The Purdue Pegboard Test: Normative Data for Older Adults with Low Vision

Walter Wittich, Ph.D., CLVT, FAAO, Assistant professor, School of Optometry, University of Montreal, CRIR/MAB-Mackay Rehabilitation Centre du CIUSSS du Centre-Ouest-de-l'Île-de-Montréal, 3744, rue Jean-Brillant, Montreal, Quebec, Canada, H3C 3J7 <walter.wittich@umontreal.ca>

Christina Nadon, M.Sc., School of Optometry, University of Montreal, 3744, rue Jean-Brillant, Montreal, Quebec, Canada, H3C 3J7 <christina.nadon.1@umontreal.ca>

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Given the aging of the population and the associated client shift within rehabilitation services, it is not surprising that the number of assistive devices used by older adults is constantly growing (Russell et al. 1997). Under ideal circumstances, these devices would be created according to the Principles of Universal Design (Story 1998), thereby being equally usable for all under all conditions. The reality, however, is that many device users encounter a variety of barriers in the usability of assistive technologies. In the context of aging and visual impairment, the visibility of any device and its components becomes crucial, and often users rely on tactile information in order to overcome visibility barriers. In low vision rehabilitation, the provision of and training in the use of assistive technologies (e.g., hand-held magnifiers, telescopes, closed-circuit televisions) is paramount. The assistance provided by these devices depends to a large extent on their usability, which is partially related to the ability of users to manipulate them. There is currently no formal assessment of manual dexterity included in the rehabilitation process; however, such an evaluation may be of particular benefit given that manual dexterity tends to decline with age (Holtrop et al. 2014). There are currently no established performance norms on common assessments of manual dexterity for older adults with a visual impairment. The aim of this study is to establish such norms, specifically for the Purdue Pegboard (Tiffin & Asher 1948).

With the aging of the population in developed countries, vision impairments are becoming more frequent given their increased prevalence with age (Congdon et al. 2004). Lamoureux and colleagues (2007) reported that vision loss negatively influences an individual's participation in activities of daily living and increases the risk for depression. Additionally, the same authors reported that vision impairments in older adults are associated with an increased risk of experiencing falls (possibly leading to hip fractures), increased dependence on family and community members, and a higher likelihood of reporting lower self-rated health. In order to address the functional consequences of vision impairment, older adults are frequently referred to low vision rehabilitation services (Owsley et al. 2009; Overbury & Wittich 2011).

One aspect of low vision rehabilitation is the provision of assistive devices that allow the individual to preserve or increase their independence and quality of life. This is accomplished by enabling, maintaining or improving their ability to complete activities of daily living (Horowitz et al. 2006). Gitlin and Burgh (1995) indicated that such devices are being used with increasing frequency among older adults, including aids for visual loss. The same study found that device users consider them as necessary for their functioning as well as enabling the user to decrease their dependence on others. Individuals with low vision may use optical aids (e.g., magnifier or telescopes) or non-optical aids, such as talking books and signature guides (Horowitz et al. 2006).

In addition to the use of vision, the completion of many activities of daily living, such as preparing a meal or self-grooming, is dependent upon the functional use of the upper limbs. It can be defined by two categories of motor skills; fine motor skills, such as eating and dressing, and gross motor skills such as postural control (Song 2015). Holtrop and colleagues (2014) identified the occurrence of a decreased ability to complete accurate and efficient movements with advancing age and its impact on the dexterity of the individual. As well, they determined that this decrease in dexterity might have an impact on the ability to complete skilled movements, such as those required to utilize certain assistive devices.

The accuracy and efficiency of movements made by older adults may be reduced due to several factors, one being age-related change in visual functioning. Song (2015) examined the relationship between age-related visual changes and manual dexterity in a sample of adults over the age of 60, and found that improved manual dexterity was associated with improved visual perceptual function. Additionally, the authors determined that cognitive performance was linked to manual dexterity, whereby better cognitive scores were associated with better results on assessments of dexterity. A study by Bowden and McNulty (2013) determined that performance on three commonly used assessments of motor functioning of the hand (handgrip strength, finger-tapping frequency, and grooved-pegboard performance) declined with age. Performance on the grooved pegboard, an assessment requiring fine dexterity movements, showed the greatest decrease in scores of the three tests, with a reduction of 46% being documented (44% for the hand-grip strength and 34% for the finger-tapping frequency).

