The Contribution of Executive Functioning to Fine Motor Control in Healthy Ageing

Dissertation submitted by
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Declaration

I declare this honours dissertation is my own work and has not been submitted in any form for another degree or diploma at any university or other institute of tertiary education. Information derived from the published or unpublished work of others has been acknowledged in the text and a list of references is given.

Signature:

Date:

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Abstract

Fine motor control involves the coordination of small muscle movements in the hands and fingers. Several studies have identified age- related deficits of fine motor control, with older adults performing poorly when compared to younger adults. As well as fine motor control deficits, older adults also demonstrate deficits in their executive functioning. Executive functioning includes processes such as planning, spatial working memory (SWM) and set-shifting abilities. Since both executive functioning and fine motor control deficits are present in healthy ageing, the relationship between the two functions is of interest. The present study examined the independent contribution of planning, set- shifting and SWM to unimanual, bimanual and sequencing movements in forty- one (N= 41) healthy older adults. It was hypothesised that planning would the primary predictor. Fine motor control was measured by the Purdue Pegboard which consisted of three subtasks; unimanual, bimanual and sequencing tasks. Executive functioning was measured by three tests on the CANTAB; stockings of Cambridge (planning), spatial working memory (SWM) and ID/ED (set- shifting). The results found that planning was a significant predictor of unimanual, bimanual and sequencing movement scores. The findings from the study can be used to help identify potential aids to help improve planning abilities and fine motor control.

Introduction

Fine motor control involves the coordination of small muscle movements in the hands and fingers. This co-ordination of the hands and fingers involves manipulating objects between the thumb and finger, maintaining the required force and the desired direction (Vielut, Mahmoodi, Godde, Reuter & Voelcker- Rehage, 2012). Several studies have identified age-related deficits of fine motor control using the Purdue Pegboard. The Purdue Pegboard is a measure of fine motor control which requires participants to place pegs on a board with one hand (unimanual) or two hands simultaneously (bimanual), and assemble objects using the two hands (sequencing). Older adults consistently perform poorly on the unimanual, bimanual and sequencing tasks of the Purdue Pegboard compared to younger adults (Ralf, 2002; Clarke, Loftus and Hammond, 2011; Marneweck, Loftus & Hammond, 2011).

According to Seilder, Bernard, Burutolu, Fling, Gordon, Gwin, Kwak and Lipps (2010), fine motor control deficits in older adults may be due to many factors. Stelmach, Goggin and Amrhein (1988) examined bimanual and sequencing tasks in older people. They reported deficits in their movements were related to proprioception (the sense of the relative position of parts of the body), which suggests spatial orientations could be a contributing factor. Later, Yan, Thomas and Stelmach (1998) suggested that deficits in fine motor control among older adults could be due to planning problems, as the difficulties they observed were in the way an aiming movement was controlled rather than muscular or physical deterioration. Further studies by Heuninchx, Wenderoth, Debaere, Peeters and Swinnen (2005) and Heuninchx, Wenderoth and Swinnen (2008) suggest that the deficit in motor control experienced by older adults could be due to 'dual- task costs.' As a person ages, there is an increased reliance on executive functions. This may result in 'cognitive overload' when performing particularly demanding tasks, resulting in less attention directed toward motor control. Taken together, these findings suggest that fine motor declines in ageing are associated with deficits in executive functions of the prefrontal cortex.

Older adults also demonstrate significant declines in executive functioning (Seilder et al., 2010). Executive functioning is an overarching term for higher cognitive processes in the prefrontal cortex that control, manage and regulate other cognitive processes (Salthouse, Atkinson, & Berish, 2003). Huppert, Bravne, Paykey and Beardsall (1995) assessed cognition in older people using the Cambridge Automated Neuropsychological Test Battery (CANTAB).

They found that some executive functions demonstrated age-related decline and others did not. The functions that demonstrated significant age related declines included set- shifting, spatial working memory and strategic planning.

According to Smith, Jonides and Koeppe (1996) spatial working memory (SWM) is responsible for attaining information about object and environment locations. For example, SWM is needed to help someone navigate around their house, as memory is required for the person to remember where certain objects are kept in the house. Robbins, James, Owen, Shahakian, Lawrence, McInnes and Rabbit (1998) examined executive functioning in participants aged 21 to 79 years old using the CANTAB SWM task. The task required participants to identify a blue square in a range of boxes and to remember which boxes contained the blue squares. Participants in the 60 to 79 year-old group demonstrated significantly more errors compared to those in the 21- 39 and 40- 59 year-old groups. This led the authors to conclude that SWM deficits develop from the age of 60.

Planning involves identifying goals and developing strategies to achieve the desired goals (Craik & Bialystok, 2006; Jurado & Rosselli, 2007). Robbins et al (1998) used the CANTAB Stockings of Cambridge task to measure planning abilities in young and older adults. In this task, there are 2 displays presented on the screen, a top display and a bottom display. The top display consists of a figure of circles, and the bottom displays a slightly different figure of circles. The participants are required to make the bottom screen match the top screen by moving the circles around. The participants are only allowed to make a limited number of moves, therefore the task involves strategic planning. Robbins et al., (1998) reported that younger adults solved significantly more problems than older adults and that older adults took longer to complete each task. The authors concluded that planning declines develop at approximately 60 years old.

Set- shifting is the ability to update or shift cognitive strategies in response to changes in the environment (Owen, Roberts, Hodges & Robbins, 1993; Liens, Ruthruff & Kuhns, 2008; Anderson, 2001). Ridderinkold, Span and van der Molen (2002) examined set-shifting abilities in young and older adults using the Wisconsin Card Sorting test. This task involves a number of different cards being displayed to the participant. The participant is then told to match the cards, and then the participant is told whether the match was correct or

incorrect. If the match was correct, the participant proceeds matching, then once the rule is learnt the participant is told this is now not correct. This then requires the participant adjust to rule changes. The findings indicated a negative relationship between performance and age, such that as age increased performance decreased. The authors concluded that set- shifting declines develop at approximately 60 years old.

Since both executive functioning and fine motor control deficits are present in healthy ageing, the relationship between these two functions is of interest (Woollacott & Shumway-cook, 2002). A number of studies suggest a common underlying neurological relationship between motor control and executive function. Van Dyck, Avery, MacAvoy, Marek, Quinlan and Baldwin (2008) found that low dopamine transporter levels were linked to decreased movement control in older adults, as well as a relationship found between low dopamine transporter levels and executive functions such as working memory. This provides evidence to suggest that the two functions share the same dopamine circuit – as low levels of dopamine in the motor cortex correspond with low levels of dopamine in prefrontal cortex (Van Dyck, Avery, MacAvoy Marek, Quinlan & Baldwin, 2008). The 'dual- task cost' theory is another neurological finding linking executive functioning to motor control. This theory proposes that there is an increased reliance on executive functions when performing movement in ageing, as additional cognitive areas of the brain are found to be activated during motor tasks (Heuninckx, Wenderoth, Debaere, Peeters, & Swinnen, 2005). The aforementioned findings suggest that executive functioning and motor control in ageing could be related via neural pathways.

Most research to date has focussed on the relationship between global cognition and gross motor control abilities (Pichierri, Wolf, Murer & de Bruin, 2011). Woollacott and Shumway-cook (2002) found that balance was worse when the participant's attention was divided between balancing and a digit memory task, suggesting that attention is needed for balance control. However, this study only considered gross motor control and did not consider the specific contribution of executive function. More recently, Samper- Ternent, Snih, Raju, Marides and Ottenbacher (2008) reported that older adult's demonstrated poorer global cognition compared to younger. The focus on global cognition and gross motor control means the relationship between specific executive functions and fine motor control has been somewhat neglected (Pichierri, Wolf, Murer & de Bruin, 2011).

The fact that low dopamine activation in motor cortex is associated with low dopamine activation in prefrontal cortex suggests the relationship between cognition and motor is most evident when a deficit is present. Thereby, the present study focused on a population of older adults with a deficit in fine motor control. The present study examined the relationship between three different components of executive functioning and fine motor control in healthy older adults with a deficit in fine motor control. The study examined the independent contribution of planning, set- shifting and SWM to unimanual, bimanual and sequencing movements in healthy older adults (see Figure 1). In light of Yan, Thomas and Stelmach's (1998) findings, the present study proposes that planning will be the primary predictor of variance in unimanual, bimanual and sequencing scores.

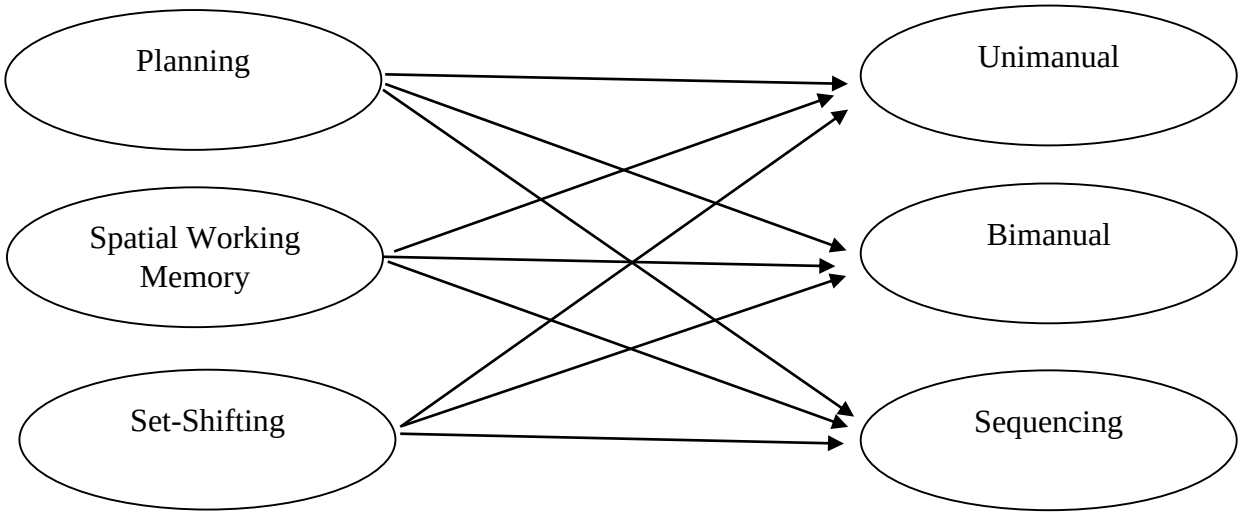

Figure 1. The study explored the independent relationship between executive functioning abilities and unimanual, bimanual and sequencing movements.

Method

Participants

Forty one participants (22 males, 19 females) aged 60- 90 (M=75, DS=7.89) were included in the study. Participants were recruited via distribution of flyer to retirement villages and advertising on Curtin FM radio station. Participants who presented a deficit in the unimanual subtest of the Purdue Pegboard were included in the study (Agnew, Bolla-Wilson, Kawas & Bleeker, 1988). Each participant received a $40 Coles/Myer voucher for participation.A priori power analysis was conducted using the G*Power program (Faul, Erdfelder, Lang & Buchner, 2007). A three predictor variable equation was used as a baseline. The alpha level used for this analysis was $p < .05$ and the power level was set to .80, two-tailed. The power analyses revealed that 40 participants would be required for detecting a medium effect size.

Research Design

This study was a within- subjects correlational design. Three separate executive functioning tasks (SWM, planning and set- shifting) were the predictor variables. Unimanual, bimanual and sequencing scores from the Purdue Pegboard were the three outcome variables. Planning, set- shifting and SWM were assessed using the CANTAB and fine motor control was assessed using the Purdue Pegboard

Measures

To screen for global cognitive impairment, a shortened version of the Mini Mental State Exam (MMSE) was used. The MMSE is a 5-10 minute test which assesses arithmetic, memory and orientation. The MMSE was conducted over the phone to see if participants were eligible to participate. Older adults who scored 20/25 and over on the MMSE were eligible for participation.

