Development and Testing of Self-Assessment Tests for Increasing Motorcycle Safety for Aging Motor Cyclists

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Motorcycle fatalities represent approximately five percent of all highway fatalities each year, yet motorcycles represent just two percent of all registered vehicles in the United States (The National Highway Traffic Safety Administration (NHTSA), 2006). The NHTSA's Fatality Analysis Reporting System (FARS) and the General Estimates System (GES) revealed that approximately 42,116 people were killed and another 3.03 million were injured on our nation's roadways in 2001. The large number of crashes has placed a tremendous burden on the U.S. costing 230.6 billion dollars a year. More specifically, in 2001, motorcycle fatalities reached an all time high of 3,181 deaths, an increase of 50% between 1997-2001. In terms of vehicle miles of travel in 2001, motorcyclists were about 26 times as likely to die in a crash than someone riding in a passenger car, and are about 5 times as likely to be injured. Recent trends indicate that the age of motorcycle ownership has increased. Since 1980, motorcycle ownership among the 40 and over age group has increased significantly, from 15.1% in 1980 to 43.7% in 1998. Motorcyclists age 40 and over riding larger motorcycle engine sizes account for the fastest growing group of motorcycle fatalities.

Multiple body systems contribute to the ability to be a safe motorcyclist. During the aging process these systems are compromised, especially the cognitive and sensory-motor systems. Motorcyclists use these systems to take-in information arising from their surrounding environment and resulting from their own actions, interpret the incoming information, and then make appropriate responses. The cognitive system also plays an important role in motorcycle safety because it encompasses the processes of attention, memory storage, and intelligence, providing us with the collective ability to search, evaluate, and execute. Declines in these systems increase the risk of accidents among “seasoned” riders.

A motorcycle requires more skill and coordination to operate than a car (NHTSA, 2006). One of the causes for motor motorcycle collision is related to failure to practice defensive driving. Good defensive driving involves complicated information processing activities ranging from constantly gathering information on the road about the conditions of the road and other drivers and cyclists to executing such decisions as slowing down and braking based on the information collected. Riding a motorcycle involves a series of mental operations to make it successful. These processes include:

- Visual Searching. To drive safely at high speeds, the motorcyclist engages in an active process of scanning the environment and searching for relevant information. Failing to notice what is going on around the motorcycle is one of the major causes of motorcycle accidents. Because older people have a reduced field of view and are more susceptible to scene clutter, they make much larger eye movements to scan the entire scene. Clutter (non-target information in the visual field) and search deficiencies make it more difficult for older workers to see critical information and easier to miss it because of the clutter which is exacerbated by illuminance. Response times increase as clutter increases and illuminance decreases.
- Identification. Visual search of scanning can only direct the operator's vision toward potential hazards and the highway traffic environment. To cope with hazards, riders must be able to identify them. And to do this, they must be able to see clearly. Deterioration in static acuity is not significant before the age of sixty, whereas deterioration in the more complex tasks (acuity for a moving object, dynamic acuity, detection of lateral motion,

detection of in and out movement) begins much earlier and accelerates faster with increasing age. The age-related average deterioration is accompanied by a marked increase in individual differences causing a problem for older individuals, especially when riding a motorcycle. Vision declines with age, in particular, night vision (Payne & Issacs, 2005). It is important for the aging motorcyclist to check vision and use eye classes to improve vision. Nighttime legibility distances of highway signs for drivers over age sixty was sixty-five to seventy-seven percent of the legibility distance for drivers under age twenty-five with equal phototrophic acuity (Haight, 2003). Dynamic visual acuity (DVA) is the ability to resolve details of a moving target and is more closely associated with accident involvement than static acuity. DVA is thought to begin around age forty-five, so those more likely to purchase motorcycles would be potentially affected (Haight, 2003).

- Prediction and Decision. The ability to exercise good judgment in making decisions is important to avoid highway hazards. Other correlates with increased vehicular accidents include perception of angular movement; movement in depth and visual field; eye-tracking movement; glare sensitivity; color vision; contrast sensitivity; and scotopic vision (ability to see in dim light) (Haight, 2003). Older people have a "restricted field of view", so they are least likely to notice signs unless they are in the direct line of sight; therefore, signs that are not posted at eye level will be less likely to be seen.
- Execution and Evaluation. The last step in information processing is the execution of the decision and the evaluation of the results for future references. To be safe on the road, the motorcyclist depends on quick execution. Reaction time refers to the time period between

the presentation of a stimulus and it is a good measure of how quickly a decision is carried out. Reaction time lengthens or slows down as we get older (Hertzog, 1991).