The Purdue Pegboard (Lafayette Instruments, IN) is an assessment tool of fine manual dexterity developed in the 1940s with the original purpose of serving as a screening tool to select individuals to work in manual labour industries (Tiffin & Asher 1948). The task in the Purdue Pegboard requires individuals to place as many small metal pegs as possible into holes that are arranged in two vertical rows. Participants have thirty seconds to complete this task, first with the dominant hand, then the non-dominant hand, and finally with both hands simultaneously, over a period of three trials. This test has since been used in neuropsychological assessments to aid in determining the location of cerebral lesions (Costa et al. 1963), with individuals diagnosed with Parkinson's disease to assess the effectiveness of an intervention focused on hand exercises (Mateos-Toset et al. 2015), as well as a potential predictor of daily functioning ability in individuals with schizophrenia (Blanchard & Neale 1994; Lin et al. 2014)

Performance norms for the Purdue Pegboard have been determined for several age groups. Healthy women aged 40 to 85 were found to have scores ranging from 13 to 16 with their dominant hand, 11 to 15 with their non-dominant hand, and 9 to 13 pin pairs when both hands were used simultaneously (Agnew et al. 1988). For men, performance norms for the same age group were generally one point lower. Average scores for healthy older women aged 60 to 89 were found to range from 11.5 to 14 for the right hand, 11 to 13 for the left hand, and 8 to 11 pairs for both hands, again with slightly lower scores for men (Desrosiers et al. 1995). Performance norms for adults with early onset visual impairment, age 18 to 65 in a vocational setting, range from 10 to 15 for men, and 12 to 16 for women when using their right hand (Maxfield & Perry 1960). Reliability estimates for the one-trial version of the Purdue Pegboard have been found to range from poor to adequate; however, for the three-trial version, reliability was determined to be excellent (Buddenberg & Davis 2000). The authors attributed this finding to a practice effect on the Purdue Pegboard.

Manual dexterity has been suggested to play a role in the ability of older adults with vision impairments to use assistive devices (Jacko et al. 2003; Jacko et al. 2004; Leonard et al. 2005; Wittich et al. 2015). Therefore, assessments, such as the Purdue Pegboard, may be beneficial in determining which devices to recommend to an older adult seeking low vision services. The goal of the current study is to establish such dexterity norms, thereby enabling low vision researchers and rehabilitation professionals to have comparison values for the performance of their clients. The availability of such values could facilitate the inclusion of a formal assessment of manual dexterity into routine practice in low vision rehabilitation, and guide the design of assistive technologies.

Method

The current analysis relied on data collected and pooled across three separate studies that had received institutional review board approval by the *Centre de recherche interdisciplinaire en réadaptation du Montréal métropolitain* (CRIR). One of these studies has already been published (Wittich et al. 2015) whereas the other two are currently being completed. While these studies examined various aspects of low vision rehabilitation, they all included the Purdue Pegboard as an assessment of manual dexterity. Pooling the data provided access to a large database of older adults with an acquired visual impairment who had completed the Purdue Pegboard, from which performance norms could be drawn.

Participants.

Participants were recruited from client lists at the MAB–Mackay Rehabilitation Center (MMRC). They were eligible to be included in the analysis if they were over the age of 60, had a measurable level of visual acuity and completed the Pegboard utilizing their remaining vision. Persons who completed the Pegboard in a tactile fashion were excluded, resulting 134 participants included in the final analysis.

Measures & Procedure.

The Purdue Pegboard is a short assessment of manual dexterity. The test consists of a rectangular board with two sets of 25 holes running vertically down the center of the board and four concave cups at the top. Small metal pegs are placed in the cups at the top of the board. Participants are asked to begin with their dominant hand and to remove one peg at a time from the cup on the side being tested, and to place it in one of the holes on the same side. The goal is to place as many pegs as possible into the holes on the board within the 30s time limit. This process is repeated with the non-dominant hand and with both hands simultaneously. In the "both-hands" condition, participants are asked to take one peg at a time with each hand and place them in the holes on the respective sides. The procedure is repeated for three trials. In the single-hand conditions, the total number of pegs placed in the holes are scored. In the “both-hands” condition, the number of pin pairs successfully placed in the holes is scored. These scores are recorded and, following the completion of the three trials, an average score of pins or pin pairs is calculated.

Results

The age of participants ranged from 60 to 97 (M = 82.6 , SD = 9.0), with 96 female and 38 male participants. Distance visual acuities in the better eye of those included in the study ranged from 20/30 to 20/604. While visual acuities are reported as Snellen fractions, statistical analyses requiring visual acuities were conducted using logMAR conversion. Sample characteristics (sex, number, and visual acuity) by age group are displayed in table 1. The majority of participants (n = 121) reported their right hand as dominant. Most individuals had a known visual impairment diagnosis, with the most frequent being age-related macular degeneration (n = 87) and glaucoma (n = 25). Contrast sensitivities for participants (n = 80), as assessed by the MARS test (Arditi 2005), ranged from 0.03 to 1.64 log contrast sensitivity units. Pearson correlation coefficients were calculated for age, performance in each Purdue Pegboard condition (dominant hand, non-dominant hand, both hands), contrast sensitivity, and distance visual acuity on the ETDRS chart. The only correlation determined to not be significant was between age and visual acuity, indicating comparable distribution of visual impairment across age groups (see table 2).