The Cambridge Automated Neuropsychological Test Battery (CANTAB) was used to assess executive function. The CANTAB is a computer based cognitive assessment tool consisting of a range of neuropsychological tests, which assesses cognitive functions. The CANTAB has been found to be sensitive to prefrontal dysfunction (Huppert, et al., 1995).

Set- shifting. The Intra Dimensional Extra Dimensional Set- Shift task (ID/ED) was used to measure set- shifting ability. The ID/ED assesses the ability to make simple discriminations and shift mental set from one dimension to another (Cambridge Cognition, 1996). For each trial, four boxes appeared on the computer screen, two of which contained stimuli. Participants were instructed to select the correct stimulus by touching the stimulus on the screen. The correct stimulus was identified based on trial and error and the computer informed the participant whether their response was correct or incorrect. The task required participants to identify an underlying rule to determine which of the stimuli was correct. At the start of the trial there were no explicit rules, the first choice was based on a guess. The participants were then informed that there would be a rule they need to learn to identify the correct stimuli, but once the rule was learnt it would change. There were nine phases, each with its own rule. Total errors were used in the present study, with a lower score (low errors) indicating better set- shifting ability. The test/re-rest reliability of the measure is good, with a Pearson's correlation of $r = .70$ (Lowe & Rabbit, 1998).

Spatial working memory. The SWM task on the CANTAB measures the ability to recall spatial information and manipulate this information in working memory (Cambridge Cognition, 1996). A number of small boxes appeared at different locations on the screen. Participants were instructed to touch one of the boxes to reveal a hidden token, which they then had to deposit in a space to the right side of the screen. Participants were instructed to select only one box at a time and that only one token would be hidden at a time. Participants were also instructed not to search for tokens in boxes they had previously found a token in, as the tokens would not appear in the same box twice. The amount of tokens to be found in each trial was the same as the number of boxes present on the screen. The total errors score was used in the present study, which indicates the amount of times a participant returned to a box which already had a token retrieved from it. Lower scores indicate better SWM ability. The test-retest reliability for this task is good with a Pearson's correlation of $r = .68$ (Lowe & Rabbit, 1998).

Planning. The Stockings of Cambridge (SOC) CANTAB task was used to assess strategic planning abilities (Cambridge Cognition, 1996). For this task, there were two figures of coloured balls on the computer screen. The top half of the screen displayed an arrangement of balls that needed to be replicated by the participant. The participants were instructed to

move the balls in the bottom half of the screen so that they matched the configuration of balls at the top of the screen. The participants were told that a ball could not be moved from underneath another ball, only one ball could be moved at a time, and balls could only be moved into another 'stocking' and not into a space on the screen. Each trial had a limited number of moves in which the desired configuration could be achieved, which was displayed on the screen. This task was scored by how many stages were completed without error (lower numbers indicate higher planning ability). The test- retest reliability of the measure is good, with Pearson's correlation r = .60 (Lowe & Rabbit, 1998).

Fine motor control. The Purdue Pegboard was used to measure fine motor control of the hands and fingers. This measure consists of three subtests (1) Unimanual (2) Bimanual and (3) Sequencing. The unimanual subtest required participants to use their preferred hand to insert pegs, one at a time, into a vertical line of holes into the Pegboard, starting from the top hole and working down. The bimanual subtest was similar to the unimanual, but required both hands to be used simultaneously to complete the same task. The sequencing subtest required participants to insert a peg into the board with one hand, then assemble three more objects together on top of the peg (a peg, a washer, a collar, and a second washer) using the two hands separately in a coordinated fashion. The Purdue Pegboard was scored by counting how many movements were performed in 30 seconds during the unimanual and bimanual subtest, and how many assembles were completed in 60 seconds in the sequencing subtest. For all three subtests, higher numbers indicate better scores. The test-retest reliability for adults 60 years and over is good, with Pearson's r ranging from 0.66 to 0.90 (Desrosiers, Hebert, Bravo & Dutil, 1995).

Procedure

All testing was conducted at the Curtin University Neuroscience Laboratory. Upon arrival, an information sheet was provided and explained and informed consent was provided. The Purdue Pegboard was administered first, followed by the stockings of Cambridge, SWM and ID/ED tasks on the CANTAB.

The participants had two minute breaks between each task to avoid fatigue.

Data Analyses

Prior to analysis, the data were screened. One variable of missing data was identified for one participant, which was dealt with via mean substitution according to the age group mean (Robbins et al., 1988). Descriptive statistics and normative data for the Purdue Pegboard can be seen in table 1a and for the CANTAB table 1b.

Three Stepwise Hierarchical Regression analyses (HRA) were conducted. The first HRA examined whether planning, SWM, and set- shifting predicted unimanual scores. The second regression examined whether planning, SWM, and set- shifting predicted bimanual scores, and the third HRA examined whether planning, SWM and set-shifting predicted sequencing scores.

Before interpreting the results of the regressions, a number of assumptions have to be met. Stem and leaf plots and boxplots indicated that there were 3 outliers. One SD above the highest non-outlier was added to each outlier (Allen & Bennet, 2010). Stem and leaf plots and boxplots indicated each variable in the regression was normally distributed. Inspection of the normal probability plots of standardised residuals and the scatterplot of standardised residuals versus standardised predictor values indicated that the assumptions of normality, linearity, and homoscedasticity of residuals were met. For all three regressions, Mahalanobis distance did not exceed the critical χ^2 for $df = 3$ (at $\alpha = .001$) of 16.27 for any cases, indicating that multivariate outliers were not a concern. Finally, relatively high tolerances for all predictors in the final regression models indicated that multicollinearity was not a concern when interpreting results. Pearson's correlations coefficients were conducted to establish relationships between variables (see table 2).

Table 1a

Descriptive Statistics and Performance Means and SDs on Purdue Pegboard Compared to Published Normative Data

Task	Sample Details	Mean (SD) present study	Mean (SD) Published Normative data	Reference
Purdue Pegboard				
Unimanual	Males			
	60- 69 (n=9)	10.4 (0.88)	13.6 (1.74)	
	70-79 (n= 9)	9.7 (1.50)	13 (1.00)	
	80 + (n= 4)	8 (1.29)	11 (1.00)	Agnew, et al (1988)
	Females			
	60-69 (n=2)	13 (0)	14.6 (1.03)	
	70-79 (n=9)	10 (1.85)	13.8 (1.27)	
	80 + (n=8)	10 (1.31)	12.9 (1.00)	
Bimanual	Males			
	60- 69 (n=9)	8.9 (1.26)	10.9 (1.46)	
	70-79 (n= 9)	7.1 (2.47)	10.4 (1.27)	
	80 + (n= 4)	5.75 (0.5)	8.5 (1.21)	Agnew, et al (1988)
	Females			
	60-69 (n=2)	11.5 (0.71)	11.6 (1.87	
	70-79 (n=9)	8 (2.24)	10.5 (1.19)	
	80 + (n=8)	12.75 (1.46)	9.2 (1.92)	
Sequencing	Males			
	60- 69 (n=9)	23.7 (4.77)	28.0 (5.06)	
	70-79 (n= 9)	18.7 (5.63)	27.5 (5.06)	
	80 + (n= 4)	15.5 (0.58)	21.5 (4.81)	Agnew, et al (1988)
	Females			
	60-69 (n=2)	26 (5.66)	31.7 (6.83)	
	70-79 (n=9)	20.5 (8.66)	29.1 (4.85)	
	80 + (n=8)	17.12 (6.79)	21.9 (4.54)	

Note. SD= Standard Deviations

Table 1b

Descriptive Statistics and Performance Means and SDs on CANTAB Compared to Published Normative Data

Test	Sample Details	Mean (SD) present study	Mean (SD) published normative data	Reference
CANTAB				
SOC	60-69 (n=11)	8 (2.15)	7.77 (1.82)	
	70-79 (n=18)	6.5 (2.33)	7.31 (1.77)	Robbins et al., (1998)
	80 + (n=12)	6 (1.28)	6.46 (1.96)	
SWM				
	Males			
	60- 69 (n=9)	45.33 (21.29)	32.25 (24.52)	
	70-79 (n=9)	62.89 (44.34)	38.82 (19.71)	
	80 + (n=4)	49.75 (23.47)	37.5 (29.6)	Robbins et al., (1998)
	Females			
	60- 69 (n=2)	12 (12.73)	36.62 (12.32)	
	70-79 (n=9)	61.22 (39.31)	43.82 (21.52)	
	80 + (n= 80	65.87 (17.13)	61.83 (14.25)	
ID/ED	60- 69 (n=11)	31.55 (21.24)	10.21 (9.99)	Robbins et al., (1998)
	70- 79 (n=18)	38.72 (19.72)	12.03 (10.71)	
	80+ (n=12)	47.33 (46. 53)	9.25 (11.04)	

Note. SD= Standard Deviations

Table 2

Correlation Matrix (Pearson's Correlation Coefficient) for Each of the Study Variables

Variable	Mean	SD	1.	2.	3.	4.	5.	6.
1. Unimanual	10.10	1.65	-					
2. Bimanual	7.78	2.13	.808**	-				
3. Sequencing	20.27	7.01	.601**	.685**	-			
4. SOC	6.78	2.13	.503**	.470**	.426**	-		
5. SWM	52.66	25.05	-.205	-.344*	-.462**	-.546**	-	
6. ID/ED	37.24	21.80	-.259	-.272	-.184	-.168	.016	-

Note. **p<.001. SD= standard deviation. Means and SD for combined sample.

Results

Regression 1- Unimanual

To examine whether planning, SWM and set- shifting predict unimanual scores, a stepwise HRA was conducted. At step 1 of the stepwise multiple regression planning accounted for a significant 22.1% of the variance in unimanual scores, R^2= .221, F (1, 39) = 11.04, p = <.001. At step 2, SWM was added to the regression equation and accounted for a non-significant 0.7% of the variance in unimanual scores, Δ R^2= .007, ΔF (1, 38) = .350, p = .556. At step 3, set- shifting was added to the regression equation and accounted for a non-significant 4.2% of the variance in unimanual scores, ΔR^2= .042, ΔF (1, 37) = 2.151, p = .227. All of the predictors combined explained a significant 27% of variance in unimanual scores, R^2= .270, adjusted R^2= .211, F (3, 37) = 5.015, p = <.001. By Cohen's (1988) conventions, a combined effect of this magnitude is considered "large" (f^2= .369). Planning (sr^2= .253) was

the only significant predictor of unimanual scores. The regression statistics for regression one are presented in table 3.

Table 3

R square (R^2), Unstandardised (B), Standardised (β) and Squared Semi-Partial Correlations (sr^2) For Each Predictor Variable on Each Step of a Stepwise Multiple Regression Predicting Unimanual Scores

Predictor	ΔR^2	*B*	β	[95% CI]	sr^2
Step 1					
Planning	.253**	.392	.503	[.174- .609]	.253
Step 2					
Spatial Working Memory	.007	.007	.099	[-.016- .029]	.007
Step 3					
Set- Shifting	.029	-.013	-.174	[-.035- .009]	.029

Note. Unimanual scores as outcome variable. CI = 95% Confidence Intervals
**p<.001

Regression 2- Bimanual

To examine whether planning, SWM and set shifting predict bimanual scores, a stepwise HRA was conducted. At step 1 of the regression, planning accounted for a significant 22.1% of the variance in bimanual scores, R^2= .221, F (1, 39) = 11.039, p = <.001. At step 2, SWM was added to the regression equation, and accounted for a non-significant, 1.1% of the variance in bimanual scores, Δ R^2= .011, ΔF (1, 38) = .538, p = .468. At step 3, set shifting was added to the regression equation and accounted for a non-significant 4.3% of the variance in bimanual scores, ΔR^2= .043, ΔF (1, 37) = 2.178, p = .148. All of the predictors combined explained a significant 27.4% of the variance in bimanual scores, R^2= .274, adjusted R^2= .211, F (3, 37) = 4.66, p = <.001. By Cohen's (1988) conventions, a combined effect of this

magnitude is considered "large" (f^2 = .377). Planning (sr^2=.221) was the only significant predictor of bimanual scores. The regression statistics are presented in table 4.

