.ABSTRACT

Rationale : Investigating the relationship between working memory and reading comprehension will lead to an improved understanding of the nature of working memory and will reveal how working memory contributes to reading comprehension failure. A pattern of working memory deficits will determine if ‘signature’ working memory profiles exist which will assist in the diagnosis and treatment of children with reading comprehension difficulties.

Aims : (1) To explore the relationship between working memory and reading comprehension to determine if there are ‘signature’ working memory profiles that distinguish subgroups of Grade 5 English language learners with different comprehension capabilities. (2) To determine if a domain-specific or general working memory system is implicated in reading comprehension. (3) To explore the particular role played by the episodic buffer zone in reading comprehension.

Method : Eighty Grade 5 English learners were tested on the GORT-4, AWMA and CELF-4 Recalling Sentences Subtest. Based on their accuracy/decoding and comprehension scores on the GORT-4, participants were assigned to one of four reading ability groups: Skilled Reader Group; Reading Disabled Group; Poor Comprehender Group; or Poor Fluency Group. Comparison of mean standard scores determined how the four reading ability groups fared on the five memory components. Correlation and regression methods investigated the relationships between the five working memory variables and reading comprehension across the four reading ability groups.

Results : Working memory plays a role in reading comprehension. The Skilled Reader group displayed intact working memory profiles, whilst the Reading Disabled group performed in the low average range on four working memory variables and below average on the fifth viz. sentence recall. The Poor Comprehender group’s working memory performance resembled that of the Skilled Reader group on two working memory variables. The Poor Fluency group performed below average on visuo-spatial short-term memory. These findings gave evidence of the inter-play between domain-specific and domain-general components of working memory during the complex task of reading comprehension. In addition, the findings highlighted the predictive role of sentence recall, as well as that of verbal working memory in reading comprehension. The episodic buffer was shown to play an important binding function between fluid and crystallised knowledge. The results suggested that reading comprehension was affected by a learner’s working memory capacity, however, working memory alone did not account for variations in performance. Lower-order and higher-order cognitive processes, as well as the interaction between fluid and crystallised knowledge appear essential to authentic reading. This has ramifications for prevention and remediation of reading comprehension deficits and underscores the important role of the speech therapist in literacy promotion.

Key words :

working memory, reading comprehension

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

Division of the Deputy Registrar (Research)

HUMAN RESEARCH ETHICS COMMITTEE (NON MEDICAL)
R14/49 Irons

CLEARANCE CERTIFICATE **PROTOCOL NUMBER H0 91107**

PROJECT Subgroups of working memory deficits and reading comprehension

INVESTIGATORS Ms D Irons

DEPARTMENT Speech pathology and audiology

DATE CONSIDERED 13.11.2009

DECISION OF THE COMMITTEE* Approved Unconditionally

NOTE:

Unless otherwise specified this ethical clearance is valid for 2 years and may be renewed upon application

DATE 28.01.2010 **CHAIRPERSON** ....
(Professor R Thornton)

cc: Supervisor : Ms H Jordaan

DECLARATION OF INVESTIGATOR(S)

To be completed in duplicate and **ONE COPY** returned to the Secretary at Room 10005, 10th Floor, Senate House, University.

I/We fully understand the conditions under which I am/we are authorized to carry out the abovementioned research and I/we guarantee to ensure compliance with these conditions. Should any departure to be contemplated from the research procedure as approved I/we undertake to resubmit the protocol to the Committee. **I agree to a completion of a yearly progress report.**

DIrons
Signature

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES

UMnyango WezeMfundo
Department of Education

Lefapha la Thuto
Departement van Onderwys

Enquiries: Nomvula Ubisi (011)3550488

Date:	03 December 2009
Name of Researcher:	Irons Diane
Address of Researcher:	8 Athol Rowan Street
	Bedfordview
	2007
Telephone Number:	0114553391/0834865168
Fax Number:	0114554418
Research Topic:	Subgroups of working memory deficits and reading comprehension
Number and type of schools:	2 Primary Schools
District/s/HO	Ekurhuleni North

Re: Approval in Respect of Request to Conduct Research

This letter serves to indicate that approval is hereby granted to the above-mentioned researcher to proceed with research in respect of the study indicated above. The onus rests with the researcher to negotiate appropriate and relevant time schedules with the school/s and/or offices involved to conduct the research. A separate copy of this letter must be presented to both the School (both Principal and SGB) and the District/Head Office Senior Manager confirming that permission has been granted for the research to be conducted.

Permission has been granted to proceed with the above study subject to the conditions listed below being met, and may be withdrawn should any of these conditions be flouted:

1. *The District/Head Office Senior Manager/s concerned must be presented with a copy of this letter that would indicate that the said researcher/s has/have been granted permission from the Gauteng Department of Education to conduct the research study.*
2. *The District/Head Office Senior Manager/s must be approached separately, and in writing, for permission to involve District/Head Office Officials in the project.*
3. *A copy of this letter must be forwarded to the school principal and the chairperson of the School Governing Body (SGB) that would indicate that the researcher/s have been granted permission from the Gauteng Department of Education to conduct the research study.*

4. *A letter / document that outlines the purpose of the research and the anticipated outcomes of such research must be made available to the principals, SGBs and District/Head Office Senior Managers of the schools and districts/offices concerned, respectively.*
5. *The Researcher will make every effort obtain the goodwill and co-operation of all the GDE officials, principals, and chairpersons of the SGBs, teachers and learners involved. Persons who offer their co-operation will not receive additional remuneration from the Department while those that opt not to participate will not be penalised in any way.*
6. *Research may only be conducted after school hours so that the normal school programme is not interrupted. The Principal (if at a school) and/or Director (if at a district/head office) must be consulted about an appropriate time when the researcher/s may carry out their research at the sites that they manage.*
7. *Research may only commence from the second week of February and must be concluded before the beginning of the last quarter of the academic year.*
8. *Items 6 and 7 will not apply to any research effort being undertaken on behalf of the GDE. Such research will have been commissioned and be paid for by the Gauteng Department of Education.*
9. *It is the researcher's responsibility to obtain written parental consent of all learners that are expected to participate in the study.*
10. *The researcher is responsible for supplying and utilising his/her own research resources, such as stationery, photocopies, transport, faxes and telephones and should not depend on the goodwill of the institutions and/or the offices visited for supplying such resources.*
11. *The names of the GDE officials, schools, principals, parents, teachers and learners that participate in the study may not appear in the research report without the written consent of each of these individuals and/or organisations.*
12. *On completion of the study the researcher must supply the Director: Knowledge Management & Research with one Hard Cover bound and one Ring bound copy of the final, approved research report. The researcher would also provide the said manager with an electronic copy of the research abstract/summary and/or annotation.*
13. *The researcher may be expected to provide short presentations on the purpose, findings and recommendations of his/her research to both GDE officials and the schools concerned.*
14. *Should the researcher have been involved with research at a school and/or a district/head office level, the Director concerned must also be supplied with a brief summary of the purpose, findings and recommendations of the research study.*

The Gauteng Department of Education wishes you well in this important undertaking and looks forward to examining the findings of your research study.

Kind regards

Pp Nomvula Ubisi
Martha Mashego
ACTING DIRECTOR: KNOWLEDGE MANAGEMENT & RESEARCH

The contents of this letter has been read and understood by the researcher.	
Signature of Researcher:	[signature]
Date:	5·12·2009

APPENDIX C

SPEECH PATHOLOGY AND AUDIOLOGY

School of Human & Community Development
Faculty of Humanities
University of Witwatersrand

October 2009

Dear Principal,

My name is Diane Irons and I am conducting research for a Masters in Speech Pathology at the University of the Witwatersrand. I am studying the working memory and reading comprehension abilities of children in Grade 5. The project is entitled: Subgroups of Working Memory Deficits and Reading Comprehension. I would like to invite your school to participate in this study.

If you grant me permission to conduct the study at your school, the Grade 5 teachers will be provided with information sheets regarding the research.

The parents of learners who are currently in Grade 5 will be given information sheets and consent forms. The children who participate in the study will be given a simplified description of the study and their verbal consent to participate will also be requested.

If the parents allow their child to participate and the child gives consent, the child will be tested on an oral reading test in which he/she reads short passages and answers some questions. He/she will also be required to do a short memory test, in which he/she will show recall by looking at items on a computer screen and pressing the computer keys to answer questions. He/she will also be required to repeat sentences. It is estimated that the total testing time per child is one hour. I will do the tests at two different times to avoid fatigue and timetable disruption.

If any child is identified as having a reading memory problem, I will communicate with you to discuss possible solutions to the problem.

It is anticipated that the results of this study will have implications for teaching practice to facilitate the development of reading comprehension and working memory in learners.

Participation in this study is completely voluntary. Children are free to refuse to participate and to withdraw at any time during the study. They will not be penalised or disadvantaged in any way. Furthermore, all responses are strictly confidential and anonymity is assured.

If there are any queries please do not hesitate to contact me.

Your co-operation would be greatly appreciated.

Yours faithfully

Diane Irons
(Masters Student)
083 486 5168

Helia Jordaan
Supervisor

APPENDIX D

Project: Subgroups of Working Memory Deficits and Reading Comprehension.

I hereby give permission to the researcher to conduct the above-mentioned study at this school………………………………………………….. (name of school).

Principal: __________________________ (name) Signature: ____________________

Date: _____________________________

APPENDIX E

SPEECH PATHOLOGY AND AUDIOLOGY

School of Human & Community Development
Faculty of Humanities
University of Witwatersrand

October 2009

Dear Parent/Guardian,

My name is Diane Irons and I am conducting research for a Masters in Speech Pathology at the University of the Witwatersrand. I am studying the working memory and reading comprehension of children in Grades 5. I would like to invite you to allow your child to participate in my research.

The study involves your child doing an oral reading test in which he/she reads short passages and answers some questions. He/she will be required to do a short memory test in which he/she will show recall by looking at items on a computer screen and pressing the computer keys to answer questions. He/she will also repeat sentences. These tests will take approximately one hour during school time and testing will be done in two sessions. All testing will be conducted during school hours. I will discuss suitable times with the principal and teachers so that you child's academic programme is not disrupted in any way. If you child is identified as having a reading or memory problem, I will communicate with you to discuss possible solutions to the problem. It is anticipated that the results of this study will have implications for teaching practice to facilitate the development of reading comprehension and working memory in learners.

If you and your child decide to participate, kindly fill in the formal consent form.

Participation in this study is completely voluntary. You are not under any obligation to allow your child to participate. If you decide not to participate, or wish to withdraw your child at any time during the study, you and your child will not be penalised or disadvantaged in any way. In addition, all the test results will remain strictly confidential. Your child's identity will only be known to me.

Should you have any queries you can pass them on to the principal, who will then contact me. I will gladly respond to your questions to the best of my ability.

Your participation and contribution to this study would be greatly appreciated.

Please return the consent form below, indicating whether or not you agree to allow your child to participate.

Yours faithfully

Diane Irons
(Masters Student)

Helia Jordaan
Supervisor

APPENDIX F

Project: Subgroups of Working Memory Deficits and Reading Comprehension.
Guardian consent form:

I ……………………………………..………. (name and surname) hereby consent / do not consent (please underline you choice) to allow my child …………………………….. (name) to participate in this study. Should I consent to the study, I furthermore, give the researcher, Diane Irons permission to use the responses in the write up of the study, and in any further publications or presentations.

I understand that I am free to refuse to participate, or withdraw my child and discontinue participation in this study at any time, without it being held against me or my child in any way.

I understand that privacy will be maintained and that any responses will remain strictly confidential and anonymous. I am also aware that if I have any questions at any time, they will be answered by the researcher.

Signature: ______________________

Date: __________________________

APPENDIX G

Project: Subgroups of Working Memory Deficits and Reading Comprehension.
Minor Assent Form:

Hello, my name is Diane. I am studying at university and I am working on this project. I would like you to be part of my project. The project is about the role your memory plays when you are reading. I need you to read some passages and answer some questions. Then you are going to look at some pictures on the computer and press the computer keys to choose answers to questions. I will also ask you to repeat sentences. None of this is for marks and if you don't want to do the activities you don't have to. If at any time you do not want to do the activities anymore just tell me and I will stop. You will not get into any trouble if you decide to stop.

Would you like to help me with my project ?