The performance on the Purdue Pegboard was compared using a mixed between-within 2x4x3 ANOVA, with the factors being sex (male/female), age (6^{th}, 7^{th}, 8^{th}, and 9^{th} decade), and Purdue Pegboard condition (dominant, non-dominant, and both hands). It was determined that there was a main effect of age, $F(3, 126) = 6.95$, $p < .001$, $\eta^2 = .14$. Post-hoc analysis, using Bonneferroni correction, indicated that scores of individuals in their 9th decade were significantly lower than those of participants in their 6th or 7th decade, $p < .002$, respectively. Furthermore, a main effect of Purdue Pegboard condition was statistically significant, $F(2, 252) = 150.89$, $p < .001$, $\eta^2 = .55$. Post-hoc contrast comparisons indicated that each hand condition differed from the other twos: dominant versus non-dominant, $p < .001$, $d = 0.23$; non-dominant versus both hands, $p < .001$, $d = 0.69$; and dominant versus both hands, $p = < .001$, $d = 0.92$. Neither the main effect of sex nor any of the interaction effects were significant.

Purdue Pegboard data are conventionally displayed for men and women separately, as previous work has indicated that women generally perform better on this test (Yeudall & Fromm 1986; Agnew et al. 1988). Therefore, our data in table 3 separated by sex, even though there were no statistically significant differences between the sexes in our study. In order to compare our data further, figure 1.a and 1.b display the results of the current study in relation to performance norms established in previous studies for healthy older adults (Agnew et al. 1988; Desrosiers et al. 1995). Furthermore, figure 2.a and 2.b display Pegboard scores across several studies that involved participants with a visual impairment (Maxfield & Perry 1960; Tobin & Greenhalgh 1987). Scores, grouped by severity of visual acuity loss, indicate a worsening of Pegboard performance as visual acuity declines.

Discussion

This study aimed to establish performance norms for older adults with a visual impairment on the Purdue Pegboard, a common test of manual dexterity. The significant effect of age on Purdue Pegboard scores indicated that performance decreased with increasing age.

Specifically, participants in their 9th decade were found to have significantly lower scores than participants in their 6th or 7th decade. In addition, hand condition had a significant impact, whereby performance was best when participants used their dominant hand and performance was worst when participants were required to use both hands simultaneously. Contrary to previous findings, the results of this study did not indicate a significant difference between men and women; however, we speculate that the considerable variance among participants and the limited sample size in some of the groups may mask such a sex-effect.

Comparisons of our performance norms to those available in the literature demonstrated that the scores of older adults with low-vision were considerably lower than those of healthy older adults by about 4 to 5 pegs or peg pairs across conditions, for men and women of all age groups (figures 1.a and 1.b). Comparisons for the scores of those with low-vision in their 9th decade was not possible, as previous normalized standards for this age group have not yet been established. Given the current changes in demographics, however, such standards will soon become necessary. Figure 2.a and 2.b provide a comparison of the present data with previous studies utilizing the scores of persons with a visual impairment. These comparisons indicated that a general decrease in performance was observable with decreasing visual acuity. Additionally, overall performance of older adults with low-vision was worse than the performance of working age adults with low-vision, again demonstrating the effect of age on Purdue Pegboard scores. This comparison is likely affected by the age of onset for the visual loss, as the large majority of participants in the previous studies had congenital or early-onset visual impairments (Maxfield & Perry 1960; Tobin & Greenhalgh 1987). Our participants had normal vision for the majority of their lives; therefore, they may not have had the need to develop their tactile abilities at the same level of expertise and sensitivity as their peers with a congenital or early-onset visual impairment.