Research consistently shows that aging people are more vulnerable under stressful conditions when their reaction slows more dramatically than their younger counterparts. Part of this slowing down is explained by the declining efficiencies of the sensory organs and the musculoskeletal system (Davies & Mebarki, 1983). Depending on task complexity, older adults are slower to respond. Response speed has a linear relationship with task complexity (Haight, 2003). Older adults have more difficulty managing or coordinating multiple tasks. Some research has suggested that age-related difference in performance of multiple tasks is reduced through training (Haight, 2003). This has important implications for training motorcyclists to prepare for a multiple sensory environment Fortunately, much of the declines are preventable, or at least modifiable through early detection and intervention. Motorcycle Safety Foundation (MSF) strongly believes that rider education and training are fundamental to rider safety. The search, evaluate, and execute (SEE) paradigm is the basic curricula to promote lifelong learning for motorcyclists and professional development. Because the integrity of the cognitive and sensory-motor systems are essential to the SEE paradigm, the purpose of this project is to develop and pilot-test self-assessment tools for the "Seasoned Rider" program for participants to measure their own visual, cognitive, and motor skills. Specifically, the project was to improve the college norms for the five assessment tests already developed, to investigate the connection between the assessment tests and the level of physical activity, gender, and number of motor vehicle accidents, and finally test the nature of these self-assessment tests.

Methodology

Subjects

Eighty-five college students (females=53; males=32; mean age = 24 and SD = 6.27) from a state university in Southern California volunteered to participate in the study. They received neither financial compensation nor academic credit for participating in the survey.

Materials

All subjects completed a questionnaire that contained seven items and a battery of five hand-eye coordination tests. The seven questions dealt with age, gender, level of physical activity, number of motor vehicle accidents in the year of 2005, year in college, self rated hand-eye coordination, and self-rated reaction time speed. There were two levels of physical activity, i.e., recreationally active (working out twice a week in the last six months or year) and recreationally inactive.

The battery of self-assessment tests included three Fitts' tapping tests varying in target size, three symbol detection tests, and one number grid test (see Appendix I). The Fitts tapping tests are designed to assess perceptual and motor coordination. In 1954, Paul Pitts identified a relationship between the speed of movement and the accuracy of movement, known as the Fitts' Law (Fitts, 1954; Fitts & Peterson, 1964). According to this law, as increase in movement speed will be accompanied by a decrease in movement accuracy, or verse versa. To perform the Fitts tapping test, the performer holds a pen or pencil in a dynamic tripod position using the dominant hand and tap the rectangular boxes separated by a certain distance within 10 seconds.

The battery contained three versions of symbol detection. One common feature of them is to assess attention and perceptual differentiation. The ability to search and find a specific symbol quickly and accurately was examined. Subjects scanned a grid of symbols and marked a slash across as many target symbols as possible within a certain time limit. The three tests varied in the types of symbols presented creating different levels of familiarity to the subject and homogeneity of the surrounding material in the tests. The first version symbol detection was hypothesized to be the easiest because it consists of all uppercase English letters and the target symbols are A's and Z's. The second version was supposed to be harder because subjects were required to search for a lowercase letter "g" and a number "4" in a grid of lowercase letters and numbers. The third version consists of all strange characters and the target symbols are "И" and "§."

The last test in the battery was a number grid test made up of number 0 to 99. This test requires the subject to cross out as many sequential numbers as possible. This test required multitasking in that the subjects must scan the whole grid, identify the targets in a specific order, and execute the motor action of crossing out the number. The mental elements are hypothesized to be similar in those while handling a motorcycle.

The reliability of the tests was determined ($R_{xx'}$ = .812) using a test-retest method in a pilot using a sample of 34 college students.

Procedure

Permission was obtained before the 85 students were administered the questionnaire and battery of assessment tests. With the help of their instructors, the tests were carried out at the beginning or end of their respective undergraduate classes. A stop watch was used to time the tests. The questionnaire was completed anonymously before the assessments were completed. The entire testing procedure took about 15 minutes and researchers collected all the questionnaires on the site before leaving.

