuity and gender on finger dexterity while performing standardized tasks.

As expected, thickness of gloves was associated with significantly different performance at each level and the magnitude of the effect depended on part size. That is:

- The thicker the glove the more time was needed to complete the task or the fewer number of completed actions in a fixed time. For instance the largest differences were on the Pegboard Assembly task using both hands, where the difference was from 22% (9 mil glove) to 55% (28 mil glove).
- There was less of a performance decrease when the larger pieces on the Minnesota Board were compared to the smaller pieces of the Pegboard.

There was a difference between male and female performance for Pegboard and Grooved Board (the tasks for which fine movement of the fingers was involved). For instance, women performed 8% better than men on the Assembly task of the Pegboard and they did 10% better than men for the Grooved Board.

For visual acuity, there were no systematic differences other than at the highest level of visual impairment. The significant effect for the Acuity of <20/300 (L3) was less than 17%. The other levels of acuities also showed some differences in outcome performances, but not significant.

Among the main effects considered in this study, glove thickness appeared to play the largest role followed by gender. Visual acuity was not generally a factor until vision was significantly impaired and this effect was less than gloves and on the same order as gender.

There was no pattern of interaction between glove and visual acuity among the combinations in this study. While Wang and Kilduff (1984) study would have predicted a large interaction, that interaction was not due to loss of visual acuity.

Based on this study, several recommendations for future work can be made. These include:

- Expand the range of glove thickness. Significant effects were found over the range of 9 to 28 mil, which suggests that the range should e extended until there is a limiting value found.
- Part size appeared to be an important characteristic for both the glove and gender effects. This potential effect requires more attention.
- Consider the effects of multiple gloves. Other studies have suggested that multiple gloves affect performance, and it would be interesting to differentiate the thickness effect from a layering effect.
- Fit of glove. While this study used a self-selected fit, exploring other fit characteristics may provide insight to important changes in performance.

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Appendix A

Appendix A: Procedures

Orientation

In this first step, we introduce dexterity tests, gloves and goggles to each individual. The experimental procedures will be explained to them and informed consent will be sought. Each individual will give the opportunity to practice the task without gloves and goggles during the orientation.

Trail Steps

In this section the subject starts the Purdue Pegboard. Once the subject is seated the instructor starts the test with saying:

"This is a test to see how quickly and accurately you can work with your hands. Before you begin each part of the test, you will be told what to do and then you will have an opportunity to practice. Be sure you understand exactly what to do" (Manual for Test Board 32030, Purdue Pegboard, 2003).

Testing with Purdue Pegboard

Right Hand.

Before each test, the required task will be demonstrated to the subjects by saying:

> Pick up one pin at a time with your right hand from the right hand cup. Starting with the top hole, place each pin in the right hand row. (Leave the pin used for demonstration in the hole.) Now you may insert a few pins for the practice. If during the testing time you drop a pin, do not stop to pick it up. Simply continue by picking another pin out of the cup.

The instructor corrects any possible mistakes by the subject and once he makes sure that the subject is ready then, he says to the subject: "Stop. Now take out the practice pins and put them back into the right-hand cup."

Here the test starts with saying: "When I said 'Begin,' place as many pins as you can in the right hand row, starting with the top hole. Work as rapidly as you can until I say 'Stop'. Are you ready? Begin." Here instructor starts timing once he said, "Begin". At the end of exactly 30 seconds, the instructor stops the subject with saying: "Stop".

The number of the pins inserted in the holes with the right hand will be counted and will be considered as right hand scores.

Left Hand.

The procedures for the left hand are exactly the same as right hand but the subject is supposed to start the test with left hand. At the end of this sequence both right side and the left side pins will be returned to their cups.

Both Hands.

In this sequence test, both hands are working together. This test starts with saying:

> For this part of the test you will use both hands at the same time. Pick up a pin from the right hand cup with your right hand and at the same time pick up a pin from the left-hand cup with your left hand, and place the pins down the rows. Begin with the top hole of both rows. (Demonstrate. Then replace the pins used for demonstration.) Now, you may insert a few pins with both hands for practice.

After three or four pins being inserted correctly, then the instructor says: "Stop. Take out the practice pins and put them back into the proper cups."