Table 4

R square (R^2), Unstandardised (B), Standardised (β) and Squared Semi-Partial Correlations (sr^2) For Each Predictor Variable on Each Step of a Stepwise Multiple Regression Predicting Bimanual Scores.

Predictor	ΔR^2	*B*	β	[95% CI]	sr^2
Step 1					
Planning	.221**	.470	.470	[.184- .756]	.221
Step 2					
Spatial Working Memory	.011	-.011	-.125	[-.040- .019]	.011
Step 3					
Set- Shifting	.043	-.021	-.211	[-.049- .008]	.043

Note. Bimanual scores as outcome variable. CI = 95% Confidence Intervals
**p<.001

Regression 3- Sequencing

To examine whether planning, SWM and set- shifting predict sequencing scores, a stepwise HRA was conducted. At step 1 of the regression, planning accounted for a significant 18.2% of the variance in sequencing scores, R^2= .182, F (1, 39) = 8.667, p = <.001. At step 2, SWM was added to the regression equation, and accounted for a non-significant, 7.5% of the variance in sequencing scores, ΔR^2= .075, ΔF (1, 38) = 3.839, p = .057. At step 3, set- shifting was added to the regression equation and accounted for a non-significant 2% of the variance in sequencing scores, ΔR^2= .020, ΔF (1, 37) = 1.00, p = .323. All of the predictors combined explained a significant 22.7% of the variance in sequencing scores, R^2= .227, adjusted R^2= .218, F (3, 37) = 4.714, p = <.001. By Cohen's (1988) conventions, a combined effect of this

magnitude is considered "medium" (f^2 = .294). Planning (sr^2 = .182) was the only significant predictor of sequencing scores. The regression statistics are presented in table 5.

Table 5

R square (R^2), Unstandardised (B), Standardised (β) and Squared Semi-Partial Correlations (sr^2) For Each Predictor Variable on Each Step of a Stepwise Multiple Regression Predicting Sequencing Scores

Predictor	ΔR^2	*B*	β	[95% CI]	sr^2
Step 1					
Planning	.182**	1.405	.426	[.440- 2.371]	.182
Step 2					
Spatial Working Memory	.075	-.092	-.327	[-.186- .003]	.075
Step 3					
Set- Shifting	.020	-.046	-.143	[-.139- .047]	.020

Note. Sequencing scores as outcome variable. CI = 95% Confidence Intervals
**p<.001

Discussion

Planning as the Primary Predictor of Fine Motor Control

The main finding from the study was that planning abilities significantly predict unimanual, bimanual, and sequencing performance in healthy older adults when a deficit in fine motor control is present, which supports the hypothesis proposed. This means that as planning abilities decline in ageing, the way movement is executed and the ability to perform fine motor control will also decline.

The finding that executive functioning (planning) contributes to motor control is supported by previous studies. Woollacott and Shumway-cook (2002) found that balance was worse when the participant's attention was divided between balancing and performing the digit memory task, suggesting that attention is needed for balance control. Later, Samper- Ternent, Snih, Raju, Marides and Ottenbacher (2008) found that frailer older adults had a poorer

cognitive ability. These studies support the findings of the present study, as executive functioning is found to contribute to motor control.

Neurological Explanations for the Major Finding

An explanation for the main findings is that the two functions could decline at the same time due to a shared reliance on the dopamine system. Studies have found that low levels of the dopamine transporter is related to poor motor control (impaired gait) as well as poor executive functioning (working memory) (Van Dyck et al., 2008). Dopamine appears to control both motor functions and cognition, and perhaps a disruption in dopamine could lead to both executive functioning and fine motor control declines

The 'dual task cost' theory also supports the main finding. This theory holds that older adults increasing rely on executive functions for movement, as it was found that additional prefrontal areas are activated during movement when compared to younger adults (Heuninckx et al., 2005). This suggests that movement becomes less automatic for older adults. This would explain why planning abilities are relied on to perform accurate movement in ageing.

SWM and Set- Shifting as Non- Significant

It was also found that SWM and set- shifting were non- significant predictors. A reason why planning was the only significant predictor is because the Purdue Pegboard is a goal-directed task. Therefore planning ability is required for the task. The Purdue Pegboard does not seem to require SWM abilities as the tasks are repetitive, therefore memory of where the objects and holes are arranged is not needed. The Purdue Pegboard also does not seem to require set- shifting abilities as the tasks do not require the participant to switch their attention within each subtask due to the repetitive nature of each task. The participants also had trouble understanding the SWM and set-shifting tasks, which may have affected their performance.

Clinical and Applied Implications

The clinical and applied relevance of the study is that potential aids could be made to help older adults in the areas of deficit. As there is a relationship between planning and unimanual, bimanual and sequencing movements, then perhaps by exercising planning abilities, fine motor control abilities will improve and vice versa. This technique is referred to as neuroplasticity (a technique in which brain training strengths/creates neural pathways) and

has been found to be effective in stroke patients. A study conducted by Broeren, Claesson, Goude, Rydmark and Sunnerhagen (2008) required stroke patients to exercise their cognition via a computer intervention. The computer intervention involved playing games that required using aiming skills. It was found that the stoke patients motor control improved in the upper limbs more so than patients who did not par take in the computer intervention. In addition, Kramer, Erickson, Scalf, McAuley and Cohen (2004) found that older adults with high cardiovascular fitness levels are better at activating attentional resources and also had greater brain volumes in the prefrontal areas. These studies suggests that by exercising motor control, cognitive abilities improve, and by exercising cognitive abilities, motor control abilities improve.

A limitation of motor-cognitive interventions is that they do not know which specific cognitive abilities contribute to different types of movement. The present study has now established a relationship between planning abilities and fine motor control in health ageing, therefore aids such as computer interventions could be made for older adults to exercise their planning abilities which in turn will improve their fine motor control.

Limitations

A limitation of the present study is that the tasks were difficult. Even with additional explanations and practice trials, some of the participants admitted at the end that they did not fully understand the task, and therefore did not perform to the best of their ability. This was especially relevant for the SWM and set- shifting task. As second limitation is that the Purdue Pegboard does not seem to require into SWM and set- shifting abilities due to the repetitive nature of the tasks. Therefore, the true contribution of SWM and set-shifting to fine motor control was not examined.

Future Directions

Firstly, as the Purdue Pegboard does not seem to require the use of executive functions apart from planning, future research should aim at replicating this study by using a measure of fine motor control which requires using a wider range of executive functions, such as the Action Arm Research Test (AART) (Lyle, 1981). The AART requires the use of a range of executive functions as the subtests are not repetitive in nature and require attention to perform the tasks correctly, knowledge of where the objects need to go, as well as planning of the more

complex movement sequences (Lyle, 1981). Secondly, future studies should aim at developing computerised interventions to examine whether exercising planning abilities will help older adult's fine motor control in their daily living and vice versa. Lastly, as it has been found in the literature that older adults with high cardiovascular fitness levels are better at activating attentional resources, and have greater brain volumes, future studies should explore the relationship between executive functions and fine motor control in older adults with high levels of fitness (Colcombe, et al. 2004).

Conclusions

The present study aimed to examine the independent contribution of planning, SWM and set-shifting to unimanual, bimanual and sequencing movements in healthy older adults with a fine motor control deficit. It was found that planning was the only significant predictor of unimanual, bimanual and sequencing movements. What this means is that as planning abilities decline, as do fine motor control abilities. The relevance of this study is that this relationship has never been explored before in healthy ageing. It is also an important area that requires research so that potential aids could be made to help the older adults with deficits in their fine motor control and executive functioning in everyday life.

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Extended Literature Review

The Contribution of Executive Functioning to Fine Motor Control in Healthy Ageing

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Extended Literature Review

Introduction

As a part of healthy ageing, deficits in fine motor control become present, especially for bimanual and sequencing tasks (Bernard, Burutolu, Fling, Gordon, Kwak, & Lipps, 2010; Shiffman, 1992). It is also well established that healthy older adults demonstrate deficits in their executive functioning, specifically in planning, spatial working memory and set-shifting abilities (Huppert, Brayne, Paykey & Beardsall, 1995). As both fine motor control and executive functions decline in healthy ageing, it is of interest to explore the relationship between these two functions (Seilder, Bernard, Burutolu, Fling, Gordon, Gwin, kwak & Lipps, 2010). This theory of motor- cognition stems from neurological studies which have demonstrated that the prefrontal cortex and the motor cortex are both activated simultaneously during a motor control task (Theil, Martin, Schumacher, Bridenbaugh & Kessig, 2011). There are also studies which found that by exercising cognitive abilities, motor controls improves, suggesting the two fucntions are related (Locascio, Corkin & Growdon, 2003). However, very limited studies have investigated this relationship in healthy ageing (Pichierri, Wolf, Murer & de Bruin, 2011).

Age- Related Declines in Fine Motor Control

Fine motor control involves the coordination of small muscle movements, specifically that of the hands and fingers (also referred to as dexterity) (Vielut, Mahmoodi, Godde, Reuter & Voelcker- Rehage, 2012). Fine motor control involves the use of the fingers in grasping, lifting, manipulating objects between the thumb and finger, maintaining the required force needed as well as aiming the hands and fingers in the desired direction (Vielut, Mahmoodi, Godde, Reuter & Voelcker- Rehage, 2012). The deficit in fine motor control ability is problematic for older adults, as it has been found they experience increased difficulty in tasks such as tying their own shoelaces, fastening buttons, retrieving objects from a purse and writing a note, as they perform these tasks with more difficulty when compared to younger adults (Ranganathan, Siemoinow, Sahgal & Yue, 2001). According to Ralf (2002) several cross- sectional studies have identified age- related deficit in fine motor control could be due to changes in speed and smooth movement control.

Stelmach, Goggin and Amrhein (1988) conducted a study to measure the reaction time of young and older adults during a hand and arm aiming task. The participants were taught movement paradigms where the instruction matched the movement. However on 25% of the trials the participants were given a vague instruction, requiring the participants to choose any movement and restructurer their movement as quickly as possible. The results showed that older adults performed significantly worse, taking up to 4 seconds longer to restructure their movement. This demonstrates that older adults take longer to plan movement causing their movement tends to be less smooth when compared to younger adults.

Clark, Loftus and Hammond (2011) examined the age- related difference of fine motor control between young and older adults. This task required participants to perform different hand functions such as unimanual, bimanual and sequencing hand tasks using the Purdue Pegboard subtests. The unimanual task involves using one hand to place pins in an array of holes from top to bottom as quickly as possible in 30 seconds. The bimanual task involves placing the pins in the holes from top to bottom with two hands as quickly as possible in 30 seconds, and the sequencing task involves assembling four objects together as many times possible in 60 seconds. The results found that older adults performed significantly worse on all three tasks, however the largest decline was found on the bimanual task. This suggests that older adults perform more slowly than younger adults, and that they especially have trouble with tasks that require using the two hands at the same time.

In another study by Marneweck, Loftus and Hammond (2011) who also explored the age- related differences in fine motor control, found that the greatest age-related difference was demonstrated in the assemble task, as older adults assembled almost half the amount of items than the younger group. This study suggest that older adults experience the most difficulty when using the co- ordination of both hands in a task to assemble objects together.

Age- Related Decline in Fine Motor Control: Causes

Seilder et al., (2010) suggest that the cause of fine motor control deficits in older adults may be due to many factors. However, there is existing literature that suggests direction towards possible causes. Yan, Thomas and Stelmach (1998) suggested that the age-related decline in fine motor control could be due to a deficit in planning. The researchers conducted a study to identify the difference in arm structuring in young and older adult. The task involved

participants to reach outwards towards an object while being recorded by a high speed data capture device. In a movement task, it was found that first the arm reaches out towards an object in a motion trajectory, and then has the hands and fingers reach the object, they make a rapid adjustment to accurately reach and grasp the object. Using the high speed data capture, it was discovered that the motion trajectory over older adults is less than that of younger adults, and also that they make their rapid adjustments before grasping too early and frequently, resulting in inaccuracy. The researchers concluded that this could be caused by planning deficits, as the problem was found in the way the movement was executed and controlled, rather than due to muscular deterioration.