YES / NO

My name is ____

The date today is ____

STANDARD SCORES FOR GORT-4, RECALLING SENTENCES, CELF-4, AND AWMA

		GORT-4					CELF-4	AWMA															
								Verbal S-T Memory				Verbal Working Memory				Visuo Spatial S-T Memory				Visuo-Spatial Working Memory			
	Gender	Rate	Accuracy	Fluency	Comp.	Reading group	Sentence Recall	Digit	Word	N-Word	Comp	L R P	C R P	B D R	Comp	Dot	Mazes	Blocks	Comp	O-O-U-P	Mr X P	S R P	Comp
		SS	SS	SS	SS		SS	SS	SS	SS	SS	SS	SS	SS	SS	SS	SS	SS	SS	SS	SS	SS	SS
1	M	5	5	3	8	2 R.D.	5	79.9	75.7	79.8	73	76.5	89	92	79	83.4	88.8	76.8	79	81.6	90	80.7	77
2	F	9	10	10	11	1 S.R.	5	96	92	108	98	74	89	83	83	95	90	84	87	97	106	82	99
3	M	7	10	9	9	3 P.C.	11	80	92	81	80	71	96	93	84	83	77	79	74	97	94	104	96
4	F	6	7	6	8	2 R.D.	4	82.9	63.1	87.5	73	74.3	87.7	77.1	76	92.5	101.1	87.9	92	103.5	89.3	69.1	78
5	M	7	7	6	8	2 R.D.	11	108	95	99.9	101	87	110	86	98	92	77	67	73	101	87	82	87
6	M	12	12	12	12	1 S.R.	8	91.7	88.3	95.1	89	107	103.7	92	104	92.5	88.8	98.9	91	100.2	96	79.2	93
7	F	1	2	1	8	2 R.D.	11	94.6	96.7	118.1	103	92.8	92.2	86	88	95.5	88.8	87.9	88	96.9	84.1	80.7	86
8	M	5	7	5	10	4 P.F.	8	108	99	112	108	84	96	86	90	95	93	93	92	94	99.9	117	110
9	M	8	7	7	10	4 P.F.	15	120	102	112	114	97	99	99	103	86	83	90	83	97	96	87	95
10	M	10	10	10	11	1 S.R.	6	88	95	99.9	93	78	91	80	79	86	70	73	70	93	85	89	84
11	M	4	4	3	9	2 R.D.	9	112	113	99.9	110	88	97	86	90	86	90	84	83	97	97	99.9	98
12	M	5	7	5	8	2 R.D.	12	101	107	105	105	107	116	107	116	112	106	109	111	125	134	108	127
13	M	5	6	4	9	2 R.D.	9	88	92	104	93	94	116	80	102	103	93	102	99	132	113	107	120
14	M	10	11	11	12	1 S.R.	6	112	86	102	99	87	99	114	105	88	83	89	83	99	103	98	101
15	M	9	8	8	7	2 R.D.	8	112	86	99	99	108	124	121	127	115	116	92	110	128	130	133	137
16	M	7	6	5	10	4 P.F.	6	108	92	57	82	71	113	93	83	92	64	81	74	95	103	103	99
17	M	6	5	2	8	2 R.D.	7	88.7	79	68.3	74	77.6	85.2	86	76	83.4	73.5	51.9	62	72.8	81.1	93.7	81
18	M	6	6	4	8	2 R.D.	6	82.9	92.5	72.1	79	86.3	76.3	89	82	74.2	85.7	74	73	79.9	81.8	74.1	70
19	M	14	14	15	13	1 S.R.	15	112	113	96	109	122	114	96	121	86	77	99	84	97	106	99	105
20	M	10	10	10	11	1 S.R.	7	88	106	99.9	97	85	90	86	90	103	93	81	90	97	99.9	89	96
21	F	10	10	10	9	3 P.C.	11	108	95	96	99	99	94	80	91	89	93	99	92	99	99.9	87	94
22	F	11	12	13	11	1 S.R.	14	99.9	123	108	113	119	123	105	119	95	90	87	88	92	96	81	92
23	F	11	11	11	11	1 S.R.	9	96	95	104	98	71	87	105	85	95	70	79	76	94	95	101.5	98
24	M	10	11	11	10	1 S.R.	14	120	106	112	116	91	107	99	105	75	87	90	80	97	99	91	99
25	M	14	12	12	13	1 S.R.	13	112	102	108	109	98	81	86	87	99.9	70	93	84	108	99.9	98	105
26	F	10	9	10	8	2 R.D.	12	104	109	96	104	92	109	90	101	98	99.9	114	105	97	109	94	105
27	M	10	10	10	11	1 S.R.	9	120	95	99.9	106	98	112	83	101	92	97	102	96	98	105	93	105
28	F	11	10	11	11	1 S.R.	13	120	116	120	123	78	99	99	98	106	97	96	99	99	99	99.9	102
29	F	11	13	12	11	1 S.R.	11	88	102	124	106	91	102	99	101	98	99.9	96	97	105	109	96	110
30	F	9	9	9	9	2 R.D.	8	99.9	95	99.9	97	85	108	83	93	98	80	87	85	99	95	84	93
31	F	8	8	8	9	2 R.D.	13	120	113	120	122	91	108	80	96	83	67	73	68	96	95	85	92
32	M	11	12	11	10	1 S.R.	9	92	102	96	96	94	119	99	111	103	107	102	105	117	103	123	117
33	F	8	9	8	10	4 P.F.	13	104	99	99.9	101	111	119	99	119	109	70	96	89	114	113	104	115
34	F	9	10	10	10	1 S.R.	9	84	95	104	93	85	112	99	105	103	90	102	98	97	113	92	99
35	M	14	16	16	13	1 S.R.	7	99.9	99	108	103	91	96	93	95	92	103	84	91	85	95	92	89
36	M	10	11	11	9	3 P.C.	6	69	109	99.9	90	71	96	112	91	95	97	87	91	97	98	86	93
37	F	9	11	11	10	1 S.R.	13	108	113	104	111	97	119	115	119	106	103	102	105	108	120	107	115
38	F	9	11	10	12	1 S.R.	10	103.4	105.1	102.8	104	96.1	113.3	98	109	104.7	104.2	101.7	104	123.3	132	119.8	127
39	F	12	12	12	10	1 S.R.	11	104	106	104	106	92	114	96	104	109	99.9	87	98	114	113	101	113
40	M	14	15	15	11	1 S.R.	12	108	102	99.9	104	97	119	96	110	103	103	93	99	117	116	126	124
41	F	10	11	11	9	3 P.C.	11	108	109	112	112	85	105	99	102	106	80	76	84	109	98	101	101
42	M	7	8	7	8	2 R.D.	4	99.9	109	99.9	103	91	102	96	99	99.9	99.9	111	104	98	99.9	87	96
43	M	6	7	6	8	2 R.D.	7	99.9	88	104	96	82	104	96	97	81	87	87	81	99	99	87	92
44	F	10	10	10	8	3 P.C.	7	108	106	104	107	97	123	109	120	106	110	108	110	135	134	104	129
45	M	16	17	18	13	1 S.R.	15	124	106	104	114	124	99	121	125	103	103	102	103	117	120	109	122
46	M	8	10	9	8	3 P.C.	10	88	88	96	89	92	88	96	95	99.9	120	87	102	132	113	102	117
47	F	10	12	13	11	1 S.R.	12	116	102	99.9	107	92	119	99	111	86	87	90	85	99	112	92	105
48	F	9	10	10	10	1 S.R.	13	128	88	99.9	106	91	116	80	102	106	97	87	96	97	102	104	105
49	F	13	12	11	11	1 S.R.	15	108	109	96	105	109	99	102	109	106	110	102	107	117	113	124	122
50	F	11	11	11	9	3 P.C.	17	140	109	104	122	94	123	96	112	92	103	102	99	114	113	103	111
51	M	9	10	9	8	3 P.C.	8	136	113	99.9	120	84	105	96	99	89	93	87	87	114	103	85	102
52	M	10	11	11	10	1 S.R.	6	84	92	99.9	89	85	102	86	97	98	83	81	84	99	99.9	106	105
53	M	8	8	8	9	2 R.D.	9	82.9	100.9	95.1	91	86.3	97.3	86	89	98.6	119.5	85.1	101	92.5	97.5	95.9	95
54	F	10	10	11	8	3 P.C.	9	82.9	79.9	91.3	81	88.5	77.5	98	83	98.6	79.6	98.9	90	83.8	90.8	85	92
55	M	10	11	11	9	3 P.C.	10	99.9	88	108	98	95	99	105	102	98	67	87	80	102	99	86	97
56	F	8	9	9	8	2 R.D.	7	100.5	105.1	91.3	99	97.2	90.9	95	98	86.4	64.3	87.9	74	83.8	76.6	71.2	67

STANDARD SCORES FOR GORT-4, RECALLING SENTENCES, CELF-4, AND AWMA

		GORT-4					CELF-4	AWMA															
	Gender	Rate	Accuracy	Fluency	Comp.	Reading	Sentence	Verbal S-T Memory				Verbal Working Memory				Visuo Spatial S-T Memory				Visuo-Spatial Working Memory			
						group	Recall	Digit	Word	N-Word	Comp	L R P	C R P	B D R	Comp	Dot	Mazes	Blocks	Comp	O-O-U-P	Mr X P	S R P	Comp
		SS	SS	SS	SS		SS	SS	SS	SS	SS	SS	SS	SS	SS	SS	SS	SS	SS	SS	SS	SS	SS
57	M	11	10	11	11	1 S.R.	9	92	88	104	93	85	102	90	98	106	103	87	98	114	99.9	103	110
58	F	10	10	11	12	1 S.R.	9	124	92	99.9	106	95	109	96	102	106	90	99	98	101	103	92	103
59	F	11	10	10	10	1 S.R.	8	82.9	96.7	91.3	88	90.6	87.1	83.1	87	80.3	91.9	87.9	83	92	97.5	82.1	88
60	M	7	8	7	10	4 P.F.	6	71.1	71.5	87.5	72	98.3	97.3	77.1	90	95.5	79.6	82.3	82	89.8	95.3	99.5	96
61	F	10	10	10	11	1 S.R.	13	109.3	105.1	91.3	102	105.9	97.3	98	104	83.4	91.9	98.9	89	94.2	91.5	81.4	87
62	F	10	9	9	9	2 R.D.	9	100.5	100.9	106.6	102	87.4	103.1	89	91	92.5	104.2	93.4	96	92	93	90.8	92
63	M	10	11	11	12	1 S.R.	9	80	88	108	90	94	119	83	99	98	83	105	94	94	103	129	111
64	M	8	8	8	9	2.R.D.	5	99.9	92	77	87	87	99	80	89	83	77	84	76	99	95	99.9	98
65	M	11	12	13	12	1.S.R.	11	85.8	96.7	102.8	93	113.5	97.3	92	106	113.8	91.9	87.9	96	93.6	95.3	101.7	100
66	F	10	12	11	12	1.S.R.	11	91.7	88.3	95.1	89	93.9	94.8	106.9	102	101.6	101.1	98.9	100	92	96	98	96
67	F	9	8	8	9	2.R.D.	6	91.7	88.3	95.1	89	93.9	94.1	80.1	88	89.4	85.7	87.9	84	90.3	96	92.2	92
68	M	10	10	10	11	1.S.R.	8	97.6	84.1	102.8	93	100.4	98	92	99	101.6	67.3	87.9	82	94.7	97.5	85	93
69	F	10	11	11	10	1 S.R.	10	112	102	99.9	105	94	116	93	107	89	87	87	85	96	113	92	102
70	F	12	11	11	9	3 P.C.	13	124	102	99.9	111	92	114	93	104	103	90	105	99	131	116	103	119
71	F	12	12	12	9	3 P.C.	10	115.2	109.3	106.6	112	92.8	113.3	98	106	110.7	91.9	98.9	100	107.9	107.3	99.5	109
72	M	11	14	12	12	1 S.R.	15	118.1	96.7	95.1	104	93.9	110.1	127.9	118	113.8	98	98.9	104	122.2	107.3	116.9	118
73	M	10	13	12	11	1.S.R.	8	103.4	96.7	87.5	94	112.4	106.9	98	111	116.8	128.7	104.5	120	110.1	113.2	115.4	116
74	F	13	13	13	11	1.S.R.	11	116	109	99.9	110	97	119	96	112	120	113	108	117	111	120	110	118
75	F	10	13	12	11	1.S.R.	8	112	102	99.9	105	91	116	83	99	98	107	99	102	114	120	107	118
76	F	9	10	10	10	1.S.R.	11	116	102	96	106	89	102	80	93	95	90	87	88	94	95	84	90
77	M	13	12	13	12	1.S.R.	13	121.1	100.9	99	108	108.1	106.9	115.9	119	101.6	101.1	101.7	101	122.7	127.5	108.2	127
78	F	14	15	15	11	1.S.R.	12	132	109	112	122	94	115	93	107	103	90	99	97	114	113	83	106
79	F	12	13	13	11	1.S.R.	13	108	106	108	109	112	119	112	124	103	99.9	96	99	111	113	123	119
80	M	12	13	12	10	1.S.R.	12	124	113	112	97	112	116	112	122	103	103	99	102	114	120	101	117

DECLARATION

I hereby declare that this report is my own, unaided, independent work. It has not been submitted before for any degree or examination at this or any other academic institution, nor has it been published in any form.

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________________________ **January 2011**

Diane Irons

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.ABSTRACT

Rationale : Investigating the relationship between working memory and reading comprehension will lead to an improved understanding of the nature of working memory and will reveal how working memory contributes to reading comprehension failure. A pattern of working memory deficits will determine if 'signature' working memory profiles exist which will assist in the diagnosis and treatment of children with reading comprehension difficulties.

Aims : (1) To explore the relationship between working memory and reading comprehension to determine if there are 'signature' working memory profiles that distinguish subgroups of Grade 5 English language learners with different comprehension capabilities. (2) To determine if a domain-specific or general working memory system is implicated in reading comprehension. (3) To explore the particular role played by the episodic buffer zone in reading comprehension.

Method : Eighty Grade 5 English learners were tested on the GORT-4, AWMA and CELF-4 Recalling Sentences Subtest. Based on their accuracy/decoding and comprehension scores on the GORT-4, participants were assigned to one of four reading ability groups: Skilled Reader Group; Reading Disabled Group; Poor Comprehender Group; or Poor Fluency Group. Comparison of mean standard scores determined how the four reading ability groups fared on the five memory components. Correlation and regression methods investigated the relationships between the five working memory variables and reading comprehension across the four reading ability groups.