Results

Alpha was set at .05 for all statistical analyses. Tukey's honestly significant difference (HSD) procedure was adopted for all follow-up comparisons, when appropriate.

Regression analysis revealed that the performance scores on the five self-assessment tests did not have any explanatory value for the number of motor vehicle accidents in 2005.

Correlation analyses of all the variables didn't show any correlations between test performance and number of motor vehicle accidents, but they indicated high correlations among the tests themselves (see Table 1).

Since no relationship was identified between the number of motor vehicle accidents and the performance of the self-assessment tests, analyses of variance were performed on the data to answer these following questions:

- Did gender affect the performance of these tests?
- Did level of physical activity influence the speed of performance in these self-assessment tests?
- Were there any differences among the symbol detection tests themselves?

Results of the five assessments were subjected to separate 2x2 (Gender x Physical Activity) ANOVAs. ANOVA on the first version of symbol detection revealed two significant main effects for gender and activity level (see Figure 1). Males crossed out more A's and Z's than females ($F_{1, 79}$=9.291; p<.005) and the active subjects identified more symbols than the inactive ones ($F_{1, 79}$=5.599; p<.05). Analyses of the second version symbol detection test also revealed similar significant gender ($F_{1, 79}$=8.926; p<.004) and activity level ($F_{1, 79}$=9.969; p<.003) main effects (see Figure 2). The number grid test analysis yielded only an activity level main effect ($F_{1, 79}$=9.291; p<.005) with active subjects identifying more sequential numbers than inactive subjects (see Figure 3). No significant results came from the analyses of the third version symbol detection test and all the Fitts' tapping tests.

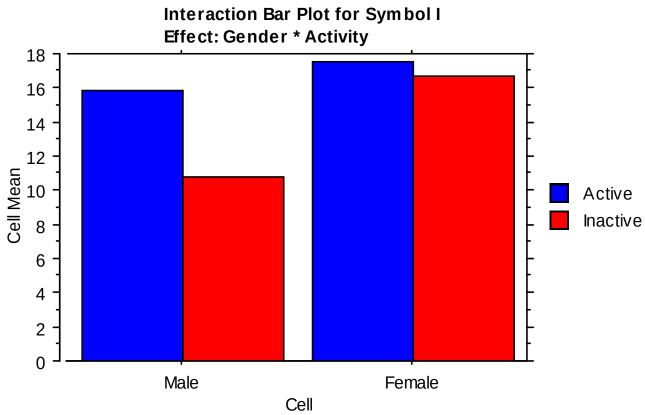

Figure 1. Significant gender and physical activity main effects for the first version symbol detection test.

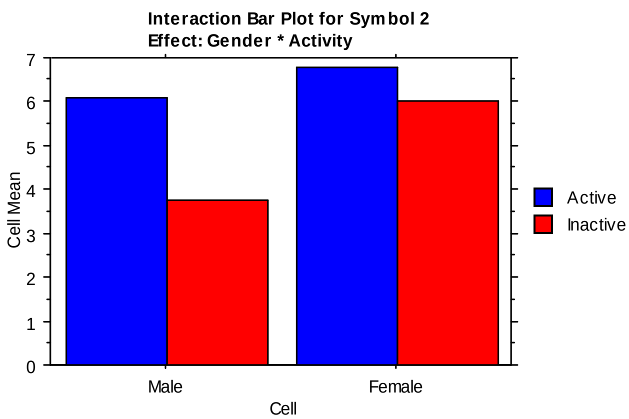

Figure 2. Significant gender and physical activity main effects for the second version symbol detection test.

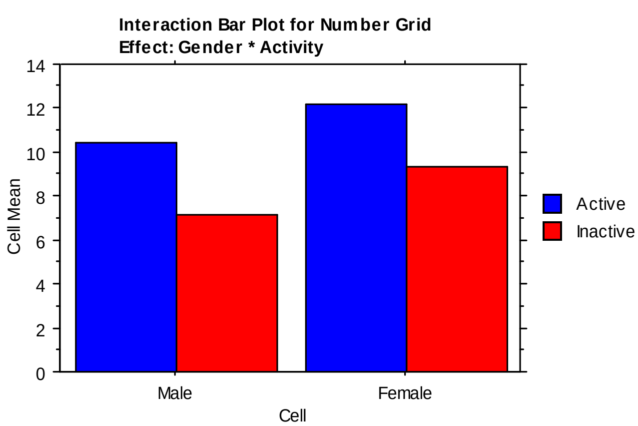

Figure 3. Significant physical activity main effect for the number grid test.

