

AGE-RELATED DIFFERENCES IN VERBAL, VISUAL
AND SPATIAL MEMORY: The Same or Different?

Thesis submitted by

Rhonda M Shaw

(B.Psych [Hons])

February 1 2007

For the Degree of Doctor of Philosophy

School of Psychology

James Cook University

Townsville Queensland

STATEMENT OF ACCESS

I, the undersigned, the author of this work, understand that James Cook University will make this thesis available for use within the University library and, via the Australian Digital Theses network, for use elsewhere.

I understand that as an unpublished work, a thesis has significant protection under the Copyright Act, and I do not wish to place any further restriction on access to this work.

Signed: _____

Dated: _____

STATEMENT OF SOURCES

DECLARATION

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 Information derived from the published or unpublished work of others has been acknowledged in the text and a list of references is given.

Signed: _____ Dated: _____

DECLARATION ON ETHICS

The research presented and reported in this thesis was conducted within the guidelines for research ethics outlined in the *National Statement on Ethics Conduct in Research Involving Human* (1999), the *Joint NHMRC/AVCC Statement and Guidelines on Research Practice* (1997), the *James Cook University Policy on Experimentation Ethics. Standard Practices and Guidelines* (2001), and the *James Cook University Statement and Guidelines on Research Practice* (2001). The proposed research methodology received clearance from the James Cook University Experimentation Ethics Review Committee (Approval numbers: H1718, H1947 and 2137).

Signed: _____ Dated: _____

ACKNOWLEDGEMENTS

There are a number of people who need to be thanked because without their assistance this thesis would never have been completed. First, and foremost, I need to thank my principal supervisor, Professor Edward Helmes. The support that you have provided over the past four years has been above what would have been expected. The advice has been invaluable and the encouragement appreciated. I have come to consider you a friend rather than just a supervisor and I hope this friendship can continue far into the future.

I would also like to thank my co-supervisor, Dr David Mitchell, for his assistance over the past four years. Although we have not always agreed on certain issues, I value your advice and opinion.

Thanks must be given to Peter Marendy who kindly wrote the code for the program that generated the tasks used in this thesis. Also, Alistair Campbell for creating the program for the spatial memory task which was needed to replace one of the original tasks. I also need to convey my thanks to Alan Baddeley and Gerry Quinn for the helpful comments they provided on my thesis at the 4th International Conference on Memory held in Sydney, 2006.

Of course, none of this would have been possible without the support and encouragement provided by my very dear family and friends. Particular mention must go to my daughter Teena, my son Richard, and to my beautiful granddaughters Jasmine and Ulani. Life certainly has been less stressful

knowing that you were all there for me if needed. To Janice, Glenda, Rochelle, Kellie, Donna and Debbie thank you for providing the friendly ears to listen to my endless complaints.

Finally, a very special thank you must go to the residents of Carlyle Gardens retirement village in Townsville, Queensland, who participated in the third study of this thesis. These residents are a very special group of people who were keen to assist in any way they could.

ABSTRACT

Working memory comprises a number of components, each responsible for the processing of different types of information. The phonological loop is responsible for processing verbal information while the visuo-spatial sketchpad is responsible for processing visual and spatial information. Age-related differences in verbal working memory are well documented with older adults consistently shown to have shorter memory spans than younger adults. Declines in spatial memory have also been reported. The data for visual memory performance however is less clear, with some researchers reporting decline across the adult lifespan and others reporting no difference. The purpose of the current thesis was to examine performance on a number of verbal, visual and spatial memory tasks in an effort to determine whether each type of memory declined with increased age and if so, whether they were affected by age to the same extent. Three studies were conducted to achieve these aims.