Results : Working memory plays a role in reading comprehension. The Skilled Reader group displayed intact working memory profiles, whilst the Reading Disabled group performed in the low average range on four working memory variables and below average on the fifth viz. sentence recall. The Poor Comprehender group's working memory performance resembled that of the Skilled Reader group on two working memory variables. The Poor Fluency group performed below average on visuo-spatial short-term memory. These findings gave evidence of the inter-play between domain-specific and domain-general components of working memory during the complex task of reading comprehension. In addition, the findings highlighted the predictive role of sentence recall, as well as that of verbal working memory in reading comprehension. The episodic buffer was shown to play an important binding function between fluid and crystallised knowledge. The results suggested that reading comprehension was affected by a learner's working memory capacity, however, working memory alone did not account for variations in performance. Lower-order and higher-order cognitive processes, as well as the interaction between fluid and crystallised knowledge appear essential to authentic reading. This has ramifications for prevention and remediation of reading comprehension deficits and underscores the important role of the speech therapist in literacy promotion.

Key words :

working memory, reading comprehension

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CHAPTER 1 : INTRODUCTION

"Human beings are not born to read .... Thus the modern act of reading is based on an ingenious rearrangement of older neuronal circuitries that undergird attentional, perceptual, linguistic, cognitive, and motoric processes that were originally designed for functions other than reading .... All of these attentional, perceptual, cognitive, and linguistic processes necessary for such fluent, comprehending reading rest on an intricate re-organisation of regions in the developing brain .... A major implication of this particular view of reading is that the multiple components involved in reading can lead to multiple sources of breakdown ..... If that is the case there should be subtypes of children with different causes of reading failure" (Wolf & O'Brien, 2004: 6, 8 ,9).

It was the purpose of this study to examine the specific relationship between working memory and reading comprehension to explore how working memory is involved in reading comprehension with a view to identifying discernable subgroups of children with different working memory profiles that may be associated with different reading ability groups. To achieve this objective, 80 Grade 5 English language learners were individually assessed on the Automated Working Memory Assessment Battery (AWMA) (Alloway, Gathercole, & Pickering, 2004), the CELF-4 Recalling Sentences Subtest (CELF-4) (Semel, Wiig & Secord, 2006) and the Gray Oral Reading Test (GORT-4) (Wiederholt & Bryant, 2001). Based on their performance on the latter test, learners were assigned to one of four reading ability groups. Data was analysed to determine if significant correlations existed between the various components of working memory and reading comprehension within the different reading ability groups and regression analysis was utilised to determine the predictive relationships between these components and reading comprehension.

Academic success is clearly linked to reading skills in children, hence the importance of identifying variables that can predict reading success. The study of how children become skilled readers, and why some children experience unexpected difficulties in learning to read, has occupied psychologists and educationalists since the end of the last century. Gathercole and Baddeley (1993) point out that the resulting body of knowledge on how reading skills develop in childhood is extensive. They cite phonological processing skill to be one factor that has consistently been found to be linked with ease of acquiring literacy, and which differentiates skilled readers from less skilled readers, particularly in the early stages, but there is substantial evidence too, that the ease with which children learn to read is associated with their phonological short-term memory (Daneman & Carpenter, 1980; Gilliam & Van Kleeck, 1996; Baddeley, 1990; Alloway, Gathercole, Adams, Willis, Eaglen & Lamont, 2005; Gathercole & Alloway, 2006). Several recent studies have shown that differences between skilled and less skilled readers on cognitive measures are related to limitations in working memory, of which short-term memory is a component (De Jong, 1998; Passolunghi & Siegel, 2001; Swanson, 2003; Swanson, Howard & Saez, 2006; Vukovic & Siegel, 2006; Pickering, 2006). The relationship between working memory and reading disability is now well established, although the nature of this relationship is unclear.

Research into the relationship between working memory and reading comprehension specifically has presented multiple conundrums: a working memory system specialised for language processing has been implicated in reading comprehension, but the visuo-spatial component of working memory has not been ruled out (Cain, Oakhill & Bryant, 2000; Swanson & Siegel, 2001; Seigneuric, Ehrlich, Oakhill & Yuill, 2000, Vukovic & Siegel, 2006). Some researchers propose that an interaction between the verbal and visuo-spatial systems of working memory in reading comprehension should be considered (Swanson & Siegel, 2001; Vukovic & Siegel, 2006). This leads to further questions regarding the best framework to describe the functioning of working memory viz. the multi component structural models (Baddeley & Hitch, 1974; Baddeley, 2000c; Gathercole & Pickering, 2000) or complementary M-capacity models (Daneman & Carpenter, 1980; Just & Carpenter, 1992; Engle, Kane & Tuholski 1999a). Both types of models include verbal and non-verbal or spatial components in their architecture, but are distinguished by a central executor, which combines storage and processing functions. In essence, it is the differences in the management of storage and processing aspects of working memory which differentiates these frameworks from each other and pose conceptual differences. Probing the relationship between reading comprehension and working memory is of particular relevance when considering storage and comprehension, as text comprehension is a task that requires simultaneous, on-line short-term storage and processing, as well as retrieval of information from long-term memory (Westby, 2004; Westby & Watson, 2004; Gathercole & Baddeley, 1993). In reading comprehension, access to information in long-term memory is considered essential to derive a text's full meaning. This binding function of working memory has been under-explored (Alloway, Gathercole & Pickering, 2004; Vance, 2008; Henry, 2001). By employing a working memory assessment battery that investigated all these functions, this study hoped to add clarity to the structural and functional issues outlined above. An in-depth discussion of the different positions and their proponents, as well as relevant research, will follow in the next chapter, where the complexities of working memory and reading comprehension will be detailed, and the uniqueness of the relationship between them unveiled.

This research therefore investigated how Grade 5 learners with different reading comprehension capabilities performed on a working memory assessment battery, to explore the relationship between working memory and reading comprehension. The study was conducted in an attempt to isolate the source of working memory deficits in less skilled readers and to explore how working memory deficits may contribute to reading comprehension failure. Given the impact that working memory deficits have on a child's ability to acquire knowledge, develop crucial skills and succeed in formal education, the identification and understanding of working memory impairments is crucial. At a practical level, Baddeley (2006) suggests that a more thorough understanding of the impact of working memory on a particular learning domain, is likely to prove vital to any principled approach to educating and supporting those individuals with an impaired capacity for learning. Westby and Watson (2004) point out that by evaluating aspects of working memory and executive function, in addition to more traditional measures of language, speech-language pathologists can be instrumental in identifying the specific learning needs of children. In the current South African education system, speech therapists are largely excluded from classroom practice and their collaborative role in promoting literacy is overlooked (O'Connor & Geiger, 2009). The role of the speech-language therapist as co-teacher, consultant, or direct service provider, who is fully integrated in the classroom, has been emphasized (Owens, 2004). Roth and Troia (2009) motivate strongly for speech-language pathologists to be integral members in a professional, collaborative partnership. Given the current alarming status of literacy levels in South Africa (Howie, Venter, Van Staden, Zimmerman, Long, Scherman & Archer, 2008), this study intends to show the value of the speech-language therapist in the educational context. Furthermore, the value of utilizing working memory measures, rather than IQ, may be of great significance in the South African context where educators are confounded by a heterogeneous population of learners with multiple differences, which could prejudice their academic success. A tool that offers a less-biased, culture-neutral and more fluid measure of the basic cognitive capacity to learn, will assist educators in differentiating those learners with a 'difference' from those with a 'disorder'. Gathercole and Alloway (2004) and Alloway (2009) emphasize that because working memory is a general skill underlying various cognitive domains, its value cannot be underestimated.

This study intends to demonstrate the merits of the working memory construct by exploring its relationship with reading comprehension. It also aims to underscore the role of the speech-language therapist as a valuable resource within the educational context, where evidence-based, best-practice methods should be employed, as well as skills and tools that accommodate differentiation in the classroom. In an analogy, Nicholson (2005: 659) points out that “Aspirin relieves the symptoms of headache and backache but they’re not the same affliction” and the International Dyslexia Society (1997) states that one of the most important factors for the prevention and treatment of reading difficulties is ‘informed instruction’. It is the hope of this study to improve our understanding of how working memory contributes to reading comprehension success or failure and this in turn will promote best-teaching practices.

CHAPTER 2 : LITERATURE REVIEW

The literature review covers a range of theoretical and conceptual areas relevant to this study. A brief discussion of the history of the study of human memory leads into the evolution of the working memory construct. Baddeley and Hitch's (1974) model and its adaptations are presented in detail as it forms the framework on which this study is constructed. Gathercole's and Pickering's (2000) reconceptualisation of this model follows, as the clarity with which these researchers view short-term and working memory is central to this study. Other models of working memory are briefly discussed to give a more complete picture of the various theoretical perspectives surrounding working memory. The significance of working memory in academic success leads to a discussion of literacy. The importance of decoding, phonological awareness and rapid automatic naming is outlined and their impact on reading failure is documented. Attention is then directed to comprehension processes where the situation model is considered of paramount importance. The relationship between working memory and reading disability is explored, followed by a more in-depth investigation of the specific relationship between working memory and reading comprehension. Relevant studies are used to document findings in this regard. The chapter concludes with a rationale for this study and its specific aims, from which a set of hypotheses is drawn.

2.1 Historical Overview of the Study of Human Memory

Philosophers have speculated about memory for over 2000 years in an effort to conceptualise this construct. Aristotle compared memory to a wax tablet, whilst Plato used the spatial metaphor of an aviary. Memory has been compared to the telephone system and more recently to the digital computer. These analogies all fall within the *structural view*, where memory is a place where memories are stored. The *proceduralist view,* where the processes that create and recreate the memory, has been tendered as an alternative to the structuralist approach. However, neither of these approaches can account for all memory phenomena hence the *functionalist* movement arose and took the position that discovering and enumerating general principles of memory offers a scientific explanation for memory phenomena (Neath & Suprenant, 2003).

Baddeley (1995) points out that the scientific study of memory began with the work of Hermann Ebbinghaus who demonstrated that by rigidly controlling experimental conditions, characteristics of human memory could be observed. Since many of the richer and more intriguing aspects of human memory are practically impossible to capture within the laboratory, this led to the criticism that much research on the psychology of memory pays scant attention to the applicability of results to remembering in the outside world. The cognitive branch of psychology which arose in the 1960's offered a more flexible approach to psychology and to the field of memory research as it attempted to counter this claim and to offer 'ecological validity'. In more recent times, the cognitive neuropsychological approach has had increasing impact and has been particularly influential in the evolution of the working memory model discussed later in this chapter. Baddeley, whilst sympathising with critics of experimental control such as Neisser, is of the opinion that, as a result of neuropsychological studies, substantial progress has been made in understanding human memories and that much of the work carried out in the laboratory does have relevance and can be directly applied in the outside world. Ellis (1990) points out that the unique value of neuro-psychological studies for theories of normal cognitive function arises from the opportunities provided by 'natural experiments' in which brain damage selectively impacts a particular psychological mechanism. Wagner (cited in Lyon et al, 1996) reveals that a research paradigm shift has occurred more recently and affords greater understanding into the cognitive processes of memory. This shift has been from within disciplinary testing to interdisciplinary investigation and interchange. Hence, over the last 30 years there has been a huge development in our knowledge of the functioning of human memory, a development which has been strongly influenced by the study of memory disorders. Alloway (2006a) asserts that this has resulted in the enrichment of theory and of its application to clinical problems. The current research reflects this shift to interdisciplinary investigation of the cognitive domains of working memory and reading comprehension.

2.2 The Evolution of the Working Memory Construct

The present day construct of working memory evolved from early theories of short-term memory. Memory had initially been conceptualised as a single system (Logie, 1995). With the introduction of the information-processing perspective, substantial evidence accumulated to consolidate the distinction between temporary and long-term memory. One such theory was proposed by Broadbent (1958) based on the discovery of a temporary information store that relied on rehearsal for maintenance of short-term information. Broadbent's model introduced the idea of structural components in short-term memory and he forwarded the notion that short-term memory comprised two sub-systems: the 's' system which briefly stored information for processing by the limited capacity 'p' system. Miller (1956) shared this limited capacity view in that he postulated that adults could retain and process a maximum of seven plus or minus two bits or chunks of information. Brown (1958) and Peterson and Peterson (1959) showed that rehearsal was essential for short-term retention and that articulatory suppression caused interference, which resulted in forgetting due to decay of the memory trace. Broadent's (1958) first information processing model of short-term memory was later expanded by modal models of memory, which were based on modality specific sensory registers and common short and long-term stores (Hitch, 1980).

Wagner (1996) described the modal model developed by Atkinson and Shiffrin in 1968 as characteristic and most influential of these approaches. In this model, information from the environment is assumed to enter a series of brief sensory registers, which then pass information onto a short-term store, capable of dealing with information in a verbal or visual code. Information that resides within the short-term store is then passed onto the long-term store, which is the third component. In this model, the short-term store plays a crucial role, since long-term learning is assumed to occur when information is transferred in this way.

The assumption that merely holding information in the short-term system would guarantee learning, proved difficult to sustain. Baddeley (1995) pointed out that evidence of normal learning, and the ability to cope with everyday life in patients with short-term memory deficits, led to the down-fall of modal models, which could not explain research findings of preserved long-term memory in patients with short-term memory impairments. These models could also not provide a satisfactory account of why an intact short-term memory failed to produce new, long-term learning (Shallice & Warrington, 1970).

Modal models which viewed short-term memory as a conduit for carrying information from sensory registers into long-term memory, were abandoned. Baddeley and Hitch (1974) undertook a detailed investigation of short-term memory functions and these investigations led them to propose a multi-component working memory. They adopted the term *working memory* to accentuate the differences between their conceptual understanding of short-term memory as having three components, compared to the unitary construct of short-term memory at that time.