To understand the differences between all the four symbol related tests including the number grid test, a 2 x 2 x 4 repeated measures ANOVA was performed. Results indicated that the most difficult tests were the ones involving crossing out both numbers and letters and the one consisting of strange symbols. The easiest test was the first version symbol detection test involving A’s and Z’s.

Finally, the study provided more data to form a more valid college norm for these tests (see Appendix I).

Discussion and Conclusions

The results of regression analyses indicate that the performance on the self-assessment tests has low or no predictive value for the number of motor vehicle accidents in the year of 2005. It may suggest that these self-assessments alone can not predict the accident rates of college students. Another explanation is that only 21 out of the 85 participants of this study reported one or two accidents last year indicating that this index was not a representative index. We do not have enough information about the accident itself, who caused the accident, the circumstances, etc. Furthermore we have no information on motorcycle handling capability. The college students involved in this study may have never handled a motorcycle, therefore, the number of motor vehicle accidents was too general an index to be linked to the performance of the battery of tests. Researchers including this team should search for other more relevant indicators to represent motorcycle handling capability in connection with these self-assessment tests in the future. Another possibility is to test people of older age and/or seasoned motorcyclists.

This study revealed that males outperformed females in three out of five symbol detection tests. This finding is consistent with the finding that females are less competent in complicated perceptual-motor skills than males (Thomas & French, 1985). Yet, these gender differences in perceptual motor skill performance or hand-eye coordination tasks cannot be simply translated into statistics of traffic accidents because gender alone cannot predict the kinds of accidents and frequency of accidents (Evans, 1991).

Another interesting finding was that active people outperformed inactive people in hand-eye coordination tasks, proving that physical activity may bestow more benefits other than enhancement of mental and physical fitness.

This study has furthered our understanding of the tests we developed. The fact that analyses of Fitts' tapping tasks did not produce any significant gender or physical activity main effects suggests that it may not be an appropriate test for assessing motorcycle handling ability, because it is not sensitive enough to differentiate these differences, probably because it is too simple and one-dimensional.

In conclusion, this study has furthered our understanding of the nature of the self-assessment tests and pointed to the necessary work for future research.

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Appendix I: Self-Assessment Survey

1. Demographics

Instructions: Answer the following questions briefly:

1. *Age________*
2. *Gender_________*
3. *Are you recreationally active? Yes/No (Recreationally active: working out twice a week in the last six months or year)*
4. *Number of motor vehicle accidents in 2005__________*
5. *Year in college__________*
6. *How is your hand-eye coordination? (1 – extremely clumsy; 5 – extremely coordinated)*

   ____
7. *How is your self-rated reaction time speed? (1 – extremely slow; 5 – extremely fast)__________*

2. Symbol Detection 1

Instructions

Please cross out as many uppercase A's and Z's as possible within 20 seconds by using a pen or pencil.

K	H	B	D	Z	E	X	A	M	T	I
L	Z	U	G	F	S	N	P	A	H	C
Q	R	V	W	Y	O	S	D	A	F	R
G	E	W	G	F	D	S	Z	G	S	H
W	R	C	J	I	K	N	R	W	A	I
V	Z	B	W	V	J	H	F	A	W	E
R	S	D	X	C	B	X	C	G	F	G
R	A	L	C	I	S	J	D	F	A	H
D	G	J	D	V	A	Z	B	C	X	Z
V	D	B	N	D	N	A	V	G	D	C
A	B	C	N	S	D	F	V	C	X	Z
Y	A	S	A	D	Z	C	X	Z	N	M
A	C	X	Z	G	V	Z	U	Y	D	F
A	G	F	G	H	D	A	F	G	B	J

T	U	R	B	G	H	F	L	K	D	J
E	A	R	I	A	F	D	S	G	R	Z
E	W	U	T	A	L	K	J	V	S	A
J	F	D	Z	H	J	R	G	A	F	J
H	D	Z	G	Z	H	J	W	A	U	E
R	K	J	Z	L	A	V	N	J	D	F

College Norm

Marginal	***11-15***
Good	***16-20***
Excellent	***21 and above***

3. Symbol Detection 2

Instructions

Please cross out as many lowercase g’s and 4’s as possible within 10 seconds by using a pen or pencil.