The Purdue Pegboard has been utilised as a test of manual dexterity in research contexts in which older adults with low-vision are asked to complete manual tasks. Although the Purdue Pegboard has been utilized previously in low vision research, some studies simply included the test in order to measure dexterity as a control variable without further analysis (Emery et al. 2002; Moloney et al. 2006). A study by Leonard and colleagues (2005) reported mean Pegboard scores for older adults age 53-82 with visual impairment of up to 20/200, equivalent to our low vision group. Comparison with our data indicates that their participants' scores (ranging from 4 to 16, mean 11.5) fell within the normative ranges for the 6th and 7th decade; however, their data were not broken down for age group to allow closer comparison. Jacko and colleagues (2003) tested older adults between the ages of 54 and 91 (mean age of 76), having either normal vision or a diagnosis of age-related macular degeneration (visual acuities ranging from 20/20 to worse than 20/100). Their study examined the effects of multimodal feedback (visual, auditory, and haptic feedback) on a variety of drag-and-drop computer tasks in which the participants received varying amounts of feedback. Given that the participants would be interacting with the computer system using a mouse, an assessment on manual dexterity was necessary to assess their abilities. The Purdue Pegboard was utilised as an assessment of manual dexterity, and the results were compared to the norms provided by Tobin and Greenhalgh (1987), indicating that the participants scored between the 40th and 50th percentile for visually impaired working age adults and at the 5th percentile for unimpaired adults. As stated by the authors, their participants were significantly older than those in the study by Tobin and Greenhalgh (1987). When comparing

Jacko's data with our norms, it is clear that their mean score of 10.6 pins for the right hand falls well within the normative range reported here for their age group.

The question that remains is why performance of visually impaired older adults is so much poorer than that of both their sighted peers and of visually impaired younger adults. Part of the answer may be found in previous research on hand-eye coordination in older adults with macular degeneration. Timberlake and colleagues (Timberlake et al. 2011) were able to demonstrate that their participants with central visual field loss showed slower visual reaction time, longer movement duration and reduced maximum movement velocity when completing reaching-and-grasping tasks. Similarly, Kotecha and colleagues (2009) demonstrated that individuals with glaucoma show significant delays in movement duration in a reaching-and-grasping task, causing slower and more tentative reaching behaviour. The studies are specifically relevant in the our context as the two main diagnostic categories in the present study are macular degeneration and glaucoma. The reach-and-grasp components of the Purdue Pegboard task in older adults with a visual impairment is likely influenced by additional scanning behaviours in order to locate and grasp each peg, then locate the hole in the peg board, align and insert the peg, and then repeat the task, all in the presence of reduced visual resolution and possible blind regions in the visual field.

The performance norms for older adults with low-vision presented here will enable future researchers and rehabilitation service providers to use the Purdue Pegboard test as an assessment of manual dexterity, and to interpret and compare their data. Low-vision rehabilitation specialists will be able to determine if the performance of their client on the Purdue Pegboard would be as expected. Our study, however, is not without limitations. We were only able to recruit five men in their 7^{th} decade. This small sample size may have biased the performance norms established for this age group and may explain why scores in this sub-group appear higher than those in other groups. Future studies should establish norms for older adults with visual impairment (partial or total) who complete the Purdue Pegboard based on tactile rather that visual cues, given that the early-blind participants in the study by Tobin and Greenhalgh (1987) completed the task without any vision. It would also be interesting to investigate the effect of age of visual impairment onset, as we speculate that early visual impairment may initiate compensation mechanisms that result in improved performance in older age. Finally, the relationship between Purdue Pegboard scores and device use and usability in older adults with visual impairment will need to be examined further in order to confirm to which extent and under which conditions lower dexterity scores indeed translate into impairments in device handling.

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Declaration of Interest

The authors have no conflict of interest to report.