Baddeley (1986, 34) defined working memory as "........ a system for the temporary holding and manipulation of information during a range of cognitive tasks such as comprehension, learning and reasoning".

2.3 A Current Model of Working Memory

This study will focus first on the Baddeley and Hitch model which was formulated in 1974 and modified in 2000. This model provides a functional framework with which to capture working memory performance. Baddeley and Hitch broke away from the serial information-processing stage paradigm and proposed that memory was a more complex system comprising a number of interacting mechanisms. They proposed that memory was a more multifaceted system than initially conceived. The key point of departure of this model from previous theories, was that working memory accessed both long and short-term memory and referred to the temporary storage and activation of information from long-term memory and the environment (Hulme & MacKenzie, 1992). Baddeley and Hitch (1974) proposed that short-term memory was a tripartite system, not a single system made up of entirely separate parts operating together. The three components of working memory that they initially proposed, comprised a limited *central executive processing system* that interacts with a set of two passive subsidiary slave systems used for the temporary storage of different classes of information: the speech-based *phonological loop* and the *visual-spatial sketchpad* (Baddeley, 1986). In subsequent years, this model has been modified and fine-tuned. As a result of adjustments, Baddeley (2000b), in a recent formulation of the model included an additional multimodal storage component called the *episodic buffer*. This buffer is a limited capacity store controlled by the central executive. Although it can be conceptualised as the storage part of the central executive, it is essentially regarded as a separate sub-system (Logie, 1999; Baddeley, 2000b).

The Central Executive

The central executive is a domain-general (modality-free) system that controls and regulates the working memory system, including co-ordinating the two domain-specific slave systems, allocating resources between processing and storage demands, activating and retrieving information from long-term memory and encoding retrieval strategies (Baddeley,1996). Barnard, Scott and May (2001) note that in the original model, the central executive was described as a general processing construct that dealt with any complex issue that could not be directly assigned to either the phonological loop or the visuo-spatial sketchpad. It was therefore envisaged to be a general pool of resources which could perform control functions or provide supplementary storage. However, later versions of this dynamic model emphasised the executive function role of the central executive. Cognitive control functions of focussing attention, dividing attention, switching attention, updating and inhibition, expand the responsibilities originally assigned to the central executive (Baddeley, 1996). These executive functions resemble those attributed to the 'supervisory activating system' (SAS) in Norman and Shallice's 1986 model of attentional control and allow for temporary storage and activation of information (maintenance) and the concurrent, 'on-line' maintenance and manipulation of information.

The Phonological Loop

The phonological loop is thought to be responsible for the temporary storage of verbal information. Baddeley (1986) in later research, showed that the phonological loop component could be further broken down into a *phonological store* which holds information in a phonological form and the *articulatory rehearsal process* which serves to maintain representations in the phonological store. The phonological store's function is the temporary storage of speech-based information. Baddeley (1982) points out that this system is constrained as memory traces appear to fade or become irretrievable after approximately 1.5 to 2 seconds. However, if the memory trace is read into the articulatory rehearsal process, it can be 'refreshed' and then fed back into the phonological store. This re-articulation of the memory trace is the process which underlies 'subvocal rehearsal' (Vallar & Baddeley, 1984). Baddeley (1996) indicates that in addition to refreshing memory traces, the articulatory rehearsal process also converts written material into a phonological code, which it in turn registers into the phonological store. Information gained from visual input, such as reading printed text, can be subvocally recoded and transferred to the phonological store. An alternate method, by which memory traces can be restored is the process of 'redintegration'. Gathercole and Adams (1994) explain that incomplete representations of a word in the phonological loop can be primed from prior lexical knowledge, which is used to fill in the gaps left by degraded memory traces.

Baddeley (1982) refers to four factors which affect the phonological memory trace. These include :

- *The phonological similarity effect,* where immediate recall is impaired when items are similar in sound or auditory characteristics. He points out that similar traces will be harder to discriminate, leading to a lower level of recall.

- *The unattended speech effect,* which is assumed to occur because any spoken material gains access to the phonological store, which is corrupted by the presence of irrelevant material.

- *The word length effect,* where the spoken duration of the words presented, determines memory span. Memory span is considered to represent the number of items that can be uttered in about two seconds. Thus the rate at which an individual speaks or reads affects recall.

- *Articulatory suppression,* where the operation of the phonological loop is disturbed by the overt or covert articulation of an irrelevant item. Baddeley (1982) assumes that the irrelevant item dominates the articulatory control process. The conversion of visual material into a phonological code may be prevented. Another hypothesis for the articulatory suppression effect is that suppression impairs performance simply because it requires attention.

The Visuo-Spatial Sketchpad

The visuo-spatial sketchpad is the second major slave system responsible for holding and manipulating visuo-spatial representations over brief periods, and plays a key role in the generation and manipulation of mental images (Logie, 1999; Baddeley, 2003). Baddeley (2003) indicates that it has a fixed capacity limited to three or four images. Although it is common practice to refer to the visuo-spatial sketchpad as a single entity, data from neuropsychological studies points to the existence of two distinct, but interacting *visual* and *spatial* components. Further evidence for two separable but related components comes from developmental fractionation. Logie and Pearson (1977) found that the visual aspect of the sketchpad developed faster than the spatial aspect in children. Baddeley (2003) refers to the work of Ungerleider and Mishkin in 1982 who believed their research pointed to two distinct components, *the visual*, concerned with processing patterns and determining 'what' and *the spatial,* concerned with location in space and determining 'where'. Thierry (2004) elaborates further and describes the visual component, or *visual cache*, to be a passive system that stores visual information and spatial locations in the form of static, visual representations, whilst the spatial component, or *inner scribe*, is an active spatial rehearsal system that maintains sequential locations and movements which refresh decaying information in the visual cache. Logie (1995) indicated that spatial memory retained both physically presented and imagined movement. He also proposed that the visual imagery and spatial sub-systems were not as easy to encode as the phonological system and the sketchpad was consequently slower and more demanding on the central executive.

When discussing the visuo-spatial sketchpad it is important to note that although images have visual and spatial components, visuo-spatial representations can be set up from verbal cues. Baddeley (2003) indicated that these are useful when solving a mathematical problem or reading a descriptive passage. Verbal recall may be enhanced by the use of visual imagery (Baddeley, 2006).

The Episodic Buffer

The episodic buffer is assumed to be a limited-capacity, multimodal temporary storage system controlled by the central executive and, according to Baddeley (2000b), it allows for the integration of information from a variety of sources. It is *episodic* in that it holds information or episodes that have been bound from a number of sources where information is integrated across space and time. It is a *buffer* in that it provides a temporary interface between the slave systems and long-term memory. It represents a 'crystallised' cognitive system that is able to accumulate long-term stored knowledge, even though it is isolated from long-term memory. In this way, the episodic buffer supplements information currently in working memory. Baddeley (2000b) put forward the concept of the episodic buffer to account for experimental observations that posed a conceptual problem to the phonological component of the model. The model could not explain how subjects could recall visually presented verbal items from memory whilst engaging in articulatory suppression. Articulatory suppression theoretically prevented rehearsal of this information so that it could not enter the phonological store, thereby making it impossible to be recalled. Studies showed that although memory span was affected, subjects were still able to recall a fair amount of information (Neath & Suprenant, 2003). Similarly, evidence from patients who could not retain information in the phonological loop, as seen in their memory span of one digit for auditory information, could remember up to four digits when the information was presented visually. Encoding of this information into the visual subsection of the sketchpad was ruled out, as the visual coding system is unable to perform serial retention. Since the central executive did not have the capacity to store information, Baddeley (2000b) proposed an additional storage system that operated when either of the 'slave' systems was engaged, so as to facilitate serial recall and to store different kinds of information – this being the episodic buffer.

Further evidence to support the claim that the episodic buffer combines or integrates short-term and long-term memory was the fact that the phonological loop component of the model could not explain how sentence and prose span was typically greater than single word or digit recall on serial tasks, particularly when sentences or prose were meaningfully related (Baddeley, 2000b). The phenomenon that a subject might possess poor single item span but better sequential sentence span could not be explained within the scope of phonological loop function. Rather it appears that long-term memory was accessed and that meaningful information was combined into chunks. This finding led to the assumption that there had to be a short-term storage system for chunked information that could access long-term memory. Accordingly, the episodic buffer was forwarded as the system that stored some information, was not restricted to the phonological loop, visual-spatial sketchpad, central executive or long-term memory systems, but was domain-general and united information across the different components of memory.

Conway et al's research (2005) provided further evidence that the episodic buffer combines different sources of information via domain-free processes. In a series of studies using factor analysis, it was found that verbal and spatial span tasks were part of the same factor, suggesting that the phonological loop and visuo-spatial sketchpad, draw on domain-general processes via the episodic buffer during working memory tasks.

2.4 Short-term Memory Versus Working Memory

In the context of this research, the Baddeley and Hitch prototype model of working memory has been described in detail to facilitate understanding of the terminology used and to explain how the components work. The term *working memory* adopted by Baddeley and Hitch emphasises the functional aspect of short-term memory and its role as part of a system responsible for maintaining information in the short-term and manipulating that information whilst performing multiple cognitive tasks (Baddeley, 2003). This model proposes that short-term memory is a tripartite system compared to previous models which considered it to be a single system. Storage demands of complex memory tasks depend on two distinct supplementary sub-systems, with processing demands being supported principally by the over-arching central executive (Baddeley & Logie, 1999). The supplementary systems constantly contend for central executive resources (Gazzaniga, Ivry & Mangun, 2002). Zillmer and Spiers (2001) point out that working memory includes some of the capacity constraints of short-term memory but that working memory can access and manipulate attention and executive functioning.

The role of working memory in combined storage and processing of information, is emphasised in the Baddeley and Hitch model. Furthermore, this tripartite system operates in alliance with other aspects of cognition, such as language comprehension and reasoning (Hancock, La Pointe, Stierwalt, Bourgeois & Zwaan, 2007) as it is flexible enough to be involved in other aspects of cognition simultaneously. This led to the concept of a functional memory system that held information ‘on-line’ whilst an individual was involved in executing complex cognitive tasks. Neath and Suprenant (2003) sum up by showing, that in effect, short-term memory acts as a working memory system that facilitates the ability to process and manipulate information in parallel.

2.5 Limitations of the Prototype Model

Although short-term memory and working memory clearly share a close relationship, as both refer to transient memory, Gathercole and Pickering (2000) argue on both empirical and conceptual grounds that there are important distinctions to be made between them. Alloway, Gathercole and Pickering (2006) assert that working memory tasks are assumed to place heavy demands on the central executive system and tap into mental resources not relied on when performing more passive, short-term memory tasks. Working memory involves both the storage and processing of information, whilst short-term memory is specialised for the temporary storage of material within particular informational domains. This reconfiguration led Gathercole and Alloway (2004) to redefine their understanding of working memory to be the ability to hold and manipulate information in the mind for a short period of time. They view working memory as a flexible mental workspace in which information can be stored temporarily in the course of performing complex mental activities.

As a result, Gathercole and Pickering (2000) reconceptualised Baddeley’s working memory model and proposed a multi-component model comprising separate storage/recall (short-term memory) and processing (working memory) systems.

They applied their own terminology to Baddeley's (2000c) working memory model, using the term *short-term memory* to refer to Baddeley's passive storage components, namely the concepts of the phonological store and visual cache, whilst using the term *working memory* to refer to the active processing components or concepts of articulatory rehearsal and inner scribe.

2.6 Gathercole and Pickering's Working Memory Model (2000)

Gathercole and Pickering's (2000) model includes two separate systems of short-term memory and working memory. Short-term memory is domain-specific and comprises verbal and visuo-spatial components. It is utilised for the passive storage of verbal information within the phonological loop, and for the storage of visual and/or spatial information within the visuo-spatial sketchpad. Short-term memory is called into action when tasks require no processing, or when the preservation of sequential order information is necessary and involves situations where small amounts of information are held passively and then reproduced in sequential fashion. Short-term memory's capacity is measured by simple tasks, such as digit or word span tasks, that require the storage of information for a short-time period. In contrast, the working memory system is a domain-general composite of both verbal and visuo-spatial working memory. It is the processing resource which is involved in the concurrent preservation and processing of information. Verbal working memory refers to the temporary memory capacity of the central executive used for the storage and processing of verbal information. Alternatively, visuo-spatial working memory refers to the temporary memory capacity of the central executive used for the storage and processing of visual and/or spatial information. Working memory's capacity is measured by complex span tasks, such as dual tasks, that require the simultaneous short-term storage of information and active processing of additional and sometimes unrelated material. Alloway and Gathercole (2006) designed research to corroborate the above. Factor analysis confirmed their hypothesis that the actual processing components of working memory were supported by the central executive which served as a common resource pool, as compared to short-term storage aspects which depended on domain-specific, verbal or visuo-spatial resources.