The first study explored the role of articulatory suppression, which has been shown to disrupt performance on verbal memory tasks; the effect on visual and spatial memory tasks is not so clear however. Fifty university undergraduates (12 men, 38 women) aged between 18 and 53 years ($M = 24.38$; $SD = 8.62$) completed verbal, visual and spatial memory tasks of differing memory set sizes under suppression and no suppression conditions in Study One. Results show that performance on all the tasks at each set

size was significantly affected by concurrent verbal suppression. It was concluded that articulatory suppression prevents participants from verbally encoding visual and spatial stimuli, leaving them to rely on purely visual or spatial representations. As a result articulatory suppression may provide researchers with an effective means to examine these types of memory with minimal contributions from the verbal system.

Study Two examined the reliability and validity of nine working memory tasks. One hundred and two first and second year psychology undergraduates aged between 18 and 56 years ($M = 23.96$, $SD = 9.78$) completed three verbal, three visual and three spatial working memory tasks. Seventy-three of these participants returned for retesting 14 days later. Results show that the test-retest reliability of the tasks was adequate to good with reliabilities ranging from 0.51 for letter orientation to 0.89 for the arithmetic task. Three factors, interpreted as verbal, visual and spatial factors, emerged from the data, accounting for a total of 58.8% of the variance. The tasks, with the exception of letter orientation, appeared to be reliable and valid indicators of the constructs they were designed to measure and were therefore used in Study Three of the current thesis. However, it is suggested that the psychometric properties of the tasks be examined in additional and preferably larger samples and using a smaller memory set size and different age groups.

Study Three examined age-related differences in verbal, visual and spatial memory using all of the tasks from Study Two except for letter orientation.

Letter orientation was replaced with a letter location memory task, which was similar in design to the dot memory task used in Study Two. Two hundred and one university undergraduates and community dwelling residents aged between 18 and 80 years, 139 females and 62 males ($M = 44.95$; $SD = 21.08$) completed three processing speed tasks, three verbal, three visual and three spatial memory tasks. Results of a 3 (task: verbal, visual, spatial) \times 3 (age group: young middle, older) mixed ANOVA with Bonferroni corrected comparisons revealed that there were no significant differences between young and middle aged adults performance on the verbal, visual or spatial memory tasks. Significant differences were revealed between the young and older adults' verbal and spatial memory performance but not for visual memory performance. The differences between the middle and older age groups' verbal, visual and spatial memory scores were significantly different.

The relationship between age and each type of memory was examined using a series of regression analyses. The first, using age as a predictor of each type of memory, showed that age explained a significant amount of the variance in verbal (11%), visual (3%), and spatial (16%) memory. After controlling for processing speed, the amount of age related variance on each type of memory decreased (verbal 5%, visual 0.08% and spatial 9%). Speed acted as a partial mediator of verbal memory variance and a full mediator of visual memory variance but not of spatial memory variance. Regression models using age, number of medications and processing speed explained a significant 15% of the variance in verbal memory, 17% of the visual memory

variance and 17% of the spatial memory variance. Age made significant contributions to verbal and spatial memory variance but not to visual memory variance. Processing speed made significant contributions to the variance in verbal and visual memory but not in spatial memory. The number of medications taken per day was the strongest contributor to visual memory variance.

Because the *n*-back tasks used in this study may have been tapping central executive processes, further models were examined using these tasks as a central executive variable along with age, number of medications, and processing speed. The results of these analyses revealed that the model explained a significant 36% of the variance in verbal memory, 32% of the visual memory variance and 28% of the spatial memory variance. The central executive variable was the strongest contributor to the variance in verbal memory (25%) and visual memory (11%); however age remained the strongest contributor to spatial memory variance (12%). Processing speed no longer made a significant contribution to verbal memory variance when the central executive variable was included in the model.