Stelmach, Goggin and Amirhein (1988) also found that age- related declines in motor control could be due to a decline in proprioception (the sense of where body limbs are positioned). The researchers conducted a study to investigate the age differences in bimanual coordination between younger and older adults. Participants performed unimanual, bimanual symmetrical (equal extent amplitude) and bimanual asymmetrical (unequal extent amplitude) movement tasks. In all bimanual movement tasks it was found that the older adults showed greater asynchrony than the younger adults. The researchers suggested that this could be due to a decline in proprioception. This suggestion is consistent with the literature as Kalpan, Nixon, Reitz, Reindfleish and Tucker (1985) found that age-related declines in gross motor control could be due to a decline in proprioception. The study used a goniometer to measure the movement abilities between young and older adults. The participants were required to perform tasks such as copying the perceived position of each knee with that of the other knee while blind folder. The young adult's scored significantly higher on all tasks, indicating that proprioception declines with age.

Another theory that is used to explain the decline of motor control in ageing is the dual-task cost theory. Heuninckx, Wenderoth, Debaere, Peeters and Swinnen (2005) and Heuninckx, Wenderoth and Swinnen (2008) found that older adults activated additional prefrontal brain regions to perform motor tasks when compared to young adults. Due to the increased reliance on cognitive processes for basic movement, the neural resources become over loaded, with not enough resources left to perform movement as smoothly as younger adults. These findings indicate that older adults rely on executive functions to perform movement, and could be the contributing factor towards the decline in fine motor control.

Age- Related Declines in Executive Functioning

Along with motor control deficits in healthy ageing, older adults also demonstrate deficits in executive functioning. Seilder et al., (2010) suggest that the prefrontal cortex is responsible for higher- cognitive functions such as Executive Functioning. According to Salthouse, Atkinson, and Berish (2003) executive functioning is an overarching term for cognitive processes that control, manage and regulate other cognitive processes. The cognitive processes that make executive functioning include planning, working memory and set-shifting.

The age related decline of executive functions is thought to be due to the deteriorations of white matter volume (responsible for cognition and co-ordinating communication between different brain regions) in the prefrontal cortex (Seilder et al., 2010). MRI scans have been able to identify that older adults have a significantly lower white matter volume mass than young adults, and it also shows that the prefrontal cortex is the region of the brain most affect by this white matter deterioration in healthy ageing (Seilder et al., 2010).

Spatial working memory. According to Smith, Jonides and Koeppe (1996) spatial working memory is responsible for attaining information about one's environmental, object or bodily orientation. Spatial working memory is required for everyday tasks such as driving a car. Memory is needed to know what the next sequence is in the task, as well as where all the controls are located in the car. There are significant age- related declines in spatial working memory, with older adults commonly performing poorly compared to younger adults (Robbins, James, Owen, Shahakian & Lawrence et al., 1998).

Robbins et al., (1998) examined executive functioning in participants aged 21 to 79 years old using the spatial working memory task. The Spatial Working Memory task required participants to identify a blue square in a range of boxes, and to remember which boxes contained the blue squares. The results found that the 65 to 79 year olds committed significantly more errors when compared to the 21- 40 and the 40- 65 year old group. The study concluded that age related deficits are present spatial working memory from 65 years old onwards. These results are also consistent with Tubi and Calev's (1989) and Myserson, Hale, Rhee and Jenkins (1999) studies which also found that visuo-spatial response times presented age-related declines

Planning. There are also age-related deficits in planning (Salthouse, Atkinson & Berish, 2003; Kafer & Hunter, 1997; Kliegel, McDaniel & Einstein, 2000), which is the ability that involves identifying goals, and then developing strategies to achieve the desired goal (Craik & Bialystok, 2006; Jurado & Rosselli, 2007).

Robbins et al., (1998) used the Stockings of Cambridge task to measure planning abilities in young and older adults. In this task, there are 2 displays presented on the screen, a top display and a bottom display. The top display consists of a figure of circles, and the bottom displays a slightly different figure of circles. The participants are required to make the bottom screen match the top screen by moving the circles around. The participants are only allowed to make a limited number of moves; therefore the task involves strategic planning. The results showed that the younger adults solved significantly more problems that the older adults. The results also showed the older adults took longer to carry out each task. This study concluded that older adults planning abilities begin to decline from 60 years old onwards.

Set- shifting. According to Lien, Ruthruff and Kuhns (2008) set shifting is an executive function which also presents age- related declines. Set- shifting is the ability of being able to update or shift cognitive strategies in response to changes in the environment (Owen, Roberts, Hodges & Robbins, 1993; Liens, Ruthruff & Kuhns, 2008; Anderson, 2001). Being unable to adjust to different environments and tasks and cause many problems for older adults such as how to move onto the next action task in a sequenced task (such as making a cup of tea).

A study conducted by Ridderinkold, Span and van der Molen (2002), examined set-shifting abilities in young and older adults using the Wisconsin Card Sorting test. This task involves a number of different cards being displayed to the participant. The participant is then told to match the cards, and then the participant is told whether the match was correct or incorrect. If the match was correct, the participant will proceed matching, then once the rule is learnt the participant is told this is now not correct. This then requires the participant to adjust to rule changes. The results showed that as age increased, performance decreased. The study concluded that set-shifting abilities begin to decline from age 60.

Correlates of the Prefrontal and Motor Cortex

Research has focused primarily on deficits in the motor cortex as being the cause of poor motor control. Recently, researchers have shifted their focus to the influence of prefrontal processes as a potential explanation for the decline in motor control movements (Rubia, Overmyer, Taylor, Brammer, William & Simmons, 1998).

Heuninckx, Wenderoth, Debaere, Peeters, and Swinnen (2005) conducted a study to explore the neural changes during motor tasks between young and older adults. The participants were required to perform isolated flexion- extension movements of the right and left wrist, while functional magnetic resonance imaging recorded brain activation. Activation of typical motor areas in the brain were found in both the young and older adults, however the older adults exhibited additional activation of the prefrontal cortex and somatosensory areas. These findings indicate that as an individual ages, there is an increased reliance on cognitive monitoring of motor performance.

Studies of brain imaging using positron emission tomography (PET) have identified age- related decreases in the level of the neurotransmitter dopamine (Kaasinen, Vilkman & Hietala, 2000). Studies have been conducted to explore the relationship between dopamine and motor control which show that the dopamine transporter is related to impaired gait (slowed speed and balance). Along with this, Van Dyck et al. (2008) showed that dopamine has also been found to be correlated with deficits in cognitive functions such as working memory. The fact that dopamine influences both cognitive abilities as well as motor control abilities provides evidence that the two functions are related via sharing the same dopamine circuit, or rely on dopamine signals sent between each other

Using MRI scans, Seilder et al., (2010) found that healthy older adults with above average aerobic fitness levels may have greater brain volume of the prefrontal region, middle/inferior temporal cortices and anterior white matter tracks (all vulnerable to age-related declines). This demonstrates that motor control can improve or keep cognitive functions intact, suggesting a relationship between the two.

A study was conducted by Locascio, Corkin and Growdon (2003) which aimed to examine how cognitive deficits in Parkinson's disease (PD) are related to motor impairment. The participants were required to complete multiple cognitive tests of frontal lobe function such as declarative memory, language and visuo- spatial abilities. After completing this task

their motor control ability was measure via the Hoehn and Yahr (1967) scale of severity of disability. The results found that the Parkinson's patients performed significantly worse than the healthy participants and that motor impairment indexed by Hoehn and Yahrs (1967) scale was positively correlated with deficits on all of the cognitive tests, indicating that a cognitive and motor ability deficits are related in Parkinson's disease. This suggests that cognitive and motor abilities are related and decline at the same time in normal ageing and in disease. However, the relationship between these two functions cannot be generalised, as this relationship was examined in a people with a disease, therefore it is not appropriate to say that movement and executive functioning are related in all people- this relationship could just be reflecting the nature of the disease.

It has also been found that by exercising cognitive abilities, motor control abilities improve. A study conducted by Broeren, Claesson, Goude, Rydmark and Sunnerhagen (2008) required stroke patients to exercise their cognition via a computer intervention. The computer intervention involved playing games that required using aiming skills and speed. It was found that their motor control improved in the upper limbs. This suggests that motor abilities and cognitive abilities are related, as motor abilities are improved when cognitive abilities are exercised.

Executive Functioning and Motor Control Relationships in Ageing

There is some evidence of a fine motor control and executive functioning relationship in healthy older adults. However, there are very limited studies conducted on this relationship with most researchers focusing on global cognition and gross motor control (Pichierri, Wolf, Murer & de Bruin, 2011). There are currently no studies looking the contribution of executive functioning contributions towards fine motor control in healthy older adults.

Woollacott and Shumway-cook (2002) investigated the influence attention had on posture and gait in older adults. Participants were required to stand on a balance and posture mat while concentrating on a digit memory task. It was found that when the participants divided their concentration between balancing and completing the digit memory task there was an increase in the number of sways (errors) in the balancing task. This study adds to the literature that in ageing, cognitive processes are needed for adequate motor control. However

this study only looks are gross motor control, with no investigation into how this could affect fine motor control.

Samper- Ternent, Snih, Raju, Marides and Ottenbacher (2008) examined the relationship between frailty and cognitive decline in healthy older adults. Frailty was defined as weight loss of more than 10 pounds, weakness, self- reported exhaustion, slow gait speed and low physical activity. Cognitive ability was assessed using the Mini- Mental State Examination (MMSE). It was found that the frailer older adults had a poorer cognitive ability (lower scores on MMSE). This study demonstrates a relationship between motor control and prefrontal cortex functioning. However, again there is no specific cognitive ability or specific movement that has been examined, which makes it hard for a particular type of therapy or prevention to be made for the older population.

In addition, Colcombe, Kramer, Erickson, Scalf, McAuley and Cohen (2004) found that older adults with high cardiovascular fitness levels are better at activating attentional resources and also had great brain volumes in the prefrontal areas. This suggests that the two functions are related as cognitive abilities improve, motor control abilities improve.

Conclusion

It is clear that as the brain ages, declines in executive functioning and fine motor control are present (Seilder et al., 2010). These deficits cause problems for the older adults as they have trouble performing simple tasks such as writing a letter or tying their shoe laces (Ranganathan, Siemoinow, Sahgal & Yue, 2001). Since both deficits are present at the same time in ageing, current research is focused on looking at the relationship between these two functions (Theil, Martin, Schumacher, Bridenbaugh & Kessig, 2011). Neurological studies confirm that additional areas of the brain are activated during movement, including the prefrontal cortex (Heuninckx, Wenderoth, Debaere, Peeters, & Swinnen, 2005). This proves that there is an increased reliance on cognitive processes in ageing, which is known as the dual cost theory. There is very limited research investigating the relationship between executive functioning and motor control (Pichierri, Wolf, Murer & de Bruin, 2011). With our ageing population, it is crucial to better understand the physical and cognitive declines that older adults experience, so that potential aids could be made to keep the ageing population functional and independent for longer (Yan, Thomas & Stelmach, 1998). Therefore, the

present study aims to investigate the contribution of executive functions to fine motor control in healthy older adults.

Aims/Hypothesis

The present study will examine the relationship between 3 different executive function tasks and fine motor control in healthy ageing. The present study will examine the independent contribution of planning, set shifting and spatial working memory to unimanual, bimanual and sequencing movements in health older adults. The research question being: what is the independent contribution of planning, set-shifting and spatial working memory to unimanual, bimanual and sequencing movements in healthy ageing?

The following hypotheses can be proposed:

The following hypothesis can be proposed:

H1a: Planning will significantly predict unimanual scores.

H1b: After controlling for planning, spatial working memory will significantly predict unimanual scores.