2.7 Domain-General Versus Domain Specific Working Memory Models

Baddeley's (2000c) original model of working memory and Gathercole and Pickering's (2000) adapted and extended version of the original model are domain-general models in that the combined storage and processing aspects of working memory are located within the central executive. However, Just and Carpenter (1992) proposed a domain-specific working memory model based on the capacity theory of comprehension. These authors coined the term, *working memory for language* (WMFL) to refer to a set of processes and resources that specifically perform language comprehension. WMFL worked as a single unit that could flexibly deploy its resources to either storage or processing, depending on the nature of the task. Just and Carpenter (1992) suggested that the architecture of the WMFL system should reflect that the two functions of processing and storage drew on a common resource pool. They believed that there were conceptual and empirical grounds for including the dual role of WMFL within a single system. In this model, WMFL roughly corresponds with the central executive described in the domain-general models. This theory, however, implies a domain-specific model of working memory, where WMFL draws on a global set of resources, which support both lexical and syntactic storage and processing, as opposed to involvement of the phonological loop. Both types of models suggest capacity constraints. Baddeley's

(2000b) model proposed the existence of a capacity limit in the central executive, whereas Just and Carpenter (1992) suggested a trade-off between storage and processing. If the processing of material is more demanding, then there is less capacity in working memory for storage; conversely, if little of the capacity is needed for storage then much more is available for processing. Their model implies that individual differences in working memory reflect differences in capacity available for storage and the amount of processing involved in the task carried out. Studies have supported both the domain-general model (Baddeley, 1983; Gathercole & Baddeley, 1993; Gathercole & Adams, 1994) and the domain-specific model (Daneman & Carpenter, 1980; Just & Carpenter, 1992; Miyake, Carpenter & Just, 1995; Shah & Miyake, 1996). However, there is yet another body of research that challenges both models (Waters & Caplan, 1996; Neath, Suprenant & Le Compte, 1998; Fedorenko, Gibson & Rohde, 2006) and alternate models have been proposed.

2.8 Alternative Working Memory Models

Alternate approaches to working memory have been generated and offer diverse views. From a brief discussion of three of these approaches, it will be seen that these may not be as disparate as they appear. In a comparison of theoretical models of working memory, Miyake and Shah (1999, as cited in Barnard, Scott & May, 2001) outlined several common themes. Most noteworthy, was that long-term knowledge and executive control influenced working memory performance. In line with this thinking is the *long-term working memory model* (LT – WM) put forward by Ericson and Kintsch (1995, as cited in Wagner, 1996). This model proposes an additional component to the working memory system, namely the LT – WM system, whose role is the skilled and efficient retrieval of information from long-term memory that can be used to facilitate working memory performance. Vukovic and Siegel (2006) explain that an individual's experience and prior knowledge can increase working memory performance on a given task. This model avoids the idea of inherent differences in capacity to explain individual differences. These authors suggest that efficiency of storage and retrieval is a function of prior knowledge. In Baddeley's (2000b) model the episodic buffer appears to mimic the role of the LT - WM system.

A different understanding of the concepts of working memory and attention came from Cowan (1997) via an *embedded processes model*. This model contrasted with others in that working memory was composed exclusively of processes and not structural components. Furthermore, working memory referred only to information activated in long-term memory (Neath and Suprenant, 2003). The key to this model is the role played by attention. Cowan (2005) proposed that attention activated portions of long-term memory, at which point information was further activated through the focus of attention, in order that processing and manipulation could take place in working memory. Baddeley (2003) points out that theories of attention in working memory do not detract from his model but rather emphasize the role played by the central executive in working memory.

The *time-based, resource-sharing model*, more recently formulated provides a convincing argument for the role of attention in working memory. In this model the capacity constraints of working memory are explained in terms of attention. According to this theory, the time during which a task utilises attention, determines the cognitive load. This model tendered a solution to the problem of a processing and storage trade-off and contended that working memory relied on a common attentional supply. Switching or alternating attention between tasks is necessary but cannot take place efficiently at times because of cognitive load (Barrouillet, Bernardin, Portrat, Vergauwe & Camos, 2007). This theory of attention has contributed to our knowledge of central executive functioning by showing that it can be fractionated into a number of attentional processes: focussed attention and the ability to ignore interference in maintenance of information, versus the ability to focus attention, divide and switch attention in order to process and manipulate information in parallel.

This section can be summed up in the words of Baddeley (1982) who explains that models can be viewed as tools to help explain theories and processes. He believes that like maps in general, models offer a useful way to summarise what is known and like maps, models can be proven to be fundamentally wrong. However, he points out that more commonly what happens through research, is that "further exploration leads to further refinement, rather than simple disproof of previous beliefs" (Baddeley, 1982: 7).

This discussion has shown the evolution of the working memory construct and the present-day understanding of its structural components and their functions. Within the current study, the term *working memory* is used in the context of Gathercole and Pickering's current model, which in turn originated from Baddeley's model of short-term memory with its tripartite structure. The same term is used to refer to that component of memory which taps the combined storage and processing aspect of the central executive. The term, *short-term memory,* is reserved for that component of memory which relates to the passive, temporary storage of information and which is subsumed by working memory. *Working memory* is also the term used to describe the alliance of the temporary memory systems which play a crucial role in cognitive tasks such as reasoning, learning and understanding.

Findings from experimental, neuropsychological and developmental sources converge on the view that language comprehension processes draw upon both the phonological loop and central executive components. Vukovic and Siegel (2006) point out that the relationship between working memory and reading comprehension appears more complex, as it does not seem to be restricted to a working memory system for language. Gathercole and Baddeley arrive at this conclusion too and state that the relationship between the working memory system and reading comprehension is “far from straight forward” (Gathercole & Baddeley, 1993: 230).

Consideration of the complexities involved in the reading comprehension process adds to our understanding of why the relationship between working memory and reading comprehension presents an ambiguous picture. Herewith follows a discussion of literacy and reading to highlight the multi-faceted processes involved.

2.9 Literacy and Reading

Literacy in the 21st century demands that proficient readers do more than *read along the lines*. Reading *between* and *across the lines*, as well as *beyond the lines* enables a reader to infer, interpret and evaluate the world in which he lives. This century requires that readers move beyond the basic literacy requirements of decoding. Readers must progress beyond the literal meaning of texts to critical literacy, where interpretation, explanations, analysis and synthesis are required. Finally, a reader must achieve dynamic literacy status to compare, contrast and integrate ideas from multiple texts and to act on the content gained from the text by solving or raising problems (Westby, 2004).

Unlike oral language, basic literacy seldom develops without explicit instruction, even in cultures where written language is prominent and readily available. According to Harris and Coltheart (1986), decoding of scripts is achieved by dual routes for word recognition. They propose a *direct* or *lexical route* whereby a symbol is recognised visually, or an *indirect*, *non-lexical route* where letter-sound or grapheme-phoneme correspondence is exploited to convert letters to phonemes for pronunciation. The nature of the script influences how these processes are used. The whole-word route would be relied upon more heavily by readers of logographic scripts since printed words are compared to visual representations, called lexical entries, in an individual's mental lexicon. The phonics procedure, or indirect route is more likely to be used by readers of syllabic and alphabetic scripts. Despite this distinction, it is essential to note that readers of *all* languages employ both methods. Research into reading acquisition has shown that children use dual-route reading strategies (Bradley & Bryant, 1983; Harris & Coltheart, 1986; Stuart & Coltheart, 1988). Stage models of reading development such as those proposed by Seymour and MacGregor (1984), Frith (1985) and Harris and Coltheart (1986) show that reading develops in a series of stages in which words are read via either the lexical or non-lexical routes. Frith's model advances a theory of reading acquisition, where the reader progresses from a logographic strategy, where the child learns to associate a familiar word with the salient graphic features present in its printed form, to an alphabetic strategy, where the child exploits the correspondences between letters and their associated sounds as a way of guiding the reading of words not within their sight vocabulary. Finally, the reader progresses to an orthographic strategy which involves the pairing of words into multi-letter orthographic segments which map onto morphemes.

Despite the popular appeal of stage models of reading, much criticism has been levelled at them. As an alternative to strict sequential models of reading development, Seymour (1990) proposed a *dual foundations model* wherein the orthographic system is seen as a merger of a logographic lexicon (which links to semantics) and an alphabetic system (embodying knowledge of alphabetic correspondences and phonological awareness). According to this model, reading difficulties can be understood in terms of difficulties within either of these two basic sub-systems. Ehri (2005) viewed children's reading skills as an emergent property of the interaction between their phonological representations and the print they encounter.

In recent years, connectionist models of reading have become influential. One such model, formulated by Plaut, McClelland, Seidenberg and Patterson in 1996 is referred to as the *triangle model*. Snowling and Hulme (1999) assert that in this model a pathway between orthography and phonology via semantics is implemented and the facilitative role of context is used as a reading strategy. Accordingly, reading development is regarded as continuous, yet highly dependent on phonological and semantic skills and the opportunities for learning that are presented to the child. Despite the more recent inclusion of a semantic component in reading models, all of the models outlined above regard the need to abstract the alphabetic relationships between letters and sounds as critical to reading acquisition. This process is known as decoding.

2.10 Decoding and Phonological Awareness

Phonological awareness plays a vital role in reading. Research in the last decade has increased our understanding of the critical role that phonological awareness plays in the development of reading fluency. Phonological awareness can be considered to be a comprehensive term for a variety of skills which develop on a continuum, and according to Cockcroft (2002) may be defined as an understanding of the structural characteristics of a language, or the awareness of the sound structure of words and the ability to manipulate these sounds. Phonological awareness is comprised of a number of specific skills which develop hierarchically over time (Adams, 1990). The awareness of larger units, such as syllables is usually present by age three (Goswami, 2002) and the higher levels of phonological awareness are attained by only those children who have received some formal reading instruction. Fowler (1991) proposes that, throughout the preschool years, the child's phonological awareness undergoes constant reorganisation and that the process is only complete by approximately seven years of age. This progression can be considered on a continuum which ranges from 'shallow' to 'deep' sensitivity or from an implicit form of analysis to an explicit form (Stanovich,1992, 1993). The general sequence of phonological awareness development was found to be universal across languages (Anthony & Francis, 2005) and is proving to be important in early reading across all languages (Westby, 2004). Westby points out that in English, which has a deep orthography, the level of reading ability is strongly associated with phoneme awareness and decoding abilities. She explains that in deep orthographies, expertise in decoding takes many years to develop and sets a limit on reading comprehension until sufficient skill in decoding is achieved. She supports this hypothesis by citing studies on reading achievement in children reading languages with highly transparent orthographies such as Turkish, Italian and French where phoneme awareness has been linked to reading achievement only in first grade. In contrast, she reports on a study which showed that parity between listening comprehension and reading comprehension was only achieved by American children by the fifth grade. The rate of phonemic development appears to depend on the nature of the orthography used. In line with this thinking, Stanovich (1993) comments that beginning readers in a transparent and regular orthography appear to have more resources available for the comprehension requirements of reading.

2.11 Decoding and Rapid Automatic Naming (RAN)

Phonological awareness is not the only cognitive skill associated with successful decoding. RAN has been shown to contribute to early reading in a different manner from that of phonological awareness. Wolf and O'Brien (2004) use evidence from neuroscience on word-retrieval or naming speed which suggest that fast, automatic, retrieval processes assist decoding. They go on to say that these rate-related retrieval processes are independent of phonology and cannot be explained by phonological deficits. RAN tasks tend to be related to orthographic knowledge – the reading of words that are not phonetically regular. In contrast, phonological awareness correlates with the reading of phonetically regular words. Westby (2004) adds that children who learn to read in opaque orthographies are more dependent on good RAN skills to process large orthographic units.

2.12 Reading Failure

The conventional view of reading failure is undimensional and assumes that the source lies in the child's inability to apply the grapheme-phoneme rules, or phonological processes. In this view a phonological processing deficit sets off a chain reaction: poor phoneme awareness impedes the ability to learn grapheme-phoneme correspondence rules, which then results in decoding difficulties and comprehension deficits are the by-product of the anteceding difficulties. Wolf and Bowers (as cited in Wolf & O'Brien, 2004) underscore the need to go beyond an emphasis too exclusively placed on phonological deficits. It is their view that attentional, perceptual, cognitive and linguistic processes are necessary for fluent, comprehending reading. They contend that reading failure occurs as a result of "the painstaking bolting on and bolting together of *all* of these processes" (Wolf & O'Brien, 2004: 8). To underscore the need to go beyond an emphasis too exclusively placed on phonological deficits, they coined the term *double-deficits*. This can be viewed as an effort to understand the multiple sources of reading failure. They propose at least 3 major subtypes of dyslexic readers including : (a) poor readers who have phonological deficits, without problems in naming speed; (b) readers who have adequate phonological and word-attack skills, but early naming speed deficits and later reading fluency and comprehension deficits; and (c) children with both areas of weakness or 'double-deficits'. They claim that children with both core deficits represents the most severely impaired subtype. Westby (2004) concurs with the conclusion that children who exhibit difficulty with both phonological awareness and RAN will exhibit more severe reading difficulties than those with only a single deficit in either phonological awareness or RAN.

In the past it was assumed that once words had been successfully decoded, comprehension was the obvious outcome. Although decoding is essential for basic literacy, it is not sufficient for the development of comprehension. Successful decoding does not ensure comprehension as shown by studies on children who are hyperlexic. Westby (2004) refers to the work of Rasool, a researcher who described how many Muslims, whose native language is not Arabic, learnt to be fluent readers of the Quran, but have no comprehension of what they are reading. Vukovic and Siegel (2006) have also studied those children with poor comprehension despite adequate word reading skills.