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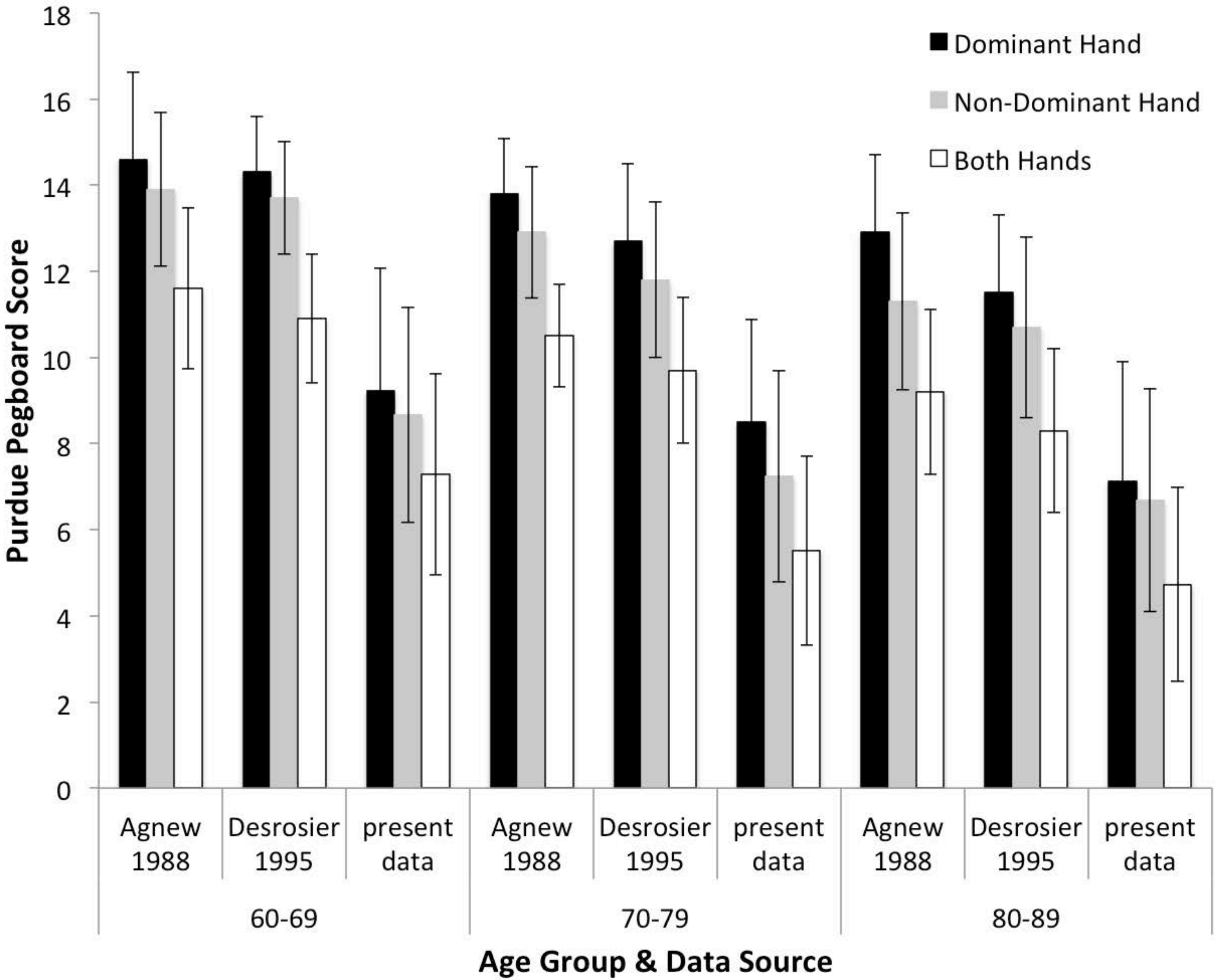
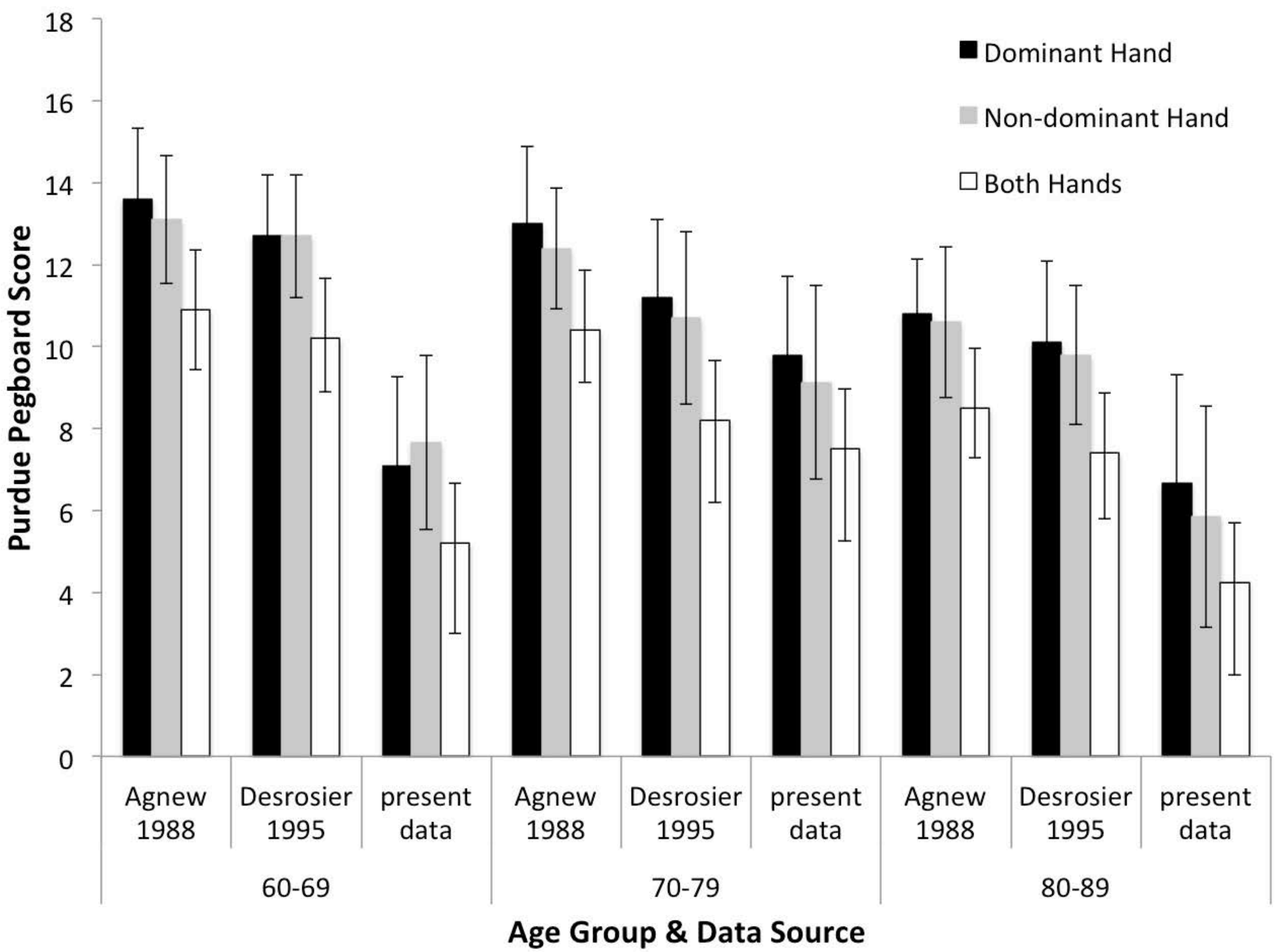