Then the instructor says: "When I say 'Begin,' place as many pins as you can with both hands, starting with the top hole of both rows. Work as rapidly as you can until I say 'Stop'. Are you ready? Begin." The instructor starts timing when he says "Begin." After exactly 30 seconds the instructor counts the total number of correctly inserted pairs of the pins and records the score.

Right plus left plus both hands (R+L+B).

This score is not a separate test, but it is just the score of combining the scores for right hand plus left hand plus both hand sequences.

Assembly.

This sequence is consisted of assembling pins, washers and collars. The instructor demonstrates the following operations while saying:

> Pick up one pin from the right hand cup with your right hand, and while you are placing it in the top hole in the right-hand row, pick a washer with

> your left hand. As soon as the pin has been placed, drop the washer over the pin. While the washer is being placed over the pin with your left hand, pick up a collar with your right hand. While the collar is being dropped over the pin, pick up another washer with your left hand and drop it over the collar.
>
> This completes the first 'assembly', consisting a pin, a washer, a collar and a washer. While the final washer for the first assembly is being placed with your left hand, start the second assembly immediately by picking up another pin with your right hand. Place it in the next hole; drop a washer over it with your left hand, and so on, completing another assembly. Now make a few assemblies for practice.

The main point in this specific task is that both hands are supposed to be working together simultaneously and operating together. Once the practice is over the instructor starts the sequence with saying: " Stop. Now return the pins, collars, and washers to the proper cups."

After that the instructor continues with saying: "When I say 'Begin,' make as many assemblies as you can, beginning with the top right hand hole. Work as rapidly as you can until I say 'stop'. Are you ready? Begin."

The instructor tells the subject to start, and after exactly 60 seconds, he stops the subject. The number of washers, pins and collars are added together as the total score for this task. For example, if six complete assemblies are made and the pin and first washer of the seventh assembly is properly placed at the end of the minute, the score is 24 plus 2; therefore the final result is 26. Once the score is completed the pins and other parts would positioned in their place and the test is over.

Testing with Grooved Pegboard Test.

The grooved pegboard test is a manipulative tactility test consisting of 25 holes with randomly positioned slots. Pegs with a key along one side must be rotated to match the hole before they can be inserted. This test requires more complex visual-motor coordination than most Pegboard tests. Holes are randomly spread over the board. There is a long shaped cup right on top of the board where the grooved pegs are supposed to be kept and there is a cup shaped container right on top of the holes designed for putting the grooved pins. For this task, the instructor explains the test and shows the pegs and the board. The procedures are described as follows:

> This is a pegboard and these are the pegs. (The examiner points out each and then picks up one of the pegs and continues.) All the pegs are the same. They have a groove, that is, a round side and a square side and so the holes in the boards. What you are supposed to do is matching the groove of the peg with the groove of the hole on the board and put these pegs into the holes like this. (The examiner demonstrates by filling the top row.)

Then examiner puts the peg back in their place and he says:

> When I say go, begin here and put the pegs into the boards as fast as you can, using only your dominant hand. Fill the top row from side to side and do not escape any of the holes. Fill each row the same as the top row. Ready? Go.

Once the subject starts putting the pegs into the board, the examiner records the time and he stops the time once the subject fills the last hole by the peg or when the test is disconnected. These procedures will be duplicated for non-dominant hand.

Here there is another score, which includes the number of “drops” (a drop is any unintentional drop of a peg from the time the subject attempts to pick up the peg from the tray until it is placed correctly in the hole). For each hand the three scores will be summed to get a complete score.

Testing with Complete Minnesota Dexterity Test

The Complete Minnesota Dexterity Test (CMDT) is a frequently administered, standardized test for the evaluation of a subject’s ability to move small objects various distances. This manual is a guide demonstrating the proper test procedure for each test battery.

The Complete Minnesota Dexterity Test (CMDT) is used to measure a subject’s simple but rapid eye hand coordination as well as arm-hand dexterity. Agencies use the CMDT as a pre-employment screening and selection tool.

Test Procedures

General Instructions.

The test administrator should have the CMDT in the starting position on the table before the arrival of the subject. Note: All subjects must stand during the duration of the test trials.