In the field of learning disability and dyslexia, two types of reading comprehension difficulties have been identified: (1) comprehension difficulties with concurrent word reading deficits; and (2) comprehension difficulties in the presence of average word reading skills. The former type of difficulty is conceptualised as a bottom-up failure such that deficits in lower-level skills masquerade as comprehension deficits (Perfetti, 1985, Torgesen, 2000). Children with deficits in both decoding and comprehension have sometimes been referred to as ‘garden variety’ poor readers (Aaron & Kotva, 1999). The second type of comprehension difficulty is thought to arise from deficits in higher-order cognitive processes, such as working memory. Vukovic and Siegel (2006) expand that this group is characterised on the basis of successful decoding yet poor comprehension. The literature refers to this group as ‘poor comprehenders’ or historically as ‘word callers’ (Aaron & Kotva, 1999). Lyon (1995) estimated that word reading difficulties occur in 5 – 20% of the school-going population whilst poor comprehenders represent approximately 10 – 15% of school-aged children (Vukovic & Siegel, 2006).

These figures show that a significant percentage of all school-aged readers experience some difficulty comprehending what they have read. This serves to underscore how complex the reading comprehension process is, as it requires the decoding and processing of print, whilst simultaneously constructing the meaning of what is being read.

2.13 Comprehension Processes

Vukovic and Siegel (2006) stress that to gain meaning from text, readers must not only read and understand the printed words on the page, but they must be able to read with accuracy and fluency, concurrently activating background information, making inferences, storing information in memory and engaging in self-monitoring strategies. In addition to these cognitive processes, they stress that factors such as text complexity and reader motivation can influence reading comprehension.

Westby (2004) shares this view of comprehension. As readers master decoding, other higher-order skills become more important for explaining differences among readers. Comprehension requires that readers integrate *microstructure* elements of language knowledge with *macrostructure* elements involving text organisation, in order that mental models of the text be generated.

Microstructure knowledge includes morphological awareness as studies have linked morphological awareness and reading proficiency. Children who possess good morphological knowledge can analyse unfamiliar words into familiar meaningful units, and then derive word meaning. Syntactic awareness is also influential in the comprehension of texts as proficient readers detect grammatical errors and use grammatical information to read with fluency and expression. Proficient readers must understand cohesive linguistic devices that are part of the syntactic structure of texts. Cohesive devices maintain text coherence by activating antecedents in a text.

Critical and dynamic comprehension require that the reader goes beyond reading the words but reads between, across and beyond the lines. To engage in this form of literacy, readers must develop a more abstract language, which at the highest level, enables them to think about what may, might, could or would happen; explain why and how; hypothesise; evaluate outcomes and arrive at judgements that go beyond the text (Vukovic & Siegel, 2006). In order to do this, the reader must build a mental model or representation of what is described in a text (Oakhill & Yuill, 1991). In the *text based model,* readers must understand the *text microstructure* (words and syntax that form sentence-by-sentence information) and the *text macrostructure* (an ordered set of propositions representing the broad theme or gist derived from the microstructure) to capture the meaning relations among the elements within a sentence and across the sentences in a text (Westby, 2004). Depending on the extent of explicitness, a *situation or scenario-mapping model* is formed. Sanford and Garrod (1998) explain that if a text is explicit, then the full referential meaning of a text is mapped onto a situation model. However, if the text is not explicit enough, then the reader must refer to long-term memory to supplement the information supplied by the text. Knowledge and experiences stored in long-term memory are accessed to complete the situation model. The textbase provides text-derived propositions, whilst long-term memory contributes its own set of propositions based on images and actions that reflect the reader's world knowledge, knowledge of inter-personal relations and domain-specific knowledge. The formula for a complete situation mental model may therefore be represented as: text-based propositions + long-term memory based propositions = situation model. By its nature, the situation model is inferential and affords the reader a coherent account of the text as it enables a reader to connect incoming information with previous text-based information, with prior knowledge or both. As such, situational models are highly dependent on the reader's cultural values, beliefs and past experiences (Westby, 2004).

Through the formulation of a situation model, the communication of thoughts and emotions is achieved between the writer and the reader. Human, Bouwer and Ribbens, (2001) postulate that strategic reading enables readers purposefully to maintain a grasp on the ideas or gist of a particular text whilst adapting flexibly to different genres of printed text, or read differently for different purposes, whilst simultaneously activating their knowledge store (Human, et al 2001). Manzo and Manzo (1995) indicate that 'authentic' readers read *reconstructively* (show understanding of the author's intended meaning), and *constructively* (the reader personalises and builds on the author's message) to achieve *transformation*, i.e. being changed by what they read. As such, they assign a host of high-order attributes to constructive, transformational comprehension, one of which is memory, to which they assign a critical role.

2.14 Identification of Reading Comprehension Deficits

Reading comprehension and listening comprehension skills are thought to be mediated at the deeper level by the same cognitive mechanisms, even though there are some differences at the surface level that are attributable to the modalities (Aaron & Kotva, 1999). When investigating the relationship between reading and listening comprehension, Royer et al (1986) found that listening comprehension places an upper bound on reading comprehension. Aaron and Kotva (1999) indicate that additional evidence of a relationship between listening and reading comprehension is provided by studies which have shown the correlation between the two forms is high, usually in the vicinity of .80. They conclude that the levels of listening comprehension and reading comprehension of normally achieving children can therefore be expected to be very similar. They suggest that children who score in the average or higher range on tests of listening comprehension, but fail to achieve in the same range on tests of reading comprehension, are usually hampered by poor decoding skills. Based on the discrepancy between their listening comprehension and reading comprehension scores and their performance on decoding tasks, a child's reading difficulty can be attributed to poor decoding, poor comprehension or a combination of the two skills.

The reading component model of reading disabilities, as advocated by Aaron and Kotva (1999) is considered to be more useful in identifying comprehension deficits than the traditional IQ-achievement discrepancy formula, where children with average or higher intellectual ability but have difficulty learning to read, are described as having a learning disability. Turner (1997) refers to this 'unexpected failing' as the hallmark of the phenomenon for which the term 'dyslexia' was later applied. Historically, criticism has been levelled at the use of the IQ or general intelligence statistic. Aaron and Kotva (1999) draw attention to a study conducted as early as 1984 by Stanovich and colleagues where it was shown that the correlation between IQ and reading achievement seldom exceeds .50 showing that IQ is not a potent predictor of reading potential. Another conceptual problem of the IQ achievement-discrepancy formula arises from the likelihood that IQ does not influence reading ability unidirectionally, but that the relationship between IQ and reading is reciprocal: not only can the level of IQ influence the reading score, but reading experience can affect IQ. Stanovich (1986) coined the phenomenon of the 'Matthew Effect' whereby good readers build large vocabularies and thereby show gains in their verbal IQ scores while poor readers do not increase their vocabulary knowledge and show noticeable decline in their verbal IQ. Conversely, it has also been shown that poor readers who show improvement in their reading achievement also show a corresponding gain in their verbal IQ scores. Furthermore, Siegel (1998) found that some children with normal reading development had low IQ's.

These observations undermine the adequacy of the IQ score as a predictor of reading achievement. Siegel (1998) argued that a more valuable approach to studying the nature of reading disability and comprehension deficits is to analyse the component skills involved in developmental impairments of reading, irrespective of intelligence level. Gathercole and Baddeley (1993) point out that this controversy between the component cognitive skill tradition and IQ-discrepancy method has at times been heated as the advocates of the two positions are firmly rooted in distinct traditions of reading research.

As a result of these two positions, criteria for identification of a reading disability and a reading comprehension deficit have been two-fold: an underachievement or IQ-discrepancy criterion has been applied, as well as a deficit criterion of one or more component skills consistent with the characteristics of reading disability.

During the course of the last decade researchers have begun investigating the use of fluid measures to assess a child's capacity to perform cognitive operations akin to those involved in complex learning situations which lead to the acquisition of mathematics and literacy skills. Bialystok, Craik, Klein and Viswanathan (2004) indicated that measures of fluid intelligence related to executive control processes whereas measures of crystallised intelligence related to well-learned knowledge and habitual procedures. Campbell, Dollaghan, Needlemar and Janoscky (1997) pointed out that any assessment tool that taps into a child's existing knowledge is at risk of identifying a difference as opposed to a disorder. They observed that fluid measures of intelligence have the advantage of reduced bias, in that the tasks and materials are equally unfamiliar to all test-takers and results are less influenced by environmental and demographic factors.

Working memory measures have been shown to correlate positively with measures of fluid intelligence (Conway, Kane & Engle, 2003; Engle, Tuholski, Laughlin & Conway, 1999b). In a recent study by Alloway (2009) working memory was found to predict academic performance in school-age children more strongly than IQ, reinforcing the value of fluid measures of intelligence. Fluid measures may present a 'third factor' which educationalists and psychologists may need to consider in their assessment of reading disability and when determining the presence/absence of a comprehension deficit. Turner (1997) alluded to the possible existence of a 'third factor' that emanated from traditional, crystallised psychometric measures of intelligence. He suggested that working memory may be at "the heart of the matter" (Turner, 1997: 60). Alloway's (2009) finding that working memory, not IQ, predicts subsequent learning in children with learning difficulties, confronts educationalists and psychologists with a new possibility and adds another dimension to the IQ-discrepancy/component deficit criterion approach to reading disability and comprehension deficits.

2.15 Working Memory and Reading Disability

In recent years, the notion that working memory is involved in the comprehension of spoken and written language has received widespread attention. Each word or sentence that has been heard or read has to be stored, as our comprehension of the complex syntactic and semantic information conveyed in both spoken language and text appears to lag behind the sensory input, so that "we have the experience of labouring with interpretation of the meaning of a sentence, sometime after either the speaker has finished speaking or the text has been read" (Gathercole & Baddeley, 1993: 201).

In the field of learning disabilities (LD), the study of individual differences in working memory has received increased attention as a potential explanation for the individual differences in academic performance. Studies that have investigated the relationship between children's working memory capacity and their achievements in areas such as literacy, language and mathematics have shown that those children who failed to reach expected levels of attainment for their age, scored very poorly on working memory measures (Gathercole & Pickering, 2000; Gathercole, Pickering, Stegman & Knight, 2004; Gathercole, Brown & Pickering, 2003, as cited in Alloway & Gathercole, 2006). It is therefore appropriate to see working memory as a *bottle-neck* for learning, a descriptive term used by Gathercole and Alloway (2006). It is not surprising to deduce that working memory will have a significant impact on reading and Swanson (2006: 83) concludes that "working memory deficits are fundamental problems of children with reading disability". Swanson adds the caveat that although working memory is not the only skill that contributes to reading disability, it plays a significant role in accounting for individual differences.

After reviewing studies in the area of working memory and reading disability, it has been suggested that children with average intelligence but who have a reading disability, suffer from deficits in the phonological system. These deficits manifest themselves in a domain-specific constraint (i.e. the inefficient accessing of phonological representations). Swanson (2000) argues that although there is abundant evidence of phonological loop involvement in children with reading disability, when high demands on processing are required, children with reading disability have difficulty controlling attentional processes to maintain task relevant information in the face of distraction and interference. Swanson points out that this impaired capability for controlled processing, manifests itself across verbal and visuo-spatial working memory tasks, reflecting central executive involvement and a domain-general constraint. The proviso is given that domain-specific codes can be reflected, based on the nature of the task and processing demand.

Vukovic and Siegel (2006) in their review of a substantial number of studies, show that they support the notion that children with reading disability experience deficits in phonological processing. This difficulty in forming and accessing phonological representations impairs their ability to retrieve verbal information from short-term memory (Stanovich & Siegel, 1994).

2.16 Working Memory and Reading Comprehension

Since this study is concerned with the role that working memory plays in reading comprehension, attention will now be given to this specific relationship. Westby (2004), when explaining the role of working memory, explains that it is involved in the executive control of all components of the reading process. She states that it is responsible for processing and storing incoming information, whilst simultaneously retrieving and integrating information from long-term memory. She states that an efficient working memory is essential for formulating situation mental models. To build a text-based model, readers must capture the micro and macro structures of the text. If the text is explicit, then a situation model is mapped, however, if the text is not explicit, then the reader must access additional knowledge and information stored in long-term memory. The complete model is then composed of text-derived propositions and propositions contributed from long-term memory. This enables the reader to gain the full meaning of the text, which is after all the end goal of reading.

Westby (2004), through this procedural account of the formulation of a situation model, implicates all aspects of the Baddeley and Hitch model of working memory in reading comprehension. Working memory is taxed when any of the elements of the reading process are not automatic. She points out that if inordinate amounts of attention are required, for example, to decode, analyse syntactic structure, or identify the discourse structure, then working memory will be taxed, and in turn comprehension will be compromised.

Research to provide evidence for these claims has been limited, with greater emphasis being placed in the learning disabilities literature on the study of individual differences in working memory as a potential explanation for individual differences in academic performance. Less is known about how working memory is involved in reading comprehension (Vukovic & Siegel, 2006). In reading comprehension, the reader must simultaneously extract and decode words, interpret the meaning of individual words, integrate the meaning of the words already read and use those to make inferences about the text, self monitor meanings already allocated and correct those meanings that are incongruent with the text. Short-term memory and working memory are needed for comprehension and working memory is essential for storing both the intermediate computations in the process, as well as the final product (Baddeley, Wilson & Watts, 1995; Just & Carpenter, 1992; Vukovic & Siegel 2006).

When reviewing the limited evidence that working memory is uniquely involved in reading comprehension, evidence in support of the importance of short-term memory and working memory in comprehension, has arisen predominantly from three types of studies : (1) Studies that examine the relationship between working memory, reading comprehension, and other variables that have a well-established relationship with reading comprehension; (2) studies that examine the influence of various working memory measures on comprehension, and (3) studies that examine whether poor comprehenders can be characterised by working memory deficits.