It was concluded that verbal, visual and spatial memories do decline with age but only after middle age; there appears to be little difference between young and middle aged adults. It was also concluded that verbal, visual and spatial memories are differentially affected by age with age explaining more of the variance in spatial memory than in verbal and visual memory. Age does

make a significant contribution to verbal memory variance but it is not a significant predictor of visual memory performance. Hence, the decline in visual memory performance after middle age is not age-related but appears to be related to other variables such as the number of medications a person takes each day and to the efficiency of central executive functioning. The relationship between verbal, visual and spatial memory performance and processing speed is also not the same across the lifespan, with processing speed mediating the variance between age and verbal and visual memory, but not spatial memory. Finally, it appears that the central executive plays an important role in performance levels on each of the different types of memory but not to the same extent in each subsystem.

TABLE OF CONTENTS

Statement of Access.....	ii
Statement of Sources.....	iii
Declaration on Ethics.....	iv
Acknowledgements.....	v
Abstract.....	vii
List of Figures.....	xvii
List of Tables.....	xviii
Chapter 1: Introduction, Aims, and Outline.....	2
1.1 <i>Introduction</i>	3
1.2 <i>Definitions</i>	5
1.2.1 <i>Working memory</i>	5
1.2.2 <i>Age</i>	6
1.3 <i>Aims and Significance</i>	8
1.4 <i>Research Overview</i>	9
1.4.1 <i>Research questions</i>	9
1.5 <i>Limits of the Research</i>	10
1.6 <i>Thesis Outline</i>	10
Chapter 2: A Model of Working Memory.....	13
2.1 <i>Chapter Introduction</i>	14
2.2 <i>Working Memory</i>	16
2.2.1 <i>The central executive</i>	16

2.2.2 <i>The phonological loop</i>	19
2.2.3 <i>The visuo-spatial sketchpad</i>	21
2.2.4 <i>The episodic buffer</i>	22
2.3 <i>Converging Evidence</i>	25
2.3.1 <i>Behavioural evidence</i>	25
2.3.2 <i>Neuropsychological evidence</i>	29
2.3.3 <i>Neurophysiological evidence</i>	31
2.4 <i>Conclusion</i>	34
Chapter 3: <i>Working Memory and Aging</i>	36
3.1 <i>Chapter Introduction</i>	37
3.2 <i>Cognitive Aging</i>	38
3.2.1 <i>Speed of information processing</i>	39
3.3 <i>Working Memory and Age</i>	42
3.3.1 <i>Age and verbal memory</i>	43
3.3.2 <i>Age and visuo-spatial memory</i>	45
3.4 <i>Differential Rate of Decline?</i>	51
3.5 <i>Conclusion</i>	57
Chapter 4: <i>Working Memory and Articulatory Suppression - Study</i>	
<i>One</i>	59
4.1 <i>Chapter introduction</i>	60
4.2 <i>Working Memory and Articulatory Suppression</i>	60
4.2.1 <i>Articulatory suppression and the phonological loop</i>	60

4.2.2 Articulatory suppression and the visuo-spatial sketchpad.....	62
4.3 Research Question and Hypotheses.....	65
4.4 Methods.....	66
4.4.1 Participants.....	66
4.4.2 Materials.....	66
4.4.3 Memory tasks.....	67
4.4.4 Procedure.....	69
4.5 Results.....	70
4.6 Discussion.....	74
4.6.1 Conclusion.....	77
 Chapter 5: Task Reliability and Validity - <i>Study Two</i>	79
5.1 Chapter Introduction.....	80
5.2 Measuring Verbal, Visual and Spatial Working Memory.....	81
5.3 Methods.....	85
5.3.1 Participants.....	85
5.3.2 Materials.....	85
5.3.3 Verbal memory tasks.....	86
5.3.4 Visual memory tasks.....	88
5.3.5 Spatial memory tasks.....	89
5.3.6 Procedure.....	90
5.4 Results.....	91
5.5 Discussion.....	96
5.5.1 Conclusion.....	100