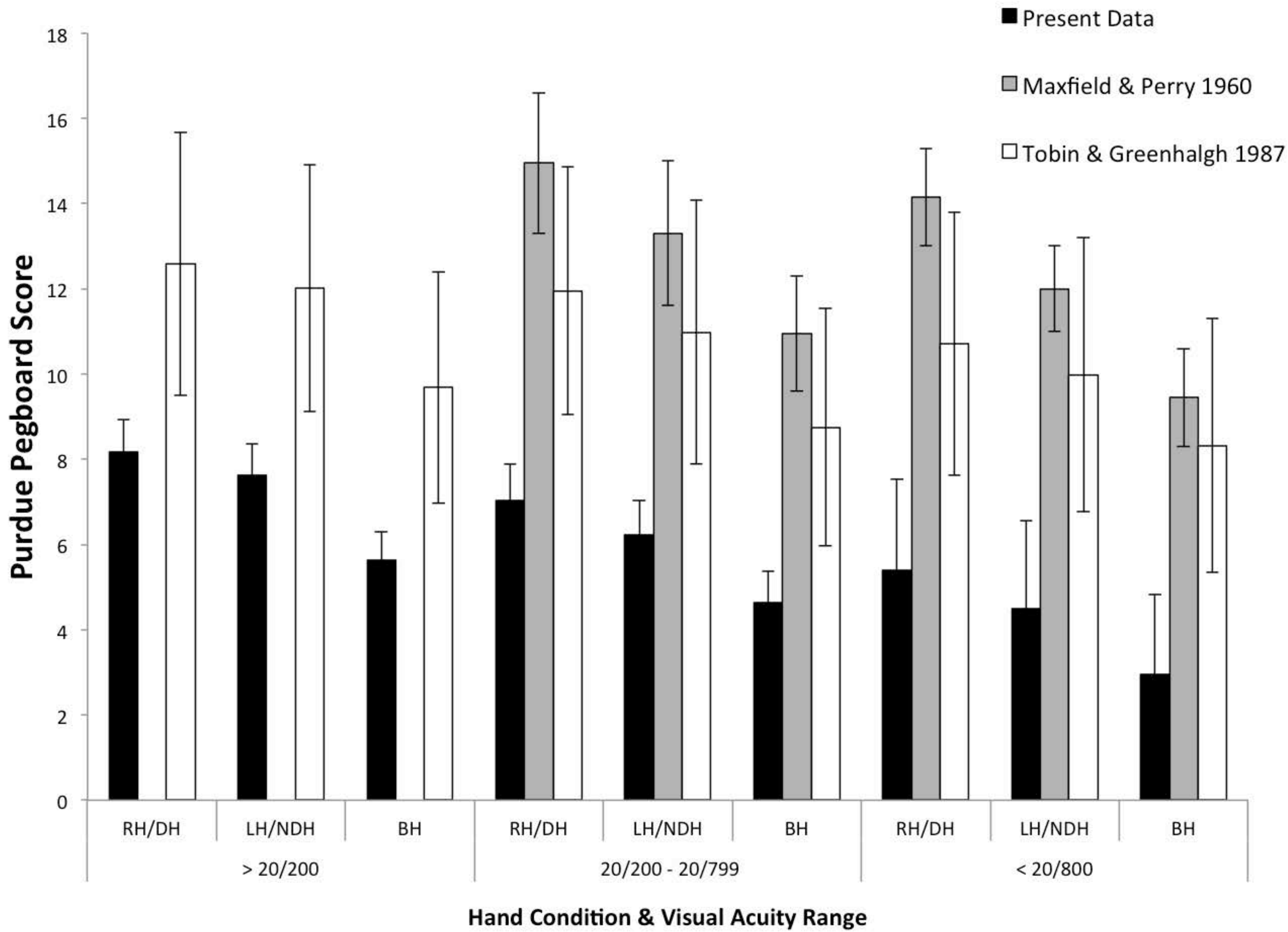
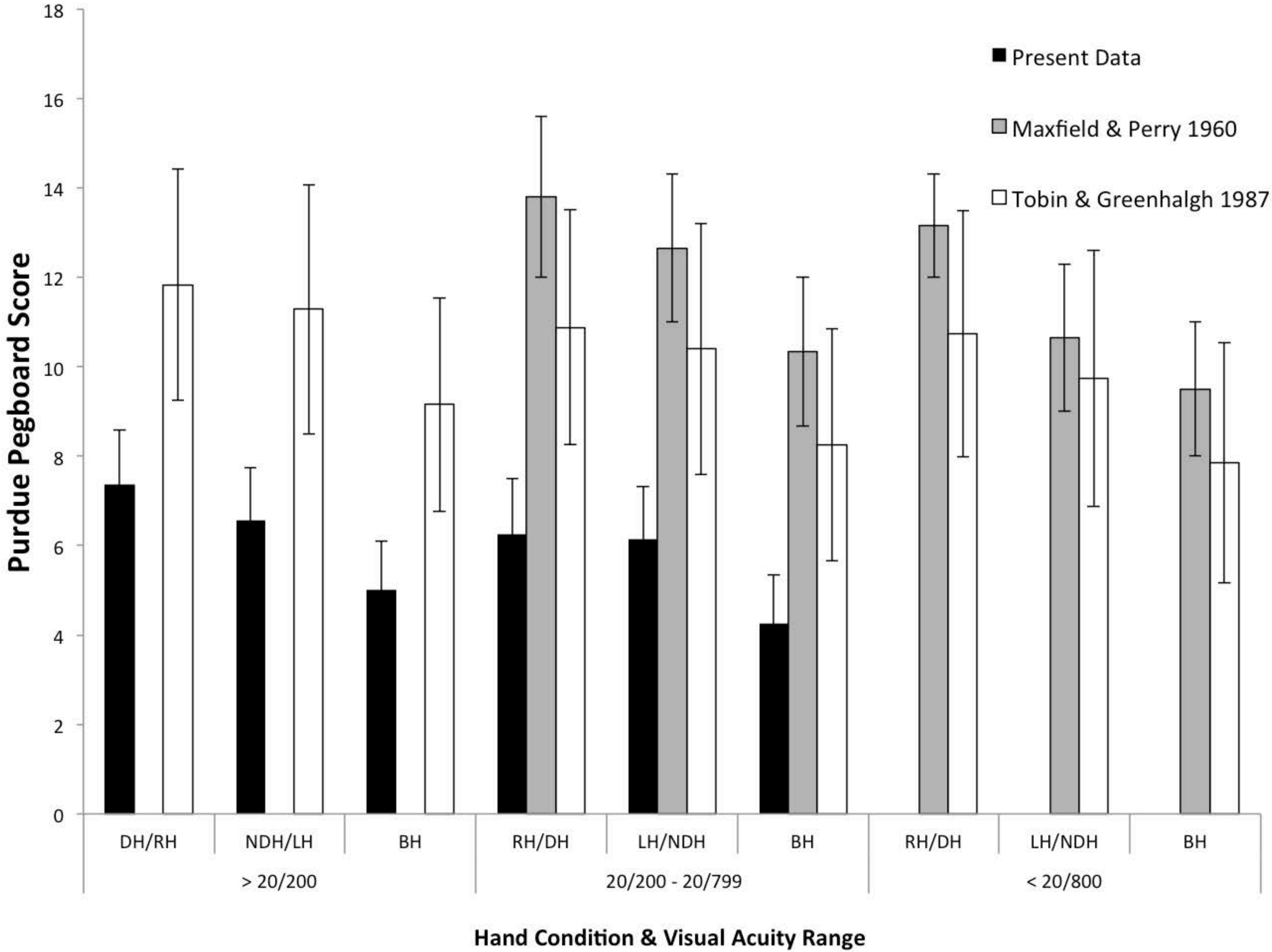