H1c: After controlling for planning and spatial working memory, set shifting will significantly predict unimanual scores.

H2a: Planning will significantly predict bimanual scores.

H2b: After controlling for planning, Spatial working memory will significantly predict bimanual scores.

H2c: After controlling for planning and spatial working memory, Set shifting will significantly predict bimanual scores.

H3a: Planning will significantly predict sequencing scores.

H3b: After controlling for planning, spatial working memory will significantly predict sequencing scores.

H3c: After controlling for planning and spatial working memory, set shifting will significantly predict sequencing scores.

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Supplementary Materials

The Contribution of Executive Functioning to Fine Motor Control in Healthy Ageing

Hayley Riddle

Curtin University School of Psychology and Speech Pathology

Ethics Approval

Curtin University

Memorandum

To	Dr Andrea Loftus, Psychology and Speech Pathology
From	Professor Stephan Millett, Chair, Human Research Ethics Committee
Subject	Protocol Approval **HR 32/2013**
Date	6 March 2013
Copy	

Office of Research and Development
Human Research Ethics Committee

TELEPHONE 9266 2784
FACSIMILE 9266 3793
EMAIL hrec@curtin.edu.au

Thank you for providing the additional information for the project titled "*The Impact of transcranial direct current stimulation on executive functioning*". The information you have provided has satisfactorily addressed the queries raised by the Committee. Your application is now **approved**.

- You have ethics clearance to undertake the research as stated in your proposal.
- The approval number for your project is **HR 32/2013.** *Please quote this number in any future correspondence*.
- Approval of this project is for a period of four years **01-03-2013** to **01-03-2017**.
- Your approval has the following conditions:
  i) Annual progress reports on the project must be submitted to the Ethics Office.
  ii) Registration as a clinical trial.
  Chapter 3.3 of the National Statement on Ethical Conduct in Human Research states:
  A clinical trial is a form of human research designed to find out the effects of an intervention.
- **It is your responsibility, as the researcher, to meet the conditions outlined above and to retain the necessary records demonstrating that these have been completed.**

Applicants should note the following:

It is the policy of the HREC to conduct random audits on a percentage of approved projects. These audits may be conducted at any time after the project starts. In cases where the HREC considers that there may be a risk of adverse events, or where participants may be especially vulnerable, the HREC may request the chief investigator to provide an outcomes report, including information on follow-up of participants.

The attached **FORM B** should be completed and returned to the Secretary, HREC, C/- Office of Research & Development:
When the project has finished, or

- If at any time changes/amendments occur, or
- If a serious or unexpected adverse event occurs.

Yours sincerely

Professor Stephan Millett
Chair Human Research Ethics Committee

PARTICIPANT INFORMATION SHEET

Planning Abilities and Movement in Older Adults

INVITATION

You are being asked to take part in a research study being conducted by Hayley Riddle, a Psychology honours student at the Curtin Neuroscience Laboratory, as you are aged over 60.

PROJECT DETAILS

This study will measure the co-ordination of your hands and fingers in performing movements and your planning abilities. The movement of your hands and fingers will be measured by using a board and pegs. You will be required to move the pegs and other objects around the board and to assemble objects as best you can. Your planning abilities will be measured using 3 different computerised tasks. You do not need to be familiar with computers to perform these tasks. This project is being supervised by Dr Andrea Loftus and has been approved by the Curtin Research Ethics Committee (Approval Number HR 32/2013).

WHAT WILL HAPPEN

You will be asked to attend the Curtin Neuroscience Laboratory at a time convenient to you. Upon arrival, the researcher will explain the study and show you the tasks. You will be asked to sign a consent form. The first task will be the Purdue Pegboard which measures your movement. In this task you will use one hand to move the pegs and drop them into a hole, use both hands at the same time to drop 2 pegs in the holes, and assemble objects together. You will then complete the three computerised tasks, which measure different aspects of your ability to plan.

TIME COMMITMENT

The testing session should take no longer than an hour to complete. You will be provided with regular breaks throughout the session, during which light refreshments will be provided.

PARTICIPANTS' RIGHTS

You may decide to stop being a part of the research study at any time without explanation. You have the right to ask that any data you have supplied to that point be withdrawn/destroyed as appropriate and without penalty. You will still receive a gift voucher. You have the right to omit or refuse to answer or respond to any question that is asked of you as appropriate. You have the right to have your questions about the procedures answered. If you have any questions as a result of reading this information sheet, you should ask the researcher before the study begins.

RISKS

The tasks are demanding but regular breaks are offered.

COST, REIMBURSEMENT AND COMPENSATION

Your participation in this study is voluntary. You will receive a $40 Coles-Myer gift card for participation in the study as a means of thanks.

CONFIDENTIALITY/ANONYMITY

Your participation in this study is completely confidential and data we collect will be not identified or linked to you in any way. Data collected will be stored on a computer for 5 years.

FOR FURTHER INFORMATION

Dr Andrea Loftus is supervising this study and will be happy to answer any questions or concerns you may have. She can be reached by phone on 9266 2308 or by email at andrea.loftus@curtin.edu.au

This study has been approved by the Curtin University Human Research Ethics Committee (Approval Number HR 32/2013). The Committee is comprised of members of the public, academics, lawyers, doctors and pastoral carers. If needed, verification of approval can be obtained either by writing to the Curtin University Human Research Ethics Committee, c/- office of Research and Development, Curtin University, GPO Box U1987, Perth, 6845 or by telephoning 9266 2784 or by emailing hrec@curtin.edu.au

CONSENT FORM

Planning Abilities and Movement in Older Adults

By signing below, you are agreeing that: (1) you have read and understood the Participant Information Sheet, (2) questions about your participation in this study have been answered satisfactorily, (3) you are aware of the potential risks (if any), and (4) you are taking part in this research study voluntarily (without coercion).

_____

Participant's Name (Printed)*

_____ _____

Participant's signature* Date

_____ _____

Name of person obtaining consent (Printed) Signature of person obtaining consent

**Participants wishing to preserve some degree of anonymity may use their initials (from the British Psychological Society Guidelines for Minimal Standards of Ethical Approval in Psychological Research)*

I am aware that participation in this study involves completion of some standardised tests [specify as relevant] which are routinely used as preliminary screens for clinical conditions/impairments of which I might not be aware. I understand that these assessments are not sufficient for diagnostic purposes, nor will they be used in this manner in this study. I also understand that the researchers cannot inform participants of individual test scores, but in the event that I produce scores of potential clinical concern, researchers should (check one and provide relevant contact information):

_____Contact me at:_____

_____Contact my GP at _____

_____Do nothing. I absolve the researchers of any obligation to contact me.

MMSE

Participant ID_____ **Date**_____

Orientation		**Response**	**Score**
1. What is today's date?	Date (day/month/year). 1 point for each correct OR		/3 OR
(if participant does not answer question1 correctly e.g., only responds 21st ask 1a,b) 1a What is the year? 1b What is the month?	1 point each for year, month, date (e.g., 21st)		/3
2. What day is today?	e.g., Monday		/1
3. Can you tell me what season it is? Allow 2 weeks flexibility	Summer= 1st Dec-28th Feb; Autumn= 1st March-31st May; Winter= 1st June-30th Aug; Spring= 1st Sep-30th Nov		/1
		Total	**/5**
5. What City/Suburb are we in?	Bentley/Perth		/1
6. What State are we in?	Western Australia		/1
7. What Country are we in?	Australia		/1
		Total	**/5**

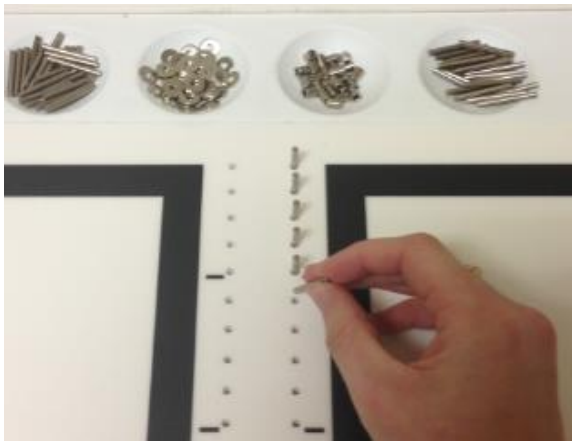
Immediate Recall		**Response**	**Score**
"I'm going to say some words. Listen carefully and when I have said all the words, please repeat them to me. So I say the words and then you say them". BALL (pause) FLAG (pause) TREE 1 point for each correct response	"Ball" "Flag" "Tree" Number of trials_____ This first repetition determines the participants score (0-3) but keep saying them until the participant can repeat all 3. Up to 6 trials- but use judgement.		**/1** **/1** **/1** **Total /3**

Attention/Calculation	**Response**		**Response**	
"I've got some mental arithmetic for you. Starting with 100 take away 7, then take away 7 from that number, and keep taking away by 7 until I tell you to stop." *continue for 5 subtractions.* AND Word **Backwards. No need** to get them to spell it forward "Spell the word "WORLD" as in the world that we live in" backwards, *This may be accompanied by a physical prompt as to what the word is.* When scoring, count an error as the number of moves the word is out of order. E.g., DRLOW is only 1 move from being correct, so only 1 error 4 points. (Score both of these tests)	**93** **86** **79** **72** **65**	If asked, you may prompt with the previous answer they gave. However, note the prompt and do not score the response as correct even if calculation is correct.	**D** **L** **R** **O** **W**	
Total		**/5**		**/5**

Recall		**Response**	**Score**
I asked you to repeat some words earlier. Can you tell me what they were? *You may tell the participant that you did not ask them to remember the words at the time.*	"BALL" "FLAG" "TREE"		**/1** **/1** **/1** **Total /3**
TOTAL SCORE (MAX 25)			**/25**

Purdue Pegboard Sub- Tasks

1. Unimanual Task:
   Pins are placed one at a time from top to bottom as quickly as possible. Scores were taken from how many pins were insert down the pegboard in 30 seconds.



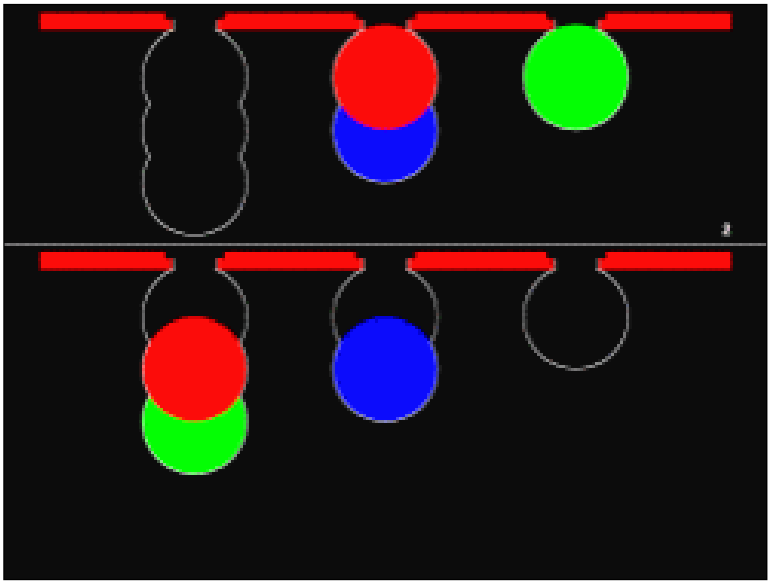
2. Bimanual Task:
   Similar to the first task, but required both hands to be used simultaneously to complete the same task. Pins are taken from either side of the board and placed down the holes at the same time. Scores were taken from how many pairs were placed down the board in 30 seconds.

3. Sequencing Task:
   participants were required to insert a peg into the board with one hand, then assemble three more objects together on top of the peg (a peg, a washer, a collar, and a second washer) using the two hands separately in a coordinated fashion.

Stockings of Cambridge (Planning)

Participants were instructed to move the balls in the bottom display so that they matched the arrangement of the balls in the top display. Participants were told that only one ball could be moved at a time. Participants were also told that they were not allowed to move a ball from underneath another ball without moving the ball on top first. A ball could not be moved into an empty space other than a pocket. . The number of moves required to achieve the configuration in the top display was shown on the right hand side of the screen.