Chapter 6: Age-Related Changes in Verbal, Visual and Spatial Working Memory Processes - <i>Study Three</i>	102
6.1 <i>Chapter Introduction</i>	103
6.2 <i>Age-Related Changes in Verbal, Visual and Spatial Working Memory</i> ..	103
6.2.1 <i>Summary and aims</i>	108
6.3 <i>Methods</i>	109
6.3.1 <i>Participants</i>	109
6.3.2 <i>Materials</i>	109
6.3.3 <i>Memory tasks</i>	110
6.3.4 <i>Processing speed tasks</i>	111
6.3.5 <i>Procedure</i>	113
6.4 <i>Data Analyses</i>	114
6.5 <i>Results</i>	116
6.6 <i>Discussion</i>	134
6.6.1 <i>Conclusions</i>	140
Chapter 7: General Discussion and Conclusions.....	144
7.1 <i>Chapter Introduction</i>	145
7.2 <i>Overview of the Results</i>	145
7.3 <i>Limitations</i>	150
7.4 <i>Implications</i>	152
7.5 <i>Recommendations for Future Research</i>	154
7.6 <i>Conclusions</i>	155

References.....	159
Appendix.....	186

LIST OF FIGURES

<i>Figure 4.1</i>	68
Example of some of the patterns used in the matrix pattern condition.	
<i>Figure 4.2</i>	73
Comparison of suppression and no suppression conditions for verbal, visual and spatial memory performance.	
<i>Figure 6.1</i>	113
Example of types of stimuli used in pattern comparison task.	
<i>Figure 6.2</i>	120
Comparison of processing speed between young, middle and older age groups.	
<i>Figure 6.3</i>	123
Comparison of performance levels on the verbal, visual and spatial memory tasks between young, middle and older age groups.	
<i>Figure 6.4</i>	128
Standardised regression coefficients for the relationship between age and verbal memory as mediated by speed of processing.	
<i>Figure 6.5</i>	129
Standardised regression coefficients for the relationship between age and visual memory as mediated by speed of processing.	

LIST OF TABLES

<i>Table 4.1</i>	71
Mean Percentages and Standard Deviations for Performance on Verbal, Visual and Spatial Memory Tasks Set Sizes Three, Four and Six during Suppression and No Suppression Conditions	
<i>Table 5.1</i>	92
Means and Standard Deviations for Verbal, Visual and Spatial Memory Tasks at Test and Retest	
<i>Table 5.2</i>	93
Correlations between Verbal, Visual and Spatial Memory Tasks	
<i>Table 5.3</i>	94
Verbal, Visual and Spatial Memory Tasks Test-Retest Reliability Coefficients	
<i>Table 5.4</i>	96
Factor Solutions from Principal Components Analysis with Varimax Rotation	
<i>Table 6.1</i>	117
Demographic Characteristics of Total Sample and Age Groups	
<i>Table 6.2</i>	119
Means and Standard Deviations for Reaction Times and Accuracy on Processing Speed Tasks, and Total Processing Speed and Accuracy Means and Standard Deviations for Young, Middle and Older Age Groups	
<i>Table 6.3</i>	121
Means and Standard Deviations for Verbal, Visual and Spatial Memory Tasks by Age Group	

<i>Table 6.4</i>	125
Correlations Between, Age, Health Status, Level of Education, Number of Medications, Processing Speed and Accuracy, and Verbal, Visual and Spatial Memory	
<i>Table 6.5</i>	126
Results of Regression Analyses using Processing Speed and Age as Predictors of Verbal, Visual and Spatial Memory	
<i>Table 6.6</i>	130
Results of Regression Analyses using Age, Number of Medications and Processing Speed as Predictors of Verbal, Visual and Spatial Memory	
<i>Table 6.7</i>	132
Correlations between Verbal, Visual and Spatial <i>n</i> -Back Tasks for Young, Middle and Older Age Groups.	
<i>Table 6.8</i>	133
Results of Regression Analyses using Age, Number of Medications, Processing Speed and a Central Executive Measure as Predictors of Verbal, Visual and Spatial Memory	