a 7 3 d g t p 9 6 2 x d e o e w q d c 5 6 o I d g v c d

w 3 6 7 9 w d z x j g e 2 3 7 b f d x c k l p o u t e e

4 c v b h t d 5 6 j k c 5 8 v b u g r 5 7 3 6 9 g d w j

s f u v 5 h 7 3 2 8 j k f r z 4 d g 6 h j w x d f 7 3 4

f e y j f e x s f g o 5 7 g w e d t 4 6 h j I 6 2 d b x

College Norm

Marginal	***5-6***
Good	***7-8***
Excellent	***9 and above***

4. Symbol Detection 3

Instructions

Mark a slash through as many “И” and “§” symbols as possible within 10 seconds.

♪	♦	♪	♣	♥	Δ	☼	Δ	£	¥	§	Γ
Ε	Θ	Π	И	Ё	J	Χ	Γ	¥	§	Γ	З
ə	®	¥	æ	ð	µ	þ	Ώ	Δ	↔	♠	¥

§	Γ	♪	И	£	J	¥	♦	¥	Γ	æ	§
Γ	Ώ	§	®	□	Д	µ	♣	u	Э	☼	И
æ	ð	µ	þ	Ώ	Δ	↔	♠	¥	Д	§	®
З	♥	♪	□	¥	Γ	И	δ	Ж	₤	∂	┘
¥	♦	¥	Γ	æ	§	З	♥	♪	□	¥	Э
§	Γ	З	Ώ	§	®	Γ	♪	И	♥	Δ	☼

College Norm

Marginal	***6-7***
Good	***8-9***
Excellent	***10 and above***

5. Number Grid Test

Instructions

Scan the following number grid and mark a slash through as many sequential numbers as possible within 1 minute. The starting number will be decided by yourself (e.g., 02, 03, 04).

32	42	39	34	99	19	84	44	03	77
37	97	92	18	90	53	04	72	51	65
95	40	33	86	45	81	67	13	59	58
69	78	57	68	87	05	79	15	28	36
09	26	62	89	91	47	52	61	64	29
00	60	75	02	22	08	74	17	16	12
76	25	48	71	70	83	06	49	41	07
10	31	98	96	11	63	56	66	50	24
20	01	54	46	82	14	38	23	73	94
43	88	85	30	21	27	80	93	35	55

College Norm

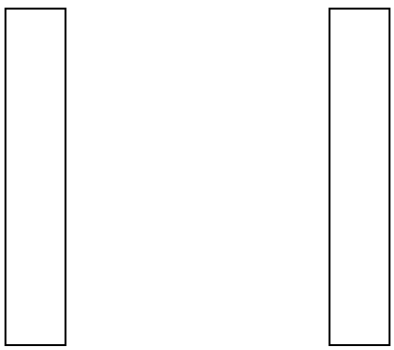
Marginal	***6-10***
Good	***11-15***

Excellent 16 and above

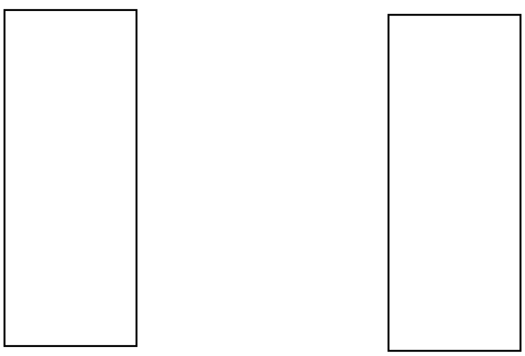
6. Fitts' Tapping Task

Instructions

You are required in a pair. Before testing starts, make sure that the test is properly organized. A regular watch is needed for this test. The requirement for the tapping movements is that no target should be missed even though fastest speed possible is produced. You should hold the pencil high enough so that the pencil will not scratch the surface of the sheet and the elbow will not touch the table.