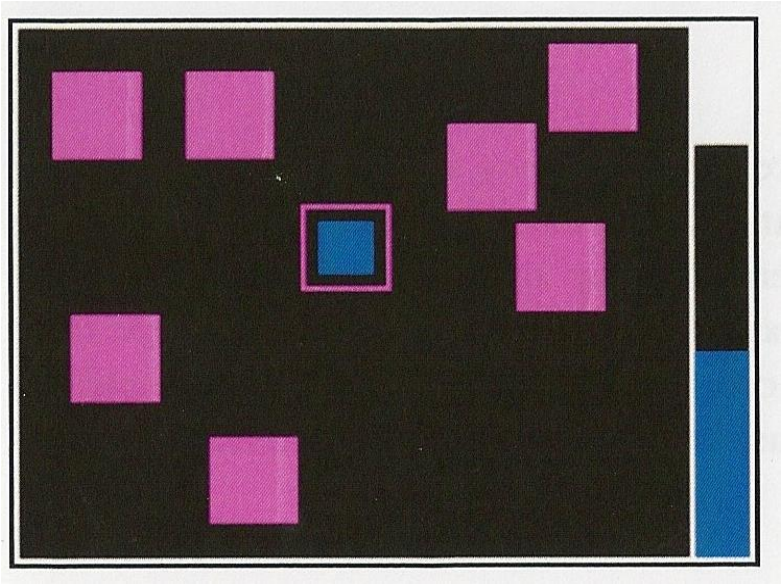
An example screen shot of a 2-move problem from the Stockings of Cambridge test. To achieve the goal state in the top display, participants would have to move red ball to the middle stocking and then move the green ball to the stocking on the right.



Spatial Working Memory (SWM) Task

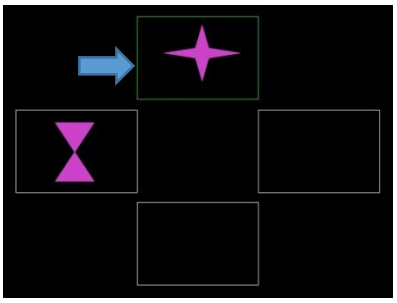
Participants were required to touch the boxes on the screen, one at a time, to reveal a hidden token, which they had to drop into an empty column located on the right hand side of the screen. They also had to remember not to search for tokens in boxes they had previously retrieved a token from, as a token would never appear in the same box twice. Participants were told that the total number of tokens present for each trial would be the same as the number of boxes that appeared on the screen. Participants were also told that when the column was filled up, all the tokens had been found.

An example screen of an eight-box problem for the Spatial Working Memory Task. Participants had to touch a box to reveal a hidden token and with their finger drag the token and drop it in the column on the right. Participants had to remember not to return to this box again as a token will never appear in the same box twice.

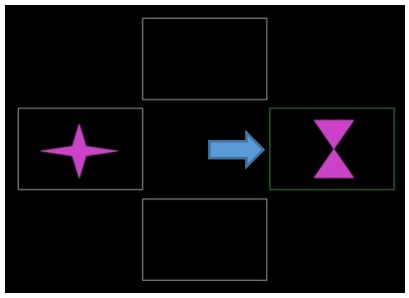


IDED Task

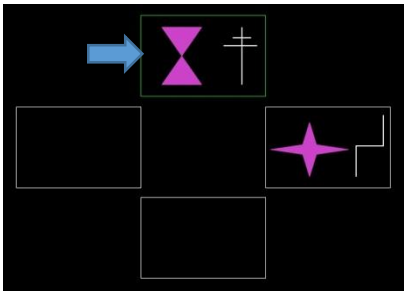
Screen shots of Stage 1 to Stage 9 of the IDED set shifting task. For explanatory purposes, a blue arrow has been insert into the pictures to demonstrate which box is the correct answer. In the actual task, there was no arrow or hint. The aim of the task was to adjust to new rules. The CANTAB gave feedback by saying 'correct' or 'incorrect' to guide the participant towards the rule. After the rule has been learnt (6 correct) the rule would change.



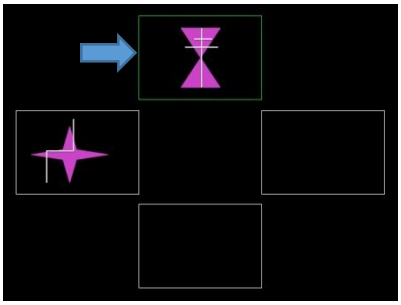
1. Simple Discrimination



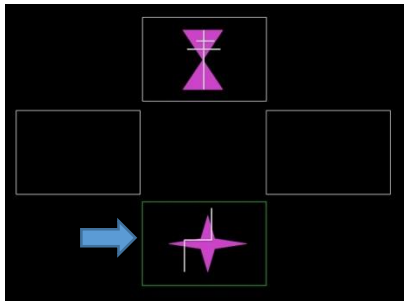
2. Simple Reversal



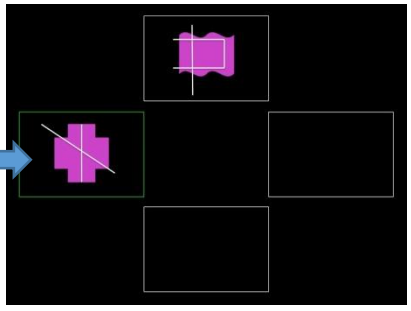
3. Compound Discrimuination I



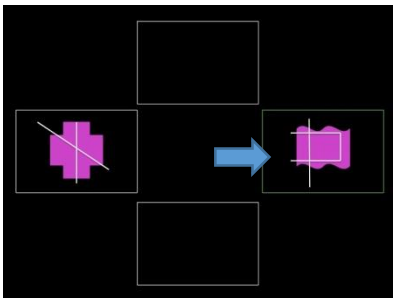
4. Compound Discrimination II



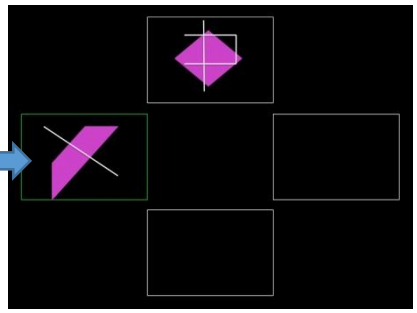
5. Compound Reversal



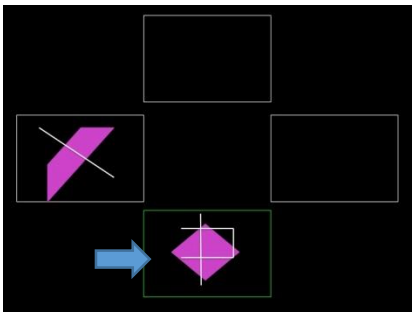
6. Intradimensional Shift



7. Intradimensional Shift Reversal



8. Extradimensional Shift



9. Extradimensional Shift Reversal

Missing Values

Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
PURDUE_UNI	41	100.0%	0	0.0%	41	100.0%
PURDUE_BI	41	100.0%	0	0.0%	41	100.0%
PURDUE_SEQ	41	100.0%	0	0.0%	41	100.0%
SOC	41	100.0%	0	0.0%	41	100.0%
SWM_TOTAL_ERRORS	41	100.0%	0	0.0%	41	100.0%
IDED_TOTAL_ERRORS	41	100.0%	0	0.0%	41	100.0%

Assumption Tests

Normality:

Stem and Leaf Plots

SOC Stem-and-Leaf Plot

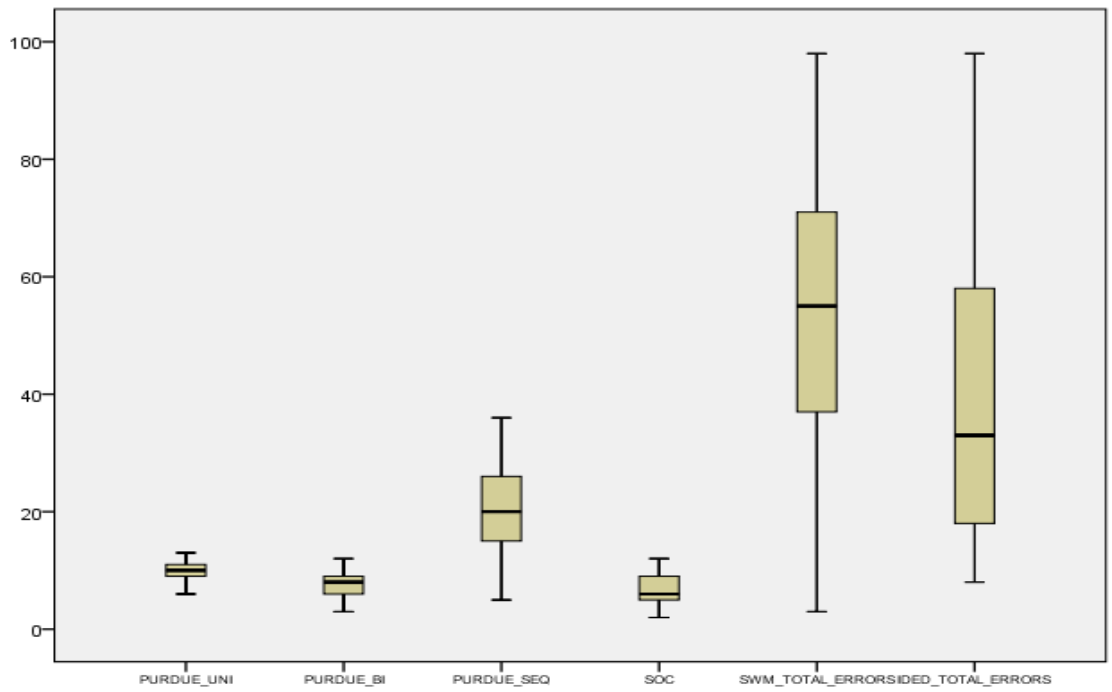
```
 Frequency    Stem &  Leaf

     1.00        2 .  0
      .00        3 .
     3.00        4 .  000
     9.00        5 .  000000000
     9.00        6 .  000000000
     5.00        7 .  00000
     2.00        8 .  00
     8.00        9 .  00000000
     3.00       10 .  000
      .00       11 .
     1.00       12 .  0

 Stem width:      1.00
 Each leaf:       1 case(s)
```

SWM_TOTAL_ERRORS Stem-and-Leaf Plot

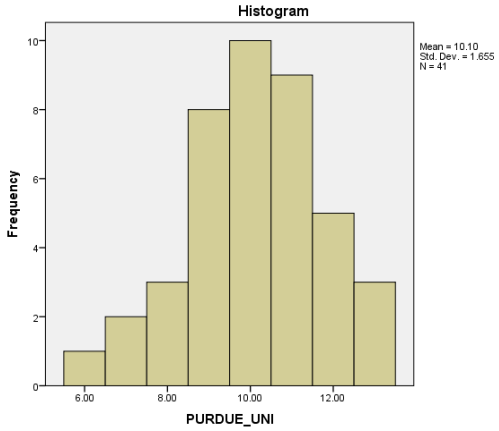
```
 Frequency    Stem &  Leaf

     1.00        0 .  3
     3.00        1 .  159
     6.00        2 .  122345
     3.00        3 .  778
     5.00        4 .  14667
     4.00        5 .  0359
     7.00        6 .  0134678
```