In order to demonstrate a unique relationship between working memory and reading comprehension, working memory must be shown to correlate with reading comprehension, after other variables that have a well-established relationship with reading comprehension have been controlled. Findings from studies using children across the spectrum of reading ability show that working memory is an important factor in explaining a reader's comprehension skills. A study conducted by Cain, Oakhill and Bryant (2000) on 7 to 8 years-olds is an example of such a study. They found that a task with high verbal working memory demands accounted for 11.4% of the variance in reading comprehension, when factors such as age, intelligence scores, vocabulary and word recognition were controlled. In a later longitudinal study, Cain, Oakhill and Bryant (2004) found that a composite working memory variable explained a significant amount of the variance in reading comprehension. This composite verbal and numerical working memory variable accounted for 69% of the variance in 7 year-olds, 55% of the variance in 8 year-olds and 52% of the variance in 10 year-olds, over and above other variables such as vocabulary, verbal ability and word recognition. Vukovic and Siegel (2006) in their longitudinal study, reproduced these findings but their study extended the previous findings by demonstrating that working memory plays an important role in reading comprehension even after controlling for phonological awareness and rapid naming. Furthermore, their findings suggested that verbal working memory is an important variable in explaining reading comprehension in children aged 7 to 11 years. Seigneuric, Ehrlich, Oakhill & Yuill (2000), as well as Swanson and Howell (2001) had found a significant correlation between a composite linguistic measure (comprising verbal and numerical working memory) and reading comprehension. Cain, Oakhill and Bryant (2004) replicated these findings and from this, the conclusion can be drawn, that both verbal and numerical working memory contributed to a reader's comprehension. However, it has been shown that numerical working memory does not make a unique contribution to reading comprehension. Seigneuric et al (2000) found that the relationship between reading comprehension and numerical memory was not particularly robust and they speculated that working memory processes involved in reading comprehension are specialised for language processing.

Swanson and Siegel (2001) posited that reading comprehension was more strongly correlated with verbal working memory than it was to visuo-spatial working memory but they cautioned that studies investigating the relationship between reading comprehension and visuo-spatial working memory were limited and the findings mixed. Vukovic and Siegel (2006) point out that research indicates that reading comprehension is most strongly related to verbal working memory measures and that a reliable relationship between visuo-spatial working memory and reading comprehension has not been established. However, shared variance between linguistic and visuo-spatial working memory has been found to be very predictive of comprehension leading to the hypothesis that language skills alone do not fully account for the relationship between reading comprehension and working memory.

In summary of evidence from the first source, these studies confirm that a relationship between working memory and reading comprehension exists, but the nature of this relationship is not clear. Investigations to clarify whether the relationship between reading comprehension and working memory reflects a language-based system or a more general system have yielded inconclusive results. Researchers have employed various working memory measures viz. linguistic measures which include verbal working memory and numerical working memory measures, and to a lesser extent, non-linguistic visuo-spatial working memory measures. Studies that find a relationship between numerical working memory and reading comprehension or visuo-spatial tasks and reading comprehension, lend some credence to the assumption that the relationship is not reflective of a working memory system specialised for language, but may indicate a more general working memory system.

Studies that examine poor comprehenders specifically – those readers who experience specific comprehension difficulties in the absence of word reading difficulties, yield insights into the relationship between working memory and reading comprehension. It has been contended that poor comprehenders have deficits in higher-order cognitive processes, as opposed to lower-level processes. In Cain, Oakhill and Bryant's (2000) study their sample group of 7 to 8 year-old poor comprehenders did not appear to have deficits in lower-level processes such as phonological awareness, rather deficits were exposed when heavy demands were placed on their working memory system. Unfortunately this study did not include a poor reader group so it is not known how the deficits of poor readers compared with those of poor comprehenders. Vukovic and Siegel (2006) refer to an earlier study by Siegel and Ryan in 1989 which showed that by 9 to 14 years of age, poor comprehenders do not manifest with lower-order deficits (although some difficulties with these might have been experienced at younger ages). In their own more recent study, they found that poor comprehenders performed similarly to typical reading achievers on working memory tasks. Vukovic and Siegel (2006) used these results to support evidence that poor comprehenders performed more similarly to typical readers than to poor readers across working memory tasks. However, the exception in their study was for verbal working memory where poor comprehenders performed significantly lower than typical achievers, but significantly higher than poor readers. They concluded that by fifth and sixth grades poor comprehenders are characterised by a higher-order working memory deficit specific to language, as opposed to a more general working system. Nation, Adams, Bowyer-Crane and Snowling (1999) had in their earlier study found that poor comprehenders tended to be characterised by working memory deficits specific to the language system. Vukovic and Siegel (2005, as cited in Vukovic & Siegel, 2006) indicated that these findings were validated by their later study's findings which suggested that working memory (in particular verbal working memory) is a potential candidate for explaining comprehension failure in poor comprehenders, as verbal working memory was found to contribute unique variance in reading comprehension independent of lower-level processes. An earlier study by Oakhill and Yuill (1991) investigated poor comprehenders and found that these children had low working memory spans and they suggested that these children had consistent deficits in their central executive capacity. In their aforementioned study, Vukovic and Siegel (2006) corroborated these findings and they too hypothesised that individuals differed in the efficiency with which their central executive processed reading related material. It was suggested that poor comprehenders used a disproportionate amount of their working memory resources for reading, leaving little for comprehension.

When overviewing the findings in the literature concerning poor comprehenders, Vukovic and Siegel (2006) sum up by saying that the evidence points to the working memory deficits of poor comprehenders being restricted to the verbal domain and this supports the notion that a language-specific working memory system, as opposed to a general working memory system, is involved. In addition to deficits in higher-order processes, evidence shows that poor comprehenders show deficits in some lower-level processes, especially at younger ages, although these deficits do not seem to persist over time. More research is needed to clarify the processes that characterise poor comprehenders, as the question is unresolved as to whether verbal working memory deficits can cause poor comprehension or whether verbal working memory deficits are a consequence of an underlying language deficit in poor comprehenders. Regardless of this debate it appears that weaknesses in the language-based working memory system impacts negatively on comprehension.

When examining studies considering the third source of evidence, a study by Swanson, Howard and Sáez is referred to. In one of the more recent neuropsychological studies, Swanson, Howard and Sáez (2006) attempted to establish if different working memory components underlie three different subgroups of less-skilled readers. The performance of children with reading disabilities (R.D.) with deficits in both word recognition and comprehension, children with comprehension deficits only (poor comprehenders) and children with low verbal IQ, word recognition and comprehension deficits (termed poor readers), was compared to that of skilled readers on working memory, short-term memory, processing speed, executive and phonological processing measures.

Ability group comparisons revealed three findings :

- skilled readers outperformed all less skilled readers on measures of working memory, updating and processing speed;

- poor comprehenders only out-performed children with R.D. on measures assessing working memory, short-term memory, phonological processing and processing speed;

- children with R.D. outperformed poor readers on working memory and phonological processing measures.

A hierarchical regression analysis revealed two more significant findings that: (a) subgroup differences on working memory tasks among less skilled readers was indicated by a storage system not specific to phonological skills; and (b) short-term memory and updating contributed significant variance to working memory beyond what was contributed by reading group classification. The latter finding suggested that some differences had emerged between skilled and less skilled readers in storage and executive processing that were not specific to reading – an interpretation consistent with the general capacity model, in that skilled readers are presumed to have greater total working memory capacity than do poor readers. Furthermore, these results support the notion that different components of working memory underlie variations in reading performance. From their sample, factors that appeared to contribute to comprehension-only deficits relative to skilled readers, emerged only at the executive level, lending support to the assumption that comprehension and recognition deficits reflect deficits from separate working memory systems.

The study of Swanson, Howard and Sáez and its results have been outlined in some detail as the nature of the study and its findings are relevant in the context of the present study. Swanson, Howard and Sáez (2006) assessed subgroups of less skilled readers and predicted from their results that different types of reading problems may manifest with different working memory profiles: children fluent in word recognition but deficient in comprehension may exhibit deficits in the executive system, whilst children with reading disability suffer deficits in storage compared to poor comprehenders. They allude to the possibility of determining other profiles through future research. They too, along with other researchers cited in this review, advocate future research to disentangle the alternative interpretations and explanations of the complex relationship between working memory and reading, of which comprehension forms the most vital ingredient. Lundberg (1999: 27) sums up by saying that the full complexity of reading and its difficulties can only be fully understood with empirical work continuing with "sharper test tools and improved control tasks in the search for fine cuts behind hidden seams".

2.17 Implications of the Relationship Between Working Memory and Reading Comprehension

Current research results show that reading comprehension deficits are resistant to remediation, hence it is of great importance to explore other treatment possibilities. Aaron and Kotva (1999) refer to the work of Kavale, who examined the findings of longitudinal studies that dealt with reading disabilities and concluded that the problems of reading disabled children are persistent, chronic and pervasive, and that even under the best circumstances, reading disabled children do not usually close the gap in their reading ability, and may in fact become worse over time. A frequently expressed concern about remedial teaching strategies is that in spite of improvement in decoding skills, poor readers continue to show little improvement in comprehension (Aaron & Kotva, 1999).

When addressing reading disabled learners, educators or clinicians endorse one of three approaches. Those who adopt a *bottom-up* approach expect learners to decode letters and words before they can obtain meaning from print. Much attention is therefore devoted by educators to the development of phonic awareness and establishing a sight word or high frequency word base. Direct instruction and basal readers feature prominently together with continuous assessment and follow-up 'reteaching'. Meaningfully processing the full content is regarded as secondary to word decoding and word recognition, thus comprehension is left somewhat to chance (Merchant, 1999; Reid, 1998; Shanker and Ekwell, 1998).

Proponents of the *top-down approach* endorse the premise that reading, which is primarily a process of meaning-making, cannot occur outside of the reader's background knowledge (Pike, Compain & Mumper, 1997). It follows that educators who subscribe to this approach regard the learner's frame of knowledge as key to engagement with the text and they strongly encourage the development of a personal response to text content. Immersion in a literate environment is preferred to standard materials and less formal or direct instruction takes place, with educators relying on incidental learning of the skills of decoding and word recognition. Continuous assessment takes the form of discussion with reference to the text and reteaching emphasises checking the text for facts and developing inferential skills and arguments.

More recently, *interactive* models have arisen to achieve synthesis and balance between bottom-up and top-down approaches to reading education. An example of such a model, is the *reconstructive/constructive model* proposed by Manzo and Manzo (1995) which advocates teaching both word-attack skills and higher-order thinking skills to engage in constructive reflection that leads the reader beyond the author's intended message. Pike et al (1997) indicate that the learner's authentic, rich communication with the text is encouraged, whilst decoding and word recognition are not neglected. Advocates of interactive models emphasise the reader's use of personal strategies. Singleton (2002) points out these strategies are often found to be unique to the individual as they derive from assorted cognitive strengths with regards to the reader's processing of meaning and print. This approach takes into account that learners can encounter an extensive range of difficulties in any phase or aspect of reading development and that these difficulties can stem from intrinsic or extrinsic barriers to learning to read, or from a combination of both. Consideration is given to numerous factors which may impact negatively on the reading process.

The 'simple view of reading' as proposed by Gough and Tunmer (1986) that reading achievement (R) = decoding (D) x linguistic comprehension (L) does not take into account all components of the reading process. Working memory is one of these components and as such will contribute to the reading process. Rourke (1985) contended that the 'treatment' for reading disabled children has traditionally been univocal, in that once a child was identified with a reading disability he/she was most often placed in a therapeutic/remedial education programme that was designed to offer all children in it, the same type and sequence of remediation procedures. Johnson and Myklebust in the nineteen sixties already resisted this trend and maintained steadfastly that there are differentiable subtypes of reading disabled learners, whose particular patterns of abilities and deficits demand vastly different forms of intervention styles and strategies (Johnson & Myklebust, 1967). Traditional approaches to reading intervention do not include working memory skills in their bottom-up or top-down armoury of methods. Interactivists regard working memory as an important cognitive factor to consider in the reading process but Alloway (2006a) asserts that research on working memory intervention strategies is only emerging. Currently there are three strands to management and intervention with children with working memory deficits: developing phonological skills to support phonological loop functioning; developing strategies to support recall; and adapting the way in which material to be learnt or remembered is presented (Vance, 2008).

As the relationship between working memory and reading comprehension is ambiguous at the present time, facilitating reading comprehension by addressing working memory through one or all three strands has not been investigated.

2.18 Rationale

As working memory is a fluid intelligence measure that is processing-dependent, rather than relying heavily on vocabulary knowledge (which is the case in most tests of intellectual ability), it offers educationalists and psychologists alike a promising alternative or 'third option' to measures of crystallised intelligence. Gathercole, Pickering, Knight and Stegmann (2004) noted that one way to reduce the bias between prior knowledge and the basic cognitive capacity to learn, may be to use fluid assessments of cognitive processing knowledge, in addition to tests of crystallised knowledge. In a multilingual country, like South Africa, working memory measures may yet be found to be measures that help to distinguish 'difference' from 'disorder' in a learner population which is heterogeneously monolingual, bilingual, multilingual, subject to classrooms of variable size, has a generally high learner : teacher ratio, are schooled in different geographical contexts from rural to urban; have different literacy exposure at home; come from different cultures and ethnic groups; and have varied socio-economic backgrounds. A measure that more reliably denotes 'disorder' would see that valuable resources are better allocated and intervention commences earlier with those learners who have been more correctly diagnosed. This study may yield results which contribute to a growing body of data on fluid measures. This would be of value to those concerned with literacy in South Africa and in the global community where the quest for less-biased and culture-neutral tools must persist.