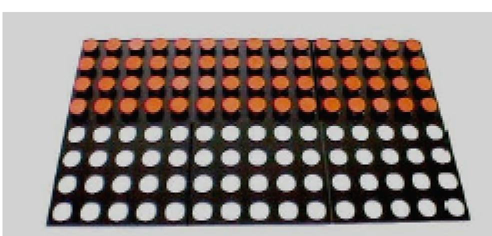
The score sheet should be placed on the table directly in front of the test subject. When the subject(s) arrives and is standing comfortably in front of the table, say: "You must enter your name, the date, and your dominant hand in the spaces provided on the score sheet. Today's date is ______________. Do not fill out any other part of the form."

Give an overview of the CMDT by saying: "The series of tests that you are going to take will measure your eye-hand-finger coordination and gross motor skills. The tests are timed, so you must complete each as quickly as you can." Now administer the first test to be given in the series.

Placing Test.

Starting Position: Put the first board on the table about 10 inches from the edge. Insert the disks into the holes in the board. Place the other board directly in front of the first board. The two boards should be touching each other and have their ends in a straight line. They should now be about 1 inch from the edge of the table nearest to the subject. This is the starting position for the placing test. Figure 3 below illustrates this position.

Figure A1 Starting position for the Placing Test.



Begin by saying and demonstrating: “The object of this test is to see how fast you can put the disks from the top board into the holes of the bottom board using only one hand. You will want to use your dominant hand.”

Demonstrate as you read the following instructions. Note: If you are facing the subject across the board, remember to demonstrate on your LEFT because the instructions pertain to the subject’s RIGHT. Also remember that TOP to the subject is BOTTOM to you.

You should start your demonstration slowly and increase speed as you speak.

> You must begin on your RIGHT. Pick up the bottom disk and insert it into the top hole of the board closest to you. Now, you must pick up the next disk above the empty hole on the first board, and so on in the right column. You will move from right to left on this test. Once you complete one column, repeat the previous sequence in the second column until you have filled the entire bottom board.

Continue demonstrating until two columns have been filled. Now, remove the eight disks from the bottom board and put them back in place into the holes in the top board. “You may hold the board with your free hand if you wish to do so. Do you remember the order in which you pick up the disks and place them down?”

If the instructions must be repeated, point to the disks in the order that they should be picked up and then point to the disks in the order that they should be placed in the holes in the bottom board.

> You must make sure that all of the disks are fully inserted into the holes of the board before the trial is complete. If you dropped a disk, you must pick it up and insert it into the proper hole before the time is stopped. Your score will be the total number of seconds it takes to complete several trials. We will record the time for each trial separately. When you finish one trial, we must rearrange the boards into the starting position before starting another trial. Please do not touch the disks until you hear further instruction.

Start the stopwatch or log the time as soon as you say the word, “GO.” During the practice trial, you can provide assistance to the subject if necessary.

You will now begin the first trial by saying: “Put your hand on the first disk. READY, GO!”

When the subject is finished with the trial, log the time in seconds in the space provided on the score sheet. Now, you must move the bottom board (now filled with disks) to the top and move the unfilled board to the bottom. Remember: The boards should be about on 1 inch from the edge of the table.

The boards should now be in the starting position for the next trial of the Placing Test. You can begin the next trial by saying: “Put your hand on the first disk. READY, GO!”

Repeat the above procedure until all of the desired trials are completed. You should encourage the subject between every trial by stating the appropriate sentence: “Remember, you are being timed, so complete each trial as quickly as possible.” Or, “You did a good job, but I believe that you can complete the next trial faster.”

And on the last trial, “This is the last trial and should be your best time.”

At the end of the last trial, you will say: “That’s all for this test.”

Biography

Mehdi Pourmoghani graduated from Esfahan University, Iran in May 1989 with a B.S in Geology. He spent his military service from 1990 to 1993. In 1995 Mr. Pourmoghani entered the University of South Florida College of Public Health for an MSPH in Industrial Hygiene and graduated in May 1997. In Fall 2001, he entered the Ph.D. program in Industrial Hygiene. This dissertation represents his research efforts into finger dexterity with personal protection.