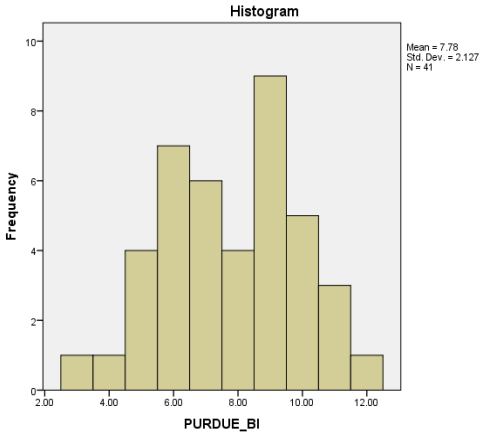
```
     7.00        7 .  1113446
     2.00        8 .  48
     3.00        9 .  488

 Stem width:     10.00
 Each leaf:       1 case(s)

IDED_TOTAL_ERRORS Stem-and-Leaf Plot

 Frequency    Stem &  Leaf

     2.00        0 .  89
    11.00        1 .  12235566899
     6.00        2 .  112457
     3.00        3 .  034
     3.00        4 .  169
    12.00        5 .  355688899999
     3.00        6 .  122
      .00        7 .
      .00        8 .
     1.00        9 .  8

 Stem width:     10.00
 Each leaf:       1 case(s)
```

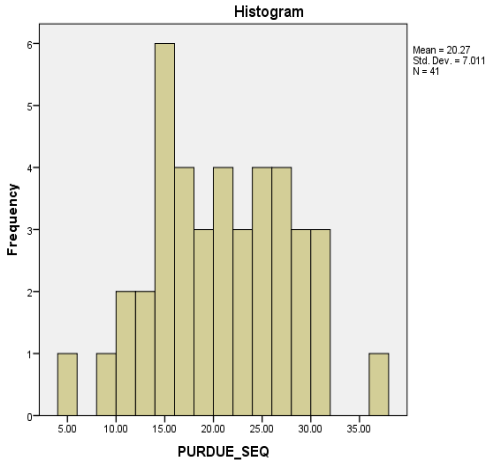
Boxplots

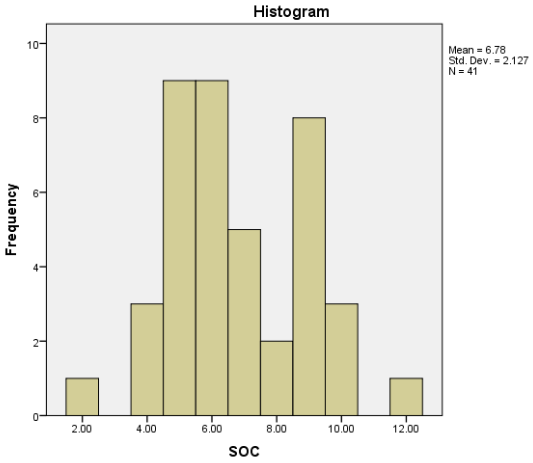


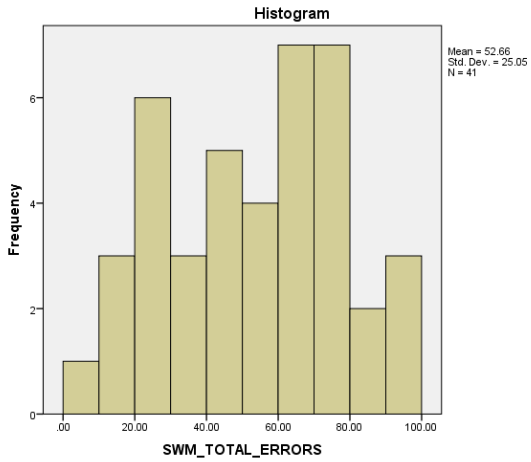
Histograms

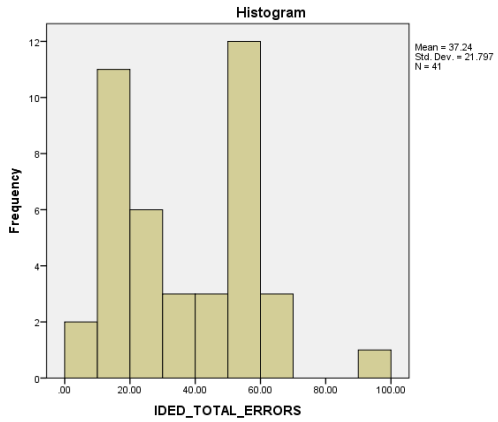

Histogram
Mean = 10.10
Std. Dev. = 1.655
N = 41
Frequency
PURDUE_UNI


Histogram
Mean = 7.78
Std. Dev. = 2.127
N = 41
Frequency
PURDUE_BI


Histogram
Mean = 20.27
Std. Dev. = 7.011
N = 41
Frequency
PURDUE_SEQ


Histogram
Mean = 6.78
Std. Dev. = 2.127
N = 41
Frequency
SOC


Histogram
Mean = 52.66
Std. Dev. = 25.05
N = 41
Frequency
SWM_TOTAL_ERRORS


Histogram
Mean = 37.24
Std. Dev. = 21.797
N = 41
Frequency
IDED_TOTAL_ERRORS

Outliers:

Mahalanobis Distance Regression 1: Unimanual

Residuals Statistics[a]

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	7.7831	12.4108	10.0976	.89005	41
Std. Predicted Value	-2.600	2.599	.000	1.000	41
Standard Error of Predicted Value	.249	.742	.438	.117	41
Adjusted Predicted Value	7.4628	12.5104	10.0812	.93003	41
Residual	-3.04906	3.43003	.00000	1.39573	41
Std. Residual	-2.101	2.364	.000	.962	41
Stud. Residual	-2.177	2.718	.005	1.027	41
Deleted Residual	-3.27375	4.53723	.01634	1.59862	41
Stud. Deleted Residual	-2.300	2.997	.007	1.062	41
Mahal. Distance	.199	9.477	2.927	2.200	41
Cook's Distance	.000	.596	.039	.098	41
Centered Leverage Value	.005	.237	.073	.055	41

a. Dependent Variable: PURDUE_UNI

Mahalanobis Distance Regression 2: Bimanual

Residuals Statistics[a]

	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	5.7256	10.5919	7.7805	1.11401	41
Std. Predicted Value	-1.845	2.524	.000	1.000	41
Standard Error of Predicted Value	.323	.963	.569	.152	41
Adjusted Predicted Value	5.9027	10.9778	7.7787	1.15042	41
Residual	-3.76983	3.21780	.00000	1.81235	41
Std. Residual	-2.001	1.708	.000	.962	41
Stud. Residual	-2.148	1.865	.001	1.028	41
Deleted Residual	-4.34750	4.04273	.00178	2.07593	41
Stud. Deleted Residual	-2.265	1.933	.000	1.048	41
Mahal. Distance	.199	9.477	2.927	2.200	41
Cook's Distance	.000	.281	.038	.065	41
Centered Leverage Value	.005	.237	.073	.055	41

a. Dependent Variable: PURDUE_BI

Mahalanobis Distance Regression 3: Sequencing

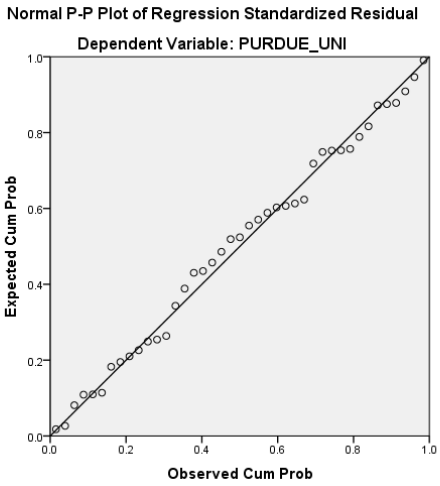
Residuals Statistics[a]

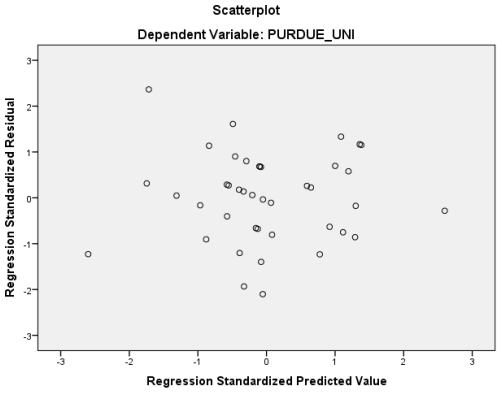
	Minimum	Maximum	Mean	Std. Deviation	N
Predicted Value	12.9498	28.2095	20.2683	3.68656	41
Std. Predicted Value	-1.985	2.154	.000	1.000	41
Standard Error of Predicted Value	1.062	3.169	1.873	.500	41
Adjusted Predicted Value	12.1897	29.2298	20.2741	3.78946	41
Residual	-14.64419	11.05520	.00000	5.96326	41
Std. Residual	-2.362	1.783	.000	.962	41
Stud. Residual	-2.397	1.928	.000	1.014	41
Deleted Residual	-15.08715	12.99491	-.00581	6.64243	41
Stud. Deleted Residual	-2.573	2.006	.000	1.038	41
Mahal. Distance	.199	9.477	2.927	2.200	41
Cook's Distance	.000	.200	.029	.044	41
Centered Leverage Value	.005	.237	.073	.055	41

a. Dependent Variable: PURDUE_SEQ

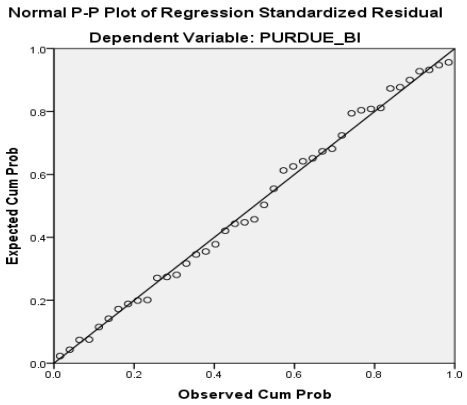
Normality, Linearity and Homoscedasticity of Residuals

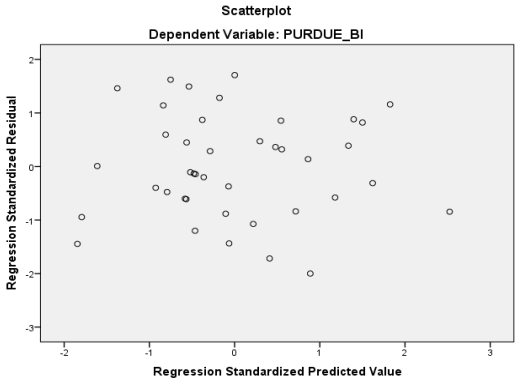
Scatterplots for Regression 1: Unimanual



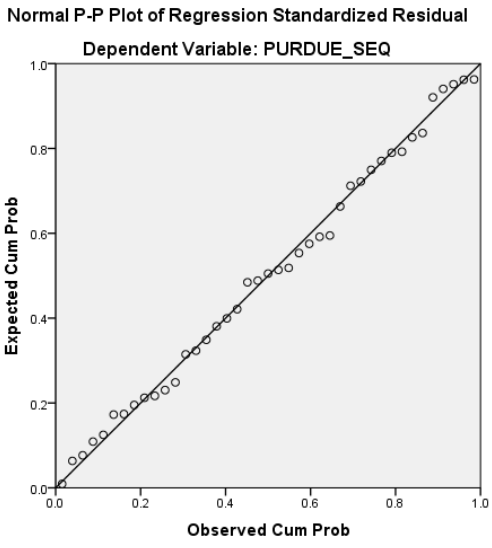


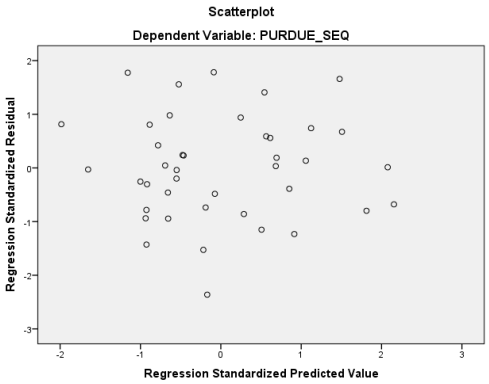
Scatterplots for Regression 2: Bimanual





Scatterplots for Regression 3: Sequencing





Correlation Matrix of All Study Variables

Correlations

		PURDUE_UNI	PURDUE_BI	PURDUE_SEQ	SOC	SWM_TOTAL_ERRORS	IDED_TOTAL_ERRORS
PURDUE_UNI	Pearson Correlation	1	.808**	.601**	.503**	-.205	-.259
	Sig. (2-tailed)		.000	.000	.001	.198	.102
	N	41	41	41	41	41	41
PURDUE_BI	Pearson Correlation	.808**	1	.685**	.470**	-.344*	-.272
	Sig. (2-tailed)	.000		.000	.002	.028	.085
	N	41	41	41	41	41	41
PURDUE_SEQ	Pearson Correlation	.601**	.685**	1	.426**	-.462**	-.184
	Sig. (2-tailed)	.000	.000		.005	.002	.249
	N	41	41	41	41	41	41
SOC	Pearson Correlation	.503**	.470**	.426**	1	-.546**	-.168
	Sig. (2-tailed)	.001	.002	.005		.000	.295
	N	41	41	41	41	41	41
SWM_TOTAL_ERRORS	Pearson Correlation	-.205	-.344*	-.462**	-.546**	1	.016
	Sig. (2-tailed)	.198	.028	.002	.000		.923
	N	41	41	41	41	41	41
IDED_TOTAL_ERRORS	Pearson Correlation	-.259	-.272	-.184	-.168	.016	1
	Sig. (2-tailed)	.102	.085	.249	.295	.923	
	N	41	41	41	41	41	41