Dominant Hand
Non-Dominant Hand
Both Hands
Purdue Pegboard Score
0
2
4
6
8
10
12
14
16
18
Agnew 1988
Desrosier 1995
present data
Agnew 1988
Desrosier 1995
present data
Agnew 1988
Desrosier 1995
present data
60-69
70-79
80-89
Age Group & Data Source


Dominant Hand
Non-dominant Hand
Both Hands
Purdue Pegboard Score
18
16
14
12
10
8
6
4
2
0
Agnew 1988
Desrosier 1995
present data
Agnew 1988
Desrosier 1995
present data
Agnew 1988
Desrosier 1995
present data
60-69
70-79
80-89
Age Group & Data Source


Present Data
Maxfield & Perry 1960
Tobin & Greenhalgh 1987
Purdue Pegboard Score
18
16
14
12
10
8
6
4
2
0
RH/DH
LH/NDH
BH
RH/DH
LH/NDH
BH
RH/DH
LH/NDH
BH
> 20/200
20/200 - 20/799
< 20/800
Hand Condition & Visual Acuity Range



Present Data
Maxfield & Perry 1960
Tobin & Greenhalgh 1987
Purdue Pegboard Score
18
16
14
12
10
8
6
4
2
0
DH/RH
NDH/LH
BH
RH/DH
LH/NDH
BH
RH/DH
LH/NDH
BH
> 20/200
20/200 - 20/799
< 20/800
Hand Condition & Visual Acuity Range

Table 1. Participant Characteristics (sex, number, and visual acuity) by age group

		n	Mean	Min	Max
WOMEN	Age	84	82	60	97
	VA		20/148	20/30	20/448
	VA by age group				
	60 - 69	8	20/182	20/50	20/399
	70 - 79	17	20/148	20/50	20/317
	80 - 89	40	20/135	20/32	20/448
	90 - 99	19	20/138	20/30	20/399
MEN	Age	36	82	62	97
	VA		20/163	20/50	20/604
	VA by age group				
	60 - 69	7	20/152	20/63	20/317
	70 - 79	4	20/121	20/80	20/200
	80 - 89	16	20/187	20/50	20/604
	90 - 99	9	20/159	20/100	20/252

Note. VA = best distance visual acuity.

Table 2.

Pearson's correlation coefficients for all variables.

Variable	1.	2.	3.	4.	5.	6.
1. Age	-	-.27*	-.09	-.34**	-.34**	-.38**
2. MARS		-	-.31**	-.27*	.29**	.32**
3. VA			-	-.36**	-.37**	-.34**
4. DH				-	.85**	.90**
5. NDH					-	.90**
6. BH						-

Note. Sample size varied from n = 76 to n = 134, depending on the data available within clinical charts. MARS = performance score on the MARS Contrast Sensitivity Assessment; VA = best distance visual acuity; DH = dominant hand score on Purdue Pegboard; NDH = non-dominant hand score on Purdue Pegboard; BH = both hands score on Purdue Pegboard.

$^{*}p<.05$, $^{**}p<.01$

Gender	Age	*n*	Hand	Mean	SD	SE	95% C.I. -	95% C.I. +
Women	60-69	9	D	9.63	2.70	0.84	7.96	11.30
			ND	8.85	2.58	0.81	7.25	10.46
			Both	7.50	2.36	0.72	6.08	8.92
	70-79	18	D	8.66	2.35	0.60	7.48	9.84
			ND	7.47	2.29	0.57	6.34	8.61
			Both	5.72	2.05	0.51	4.72	6.73
	80-89	43	D	7.33	2.74	0.39	6.57	8.10
			ND	6.95	2.47	0.37	6.21	7.68
			Both	4.95	2.16	0.33	4.30	5.60
	90-100	21	D	6.06	2.49	0.55	4.96	7.15
			ND	5.33	2.49	0.53	4.28	6.39
			Both	3.77	2.22	0.47	2.84	4.70
Men	60-69	7	D	7.10	2.17	0.96	5.20	8.99
			ND	7.67	2.13	0.92	5.84	9.49
			Both	5.21	2.21	0.81	3.60	6.83
	70-79	5	D	9.80	1.92	1.13	7.56	12.04
			ND	9.13	2.36	1.09	6.98	11.29
			Both	7.50	2.24	0.96	5.59	9.41
	80-89	16	D	6.67	2.64	0.63	5.41	7.92
			ND	5.85	2.71	0.61	4.65	7.06
			Both	4.24	2.25	0.54	3.17	5.31
	90-100	10	D	6.10	1.98	0.80	4.52	7.68
			ND	5.47	2.02	0.77	3.94	6.99
			Both	4.15	1.70	0.68	2.80	5.50