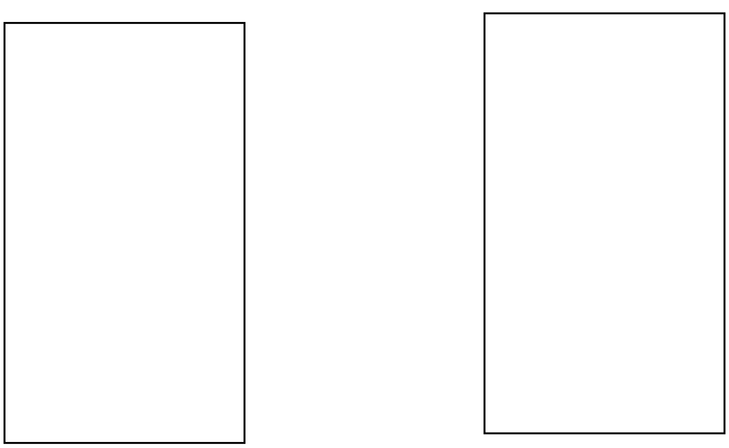


D=4 cm
W=1 cm



D=4 cm

W=2 cm



D=4 cm
W=4 cm

College Norm (Small Targets)

Marginal	***18-24***
Good	***25-31***
Excellent	***32 and above***

College Norm (Medium Targets)

Marginal	***26-34***
Good	***35-43***
Excellent	***44 and above***

College Norm (Large Targets)

Marginal	***35-43***
Good	***44-52***
Excellent	***53 and above***

Appendix II

Table 1. Correlation Analysis Results

Correlation Coefficient
Hypothesized Correlation = 0

	Correlation	Count	Z-Value	P-Value	95% Lower	95% Upper
Symbol I, Symbol 2	.611	83	6.352	<.0001	.455	.730
Symbol I, Symbol 3	.536	83	5.348	<.0001	.362	.673
Symbol I, Number Grid	.367	80	3.382	.0007	.161	.543
Symbol I, Fitts Small	-.059	83	-.530	.5960	-.271	.159
Symbol I, Fitts Medium	-.047	83	-.417	.6769	-.260	.171
Symbol I, Fitts Large	.208	83	1.884	.0596	-.009	.405
Symbol I, Reaction Time	.079	83	.707	.4798	-.139	.290
Symbol I, Hand-Eye Coordination	.241	83	2.203	.0276	.027	.435
Symbol 2, Symbol 3	.532	85	5.373	<.0001	.360	.669
Symbol 2, Number Grid	.439	82	4.187	<.0001	.245	.599
Symbol 2, Fitts Small	.233	85	2.149	.0317	.021	.425
Symbol 2, Fitts Medium	.125	85	1.140	.2542	-.090	.330
Symbol 2, Fitts Large	.195	85	1.793	.0730	-.018	.392
Symbol 2, Reaction Time	.126	85	1.147	.2513	-.090	.330
Symbol 2, Hand-Eye Coordination	.234	85	2.158	.0310	.022	.426
Symbol 3, Number Grid	.298	82	2.733	.0063	.087	.484
Symbol 3, Fitts Small	-.007	85	-.065	.9484	-.220	.206
Symbol 3, Fitts Medium	.123	85	1.122	.2618	-.092	.328
Symbol 3, Fitts Large	.200	85	1.833	.0669	-.014	.396
Symbol 3, Reaction Time	.080	85	.722	.4703	-.136	.288
Symbol 3, Hand-Eye Coordination	.240	85	2.218	.0265	.029	.431
Number Grid, Fitts Small	.209	82	1.888	.0590	-.008	.408
Number Grid, Fitts Medium	.106	82	.946	.3443	-.114	.316
Number Grid, Fitts Large	.093	82	.831	.4059	-.126	.304
Number Grid, Reaction Time	-.025	82	-.224	.8229	-.241	.193
Number Grid, Hand-Eye Coordination	.322	82	2.964	.0030	.112	.503
Fitts Small, Fitts Medium	.594	85	6.185	<.0001	.435	.716
Fitts Small, Fitts Large	.369	85	3.511	.0004	.170	.540
Fitts Small, Reaction Time	.119	85	1.087	.2772	-.096	.324
Fitts Small, Hand-Eye Coordination	.186	85	1.704	.0885	-.028	.384
Fitts Medium, Fitts Large	.651	85	7.035	<.0001	.508	.759
Fitts Medium, Reaction Time	.169	85	1.547	.1219	-.046	.369
Fitts Medium, Hand-Eye Coordination	.215	85	1.980	.0477	.002	.410
Fitts Large, Reaction Time	.028	85	.250	.8028	-.187	.239
Fitts Large, Hand-Eye Coordination	.208	85	1.908	.0564	-.006	.403
Reaction Time, Hand-Eye Coordination	.524	85	5.264	<.0001	.349	.663