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Descriptive Statistics

Descriptive Statistics

	Mean	Std. Deviation	N
PURDUE_UNI	10.0976	1.65537	41
PURDUE_BI	7.7805	2.12735	41
PURDUE_SEQ	20.2683	7.01079	41
SOC	6.7805	2.12735	41
SWM_TOTAL_ERRORS	52.6585	25.04956	41
IDED_TOTAL_ERRORS	37.2439	21.79654	41

Regression 1: Unimanual Analysis

Correlations

		PURDUE_UNI	SOC	SWM_TOTAL_ERRORS	IDED_TOTAL_ERRORS
Pearson Correlation	PURDUE_UNI	1.000	.503	-.205	-.259
	SOC	.503	1.000	-.546	-.168
	SWM_TOTAL_ERRORS	-.205	-.546	1.000	.016
	IDED_TOTAL_ERRORS	-.259	-.168	.016	1.000
Sig. (1-tailed)	PURDUE_UNI	.	.000	.099	.051
	SOC	.000	.	.000	.147
	SWM_TOTAL_ERRORS	.099	.000	.	.461
	IDED_TOTAL_ERRORS	.051	.147	.461	.
N	PURDUE_UNI	41	41	41	41
	SOC	41	41	41	41
	SWM_TOTAL_ERRORS	41	41	41	41
	IDED_TOTAL_ERRORS	41	41	41	41

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	27.751	1	27.751	13.222	.001[b]
	Residual	81.858	39	2.099		
	Total	109.610	40			
2	Regression	28.504	2	14.252	6.677	.003[c]
	Residual	81.106	38	2.134		
	Total	109.610	40			
3	Regression	31.687	3	10.562	5.015	.005[d]
	Residual	77.922	37	2.106		
	Total	109.610	40			

a. Dependent Variable: PURDUE_UNI

b. Predictors: (Constant), SOC

c. Predictors: (Constant), SOC, SWM_TOTAL_ERRORS

d. Predictors: (Constant), SOC, SWM_TOTAL_ERRORS, IDED_TOTAL_ERRORS

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.503[a]	.253	.234	1.44877	.253	13.222	1	39	.001	
2	.510[b]	.260	.221	1.46094	.007	.353	1	38	.556	
3	.538[c]	.289	.231	1.45121	.029	1.511	1	37	.227	1.870

a. Predictors: (Constant), SOC

b. Predictors: (Constant), SOC, SWM_TOTAL_ERRORS

c. Predictors: (Constant), SOC, SWM_TOTAL_ERRORS, IDED_TOTAL_ERRORS

d. Dependent Variable: PURDUE_UNI

Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B		Correlations			Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Zero-order	Partial	Part	Tolerance	VIF
1	(Constant)	7.443	.764		9.737	.000	5.897	8.989					
	SOC	.392	.108	.503	3.636	.001	.174	.609	.503	.503	.503	1.000	1.000
2	(Constant)	6.813	1.310		5.200	.000	4.161	9.466					
	SOC	.434	.130	.557	3.345	.002	.171	.696	.503	.477	.467	.702	1.425
	SWM_TOTAL_ERRORS	.007	.011	.099	.594	.556	-.016	.029	-.205	.096	.083	.702	1.425
3	(Constant)	7.577	1.442		5.254	.000	4.655	10.500					
	SOC	.403	.131	.518	3.073	.004	.137	.669	.503	.451	.426	.676	1.478
	SWM_TOTAL_ERRORS	.005	.011	.080	.482	.632	-.017	.028	-.205	.079	.067	.696	1.437
	IDED_TOTAL_ERRORS	-.013	.011	-.174	-1.229	.227	-.035	.009	-.259	-.198	-.170	.964	1.038

a. Dependent Variable: PURDUE_UNI

Regression 2: Bimanual Analysis

Correlations

		PURDUE_BI	SOC	SWM_TOTAL_ERRORS	IDED_TOTAL_ERRORS
Pearson Correlation	PURDUE_BI	1.000	.470	-.344	-.272
	SOC	.470	1.000	-.546	-.168
	SWM_TOTAL_ERRORS	-.344	-.546	1.000	.016
	IDED_TOTAL_ERRORS	-.272	-.168	.016	1.000
Sig. (1-tailed)	PURDUE_BI	.	.001	.014	.043
	SOC	.001	.	.000	.147
	SWM_TOTAL_ERRORS	.014	.000	.	.461
	IDED_TOTAL_ERRORS	.043	.147	.461	.
N	PURDUE_BI	41	41	41	41
	SOC	41	41	41	41
	SWM_TOTAL_ERRORS	41	41	41	41
	IDED_TOTAL_ERRORS	41	41	41	41

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	39.935	1	39.935	11.039	.002[b]
	Residual	141.090	39	3.618		
	Total	181.024	40			
2	Regression	41.906	2	20.953	5.723	.007[c]
	Residual	139.119	38	3.661		
	Total	181.024	40			
3	Regression	49.640	3	16.547	4.660	.007[d]
	Residual	131.384	37	3.551		
	Total	181.024	40			

a. Dependent Variable: PURDUE_BI

b. Predictors: (Constant), SOC

c. Predictors: (Constant), SOC, SWM_TOTAL_ERRORS

d. Predictors: (Constant), SOC, SWM_TOTAL_ERRORS, IDED_TOTAL_ERRORS

Model Summary[d]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.470[a]	.221	.201	1.90202	.221	11.039	1	39	.002	
2	.481[b]	.231	.191	1.91338	.011	.538	1	38	.468	
3	.524[c]	.274	.215	1.88439	.043	2.178	1	37	.148	1.780

a. Predictors: (Constant), SOC

b. Predictors: (Constant), SOC, SWM_TOTAL_ERRORS

c. Predictors: (Constant), SOC, SWM_TOTAL_ERRORS, IDED_TOTAL_ERRORS

d. Dependent Variable: PURDUE_BI

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B		Correlations			Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Zero-order	Partial	Part	Tolerance	VIF
1	(Constant)	4.596	1.004		4.580	.000	2.566	6.626					
	SOC	.470	.141	.470	3.322	.002	.184	.756	.470	.470	.470	1.000	1.000
2	(Constant)	5.614	1.716		3.271	.002	2.140	9.088					
	SOC	.402	.170	.402	2.366	.023	.058	.745	.470	.358	.336	.702	1.425
	SWM_TOTAL_ERRORS	-.011	.014	-.125	-.734	.468	-.040	.019	-.344	-.118	-.104	.702	1.425
3	(Constant)	6.805	1.873		3.633	.001	3.010	10.600					
	SOC	.354	.170	.354	2.078	.045	.009	.699	.470	.323	.291	.676	1.478
	SWM_TOTAL_ERRORS	-.013	.014	-.147	-.878	.386	-.041	.016	-.344	-.143	-.123	.696	1.437
	IDED_TOTAL_ERRORS	-.021	.014	-.211	-1.476	.148	-.049	.008	-.272	-.236	-.207	.964	1.038

a. Dependent Variable: PURDUE_BI

Regression 3: Sequencing Analysis

Correlations

		PURDUE_SEQ	SOC	SWM_TOTAL_ERRORS	IDED_TOTAL_ERRORS
Pearson Correlation	PURDUE_SEQ	1.000	.426	-.462	-.184
	SOC	.426	1.000	-.546	-.168
	SWM_TOTAL_ERRORS	-.462	-.546	1.000	.016
	IDED_TOTAL_ERRORS	-.184	-.168	.016	1.000
Sig. (1-tailed)	PURDUE_SEQ	.	.003	.001	.125
	SOC	.003	.	.000	.147
	SWM_TOTAL_ERRORS	.001	.000	.	.461
	IDED_TOTAL_ERRORS	.125	.147	.461	.
N	PURDUE_SEQ	41	41	41	41
	SOC	41	41	41	41
	SWM_TOTAL_ERRORS	41	41	41	41
	IDED_TOTAL_ERRORS	41	41	41	41

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	357.558	1	357.558	8.669	.005[b]
	Residual	1608.490	39	41.243		
	Total	1966.049	40			
2	Regression	505.132	2	252.566	6.570	.004[c]
	Residual	1460.917	38	38.445		
	Total	1966.049	40			
3	Regression	543.628	3	181.209	4.714	.007[d]
	Residual	1422.421	37	38.444		
	Total	1966.049	40			

a. Dependent Variable: PURDUE_SEQ

b. Predictors: (Constant), SOC

c. Predictors: (Constant), SOC, SWM_TOTAL_ERRORS

d. Predictors: (Constant), SOC, SWM_TOTAL_ERRORS, IDED_TOTAL_ERRORS

Model Summary[d]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics					Durbin-Watson
					R Square Change	F Change	df1	df2	Sig. F Change	
1	.426[a]	.182	.161	6.42210	.182	8.669	1	39	.005	
2	.507[b]	.257	.218	6.20042	.075	3.839	1	38	.057	
3	.526[c]	.277	.218	6.20031	.020	1.001	1	37	.323	1.730

a. Predictors: (Constant), SOC

b. Predictors: (Constant), SOC, SWM_TOTAL_ERRORS

c. Predictors: (Constant), SOC, SWM_TOTAL_ERRORS, IDED_TOTAL_ERRORS

d. Dependent Variable: PURDUE_SEQ

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B		Correlations			Collinearity Statistics	
		B	Std. Error	Beta			Lower Bound	Upper Bound	Zero-order	Partial	Part	Tolerance	VIF
1	(Constant)	10.739	3.388		3.169	.003	3.885	17.592					
	SOC	1.405	.477	.426	2.944	.005	.440	2.371	.426	.426	.426	1.000	1.000
2	(Constant)	19.550	5.561		3.515	.001	8.292	30.808					
	SOC	.817	.550	.248	1.485	.146	-.297	1.930	.426	.234	.208	.702	1.425
	SWM_TOTAL_ERRORS	-.092	.047	-.327	-1.959	.057	-.186	.003	-.462	-.303	-.274	.702	1.425
3	(Constant)	22.207	6.162		3.604	.001	9.721	34.693					
	SOC	.710	.560	.216	1.268	.213	-.425	1.846	.426	.204	.177	.676	1.478
	SWM_TOTAL_ERRORS	-.096	.047	-.342	-2.043	.048	-.191	-.001	-.462	-.318	-.286	.696	1.437
	IDED_TOTAL_ERRORS	-.046	.046	-.143	-1.001	.323	-.139	.047	-.184	-.162	-.140	.964	1.038

a. Dependent Variable: PURDUE_SEQ