Working memory measures, such as the AWMA (Alloway, Gathercole & Pickering, 2004) may yet be proven to offer a less biased option where test-takers with different linguistic, cultural, ethnic and socio-economic backgrounds are not unduly prejudiced.

Lyon and Krasnegor (1996) claim that studies of attention, memory and executive function continue to provide greater understanding of the learning process, and the nature of specific cognitive deficits. Fedorenko, Gibson and Rohde (2006: 541) state that “a major question in cognitive science concerns the functional organisation of the working memory system”. Investigating the relationship between working memory and reading comprehension will lead to an improved understanding of the nature of working memory and will reveal how working memory contributes to reading comprehension failure and if there is a pattern of working memory deficits or ‘signature’ working memory profiles that distinguish different reading comprehension subgroups. This in turn will assist in differential diagnosis of reading comprehension disorders, but more importantly, it will guide the adoption of more focussed, empirically orientated remediation procedures. This point is highlighted by Snowling and Hulme (1999: 54) who indicate that “deficits in different sub-skills place children at risk of different forms of reading failure, suggestive of the need to provide training which is judiciously titrated”. When consideration is given to the fact that a significant percentage of school-going learners experience reading comprehension difficulties, and that these are notoriously difficult to treat, then it is incumbent on educators to consider that “each child will present with a reading profile born of the interaction between the skills they bring to the task of learning to read, and the ways in which they are taught (and teach themselves) to read” (Snowling & Hulme, 1999: 55). Ascertaining which components of working memory contribute to reading comprehension failure in different sub-groups, may champion the inclusion of specific working memory strategies in programmes for children with reading comprehension deficits. By comparing relationships between reading comprehension and working memory performance, it will be determined whether *particular* working memory components are compromised and this knowledge will provide more impetus for the inclusion of specific working memory intervention measures to be instituted with poor comprehenders. Alloway (2006) asserts that investigations of this nature will provide a background to emerging research on working memory strategies. Educators and clinicians can then support their curriculum or intervention programme with more evidence-based literacy instruction. Currently there are three strands to management and intervention for children with working memory deficits (Vance, 2008). Results from this study may lead to a particular strand being considered, depending on where deficits are identified in the working memory model. Phonological awareness training and verbal rehearsal promotes the phonological loop sub-system, whereas visualisation or use of imagery improves the capacity of the visuo-spatial sketchpad. Reducing the processing load is a way of targeting central executive functioning. By examining the specific role played by the episodic buffer, a fourth strand (as proposed by the writer), may be indicated. This will promote long-term memory access and buffer zone integration, by accessing prior knowledge about the topic to be read and promoting links with this information.

When underscoring the role of working memory in reading comprehension, findings across the spectrum of reading ability, demonstrate that working memory is an important factor in explaining reading comprehension ability. It is the intention of this study to add clarity to the debate on whether reading comprehension difficulties relate to verbal memory deficits or whether other components of working memory are implicated. Evidence found should support a domain-specific and/or general working memory system in reading comprehension and this in turn should provide more insight into the nature and functional organisation of the working memory system. Vukovic and Siegel (2006) point out that research into the role of working memory in children's comprehension abilities has been limited and that "more studies with poor comprehenders are needed to understand how working memory deficits contribute to reading comprehension failure" (Vukovic & Siegel, 2006: 89).

A criticism of research into working memory performance tendered by Henry (2001) is that conflicting pictures have resulted because studies have used a wide range of working memory measures. This study will employ the Automated Working Memory Assessment (AWMA) Battery (Alloway, Gathercole & Pickering 2004) as it assesses how information is maintained and processed over the short-term by the interplay of a phonological loop, a visuo-spatial sketchpad, a central executive and a buffer zone. In this way the working memory performance of children with differing levels of reading comprehension abilities will be assessed. Henry (2001) states that an assessment tool which taps into each component of working memory affords a comprehensive design which is crucial when investigating the relationship between the extent of a reading comprehension deficit and working memory performance. The AWMA differs from earlier assessment tools for use with young children, such as the Working Memory Test Battery for children (WMTB-C) (Pickering & Gathercole, 2001) as it includes subtests designed specifically to assess visuo-spatial memory as opposed to working memory tasks which were exclusively verbal in nature. The AWMA generates results on each domain (verbal and visual) and supplies domain-specific information as each domain is independently capable of manipulating and keeping information active (Alloway, Gathercole & Pickering, 2006). In addition, the centralised component or central executive's controlling function is also measured. The AWMA test materials were designed to be equally unfamiliar to all participants in that no child can benefit from previously acquired knowledge. The AWMA will provide results on each aspect of

Baddeley's multi-component model as well as the reconceptualised separate memory/recall (short-term memory) and processing (working memory) system and as the test is relatively free of bias, working memory findings from this research can be applied both to the South African and the international context.

Furthermore, this research intends to emphasise the collaborative role of speech-language therapists and teachers in the context of reading literacy.

Pretorius and Mampuru (2007) argue the need for more South African based research on literacy development. In February 2003 the United Nations Literacy Decade was launched with the theme 'Literacy as Freedom' as literacy has come to be seen as more than a tool of schooling but rather as a necessity for achieving economic prosperity and fostering peaceful relationships amongst the nations of the world (Westby, 2004). Accordingly, the Progress in International Reading Literacy Study (PIRLS) was implemented between 2004 and 2007 with South Africa being one of forty participating countries and forty five education systems. The PIRLS 2006 (Howie et al, 2008) data revealed alarming statistics. South Africa achieved the lowest score of all 45 education systems and both Grade 4 and Grade 5 learners achieved an average score that fell substantially below the international average. Howie et al (2008) reported that almost nine out of ten Grade 4 South African learners and about eight out of ten South African Grade 5 learners do not have basic reading literacy skills and did not reach the lowest international benchmark in PIRLS 2006. The authors of the PIRLS report (Howie et al, 2008) note that the PIRLS data indicates that there is a dire need for an integrative review of all reading research in South Africa to aid in planning and educational development initiatives.

In the context of the international data where comparisons of the performance in reading literacy in the forty participating countries were undertaken it was shown, albeit to differing degrees, that *every* participating country in PIRLS 2006 had a percentage of good readers and a percentage of learners who exhibited difficulties in reading. This finding reinforces the need to explore factors that may influence reading comprehension, as reading comprehension deficits occurred in learners in even the highest performing country, the Russian Federation. This underscores the need for research into reading comprehension and a study such as this one is relevant, in that it explores the relationship between working memory and reading comprehension. Furthermore, the assessment of each component of Baddeley's (2000a) revised model of working memory will clarify the role of each component of working memory on comprehension.

Passolunghi (2006) asserts that there is limited developmental research related t2o the episodic buffer. Current research shows that this component of working memory plays an important role in learning (Alloway, Gathercole, Willis & Adams, 2004). Specific testing of this component will supplement results obtained on the AWMA, ensuring that testing captures every aspect of the working memory model. Vance (2008) refers to the role played by the episodic buffer as being as yet uncertain, therefore this investigation should yield valuable results. The episodic buffer zone is anticipated to play an important role in reading comprehension as it integrates information from the subsidiary working memory systems and long-term memory. It is predicted that good comprehenders *reconstruct* or *fill-in* degraded memory traces using long-term memory knowledge. This is in keeping with Westby's (2004) view that a situational model of the text is central to reading comprehension. This investigation will clarify the impact that working memory has on the formation of the mental model.

Howie et al (2009: 59) concluded the PIRLS report by referring to Haggerty's statement that "Whatever else they do, education systems must equip young people with sophisticated literacy skills, the alternative is poverty and lost opportunities for the individual and for society". Due to the complexities involved in literacy, it is necessary to enhance the understanding of the relationship between working memory and reading comprehension. Since there is a dearth of empirical studies which examine working memory functioning as it relates to different types of reading comprehension difficulties, insights will be gleaned into this unique relationship.

2.19 Research Aims

The main aim of this study is to explore the relationship between working memory and reading comprehension to determine if there are 'signature' working memory profiles that distinguish subgroups of Grade 5 learners with different comprehension capabilities. In addition, this study will investigate the broader role played by working memory in reading comprehension to determine if a domain-specific or general working memory system is implicated in reading comprehension. A further sub-aim will be to explore the particular role played by the episodic buffer zone in reading comprehension.

These aims are operationalised in the following hypotheses :

Hypothesis 1 : Different working memory components will contribute differently to readers with different comprehension abilities.

Hypothesis 2 : These differences in working memory components may suggest a 'signature' profile that distinguishes the reading subgroups from each other.

Hypothesis 3a : A general working memory system is involved in reading comprehension. It is assumed that the central executive will play a significant role in reading comprehension as it is involved in the *processing* of material being stored in the phonological loop and the visuo-spatial sketchpad. Baddeley (1996) suggested that central executive functioning will affect tasks that require *simultaneous processing* and *storage* of material. Reading comprehension is surely a task of this nature.

Hypothesis 3b : The integration of information in working memory rather than the focus on separate subsystems (e.g. the phonological loop) is expected to play a significant role in reading comprehension. Including a poor reading fluency group may yield valuable information in this regard, as these readers are deficient in bottom-up processes but successful comprehenders.

Hypothesis 4 : The episodic buffer zone included in Baddeley's (2000c) revised model is expected to play an important role in reading comprehension as it integrates information from the subsidiary working memory systems and long-term memory. It is predicted that good comprehenders 'fill-in' degraded memory traces using long-term memory knowledge or 'reconstruct' meaning using long-term memory based propositions. Successful comprehenders of text are predicted to build mental situational models of text that rely on the episodic buffer zone and a general working memory system.

The next chapter will discuss the methods employed to test the above hypotheses.

CHAPTER 3 : METHOD

This chapter presents the research design of the study, the descriptive statistics of the sample, the instruments utilised in obtaining the necessary data, the procedure followed and the methods for analysis of the data.

3.1 Research Design

The study falls within the non-experimental, quantitative, descriptive, between-subjects paradigm. According to Schiavetti and Metz (2006, 48) “Descriptive research is used to observe group differences, developmental trends, or relationships among variables that can be measured by the researcher”. This design does not lead to cause-and-effect conclusions, but permits the description of relationships among variables or of differences between groups (Pannbacker & Middleton, 1994). Since the main aim of this study is to explore the relationship between working memory and reading comprehension in subgroups of Grade 5 learners, it is an appropriate approach to this research : there was no control group, the variables to be observed occurred naturally or were pre-existent, and the researcher was not required to control or manipulate the independent variable (Babbie, 2004). Descriptive research involves the observation of relations between attribute independent variables and dependent variables. The form of descriptive research employed, involved participants of one classification being measured on a number of criterion variables to determine the relationships among these variables and the ability to predict one variable from another (Schiavetti & Metz, 2006). In this study the attribute independent or predictor variable is working memory, whilst reading comprehension is the dependent or predicted variable. Gender and reading comprehension subgroup data were nominal, whilst the standardised test scores were measured at the interval level. Both comparative and correlational components were included in order to fulfil the aims of this study.

A comparative research strategy enables conclusions to be drawn about the similarities or differences on the measures between the subgroups, whilst a correlational research strategy studies the relationships amongst the variables to indicate the strength and direction of the relationships. This research was undertaken with the knowledge that correlation does not imply causation. In addition, caution was exercised in the interpretation of correlation coefficients since Schiavetti and Metz (2006) highlight that correlational studies can suffer from problems of interpretation.

3.2 Sample

The sample was a non-probability convenience sample and consisted of Grade 5 volunteer participants. These were recruited from two English medium state suburban schools and from two English medium private suburban schools, in the Johannesburg region of the Gauteng Province of South Africa.

A total of 80 Grade 5 learners participated in the study. Grade 5 learners were selected for participation in this study as Westby (2004) indicates that since English has a deep orthography, the level of reading ability is strongly associated with phoneme awareness and decoding abilities. As expertise in decoding takes many years to develop, this sets a limit on reading comprehension. Westby (2004) refers to a study conducted by Stanovich, Cunningham and Freeman in 1984 who found that by the fifth grade, American children's listening comprehension and reading comprehension ability were similarly associated, but not at younger grades. The selection of Grade 5 learners for this study will place less emphasis on decoding skills, as when readers master decoding skills, “other higher-order skills become more important for explaining differences among readers” (Westby, 2004, 259).

The original intention had been to draw the sample of participants from two state suburban schools, but it became necessary to supplement the sample with learners from two private remedial schools to yield learners who fell into the reading disabled category in particular, as well as in the poor comprehender and poor fluency subgroups. Only learners with English as a primary home language were eligible, as an analysis of the effects of bilingualism was beyond the scope of this study. Learners who had severe physical disabilities, cognitive impairments and hearing loss attending the schools selected for this study were excluded, as these conditions may affect their performance on the assessment measures for reasons other than reading comprehension and working memory. Learners from the remedial schools were included on the basis of their intellectual functioning falling within average limits on a standardised intellectual assessment tool. In the total of 80 learners who participated in this study 42 were male, as opposed to 38 female participants. Forty-five learners originated from the two state suburban schools, whilst 35 were from the two private remedial schools. The mean age of the total sample of learners was 10.7 years. The age range of the total sample was from 10 years to 11.9 years .

3.3 Instruments

Three instruments were used to conduct the research. These were administered in English to all participants of the study. Details of the instruments are given below.

Gray Oral Reading Test-4 (GORT-4) (Wiederholt & Bryant, 2001)

The GORT-4 is a norm-referenced, reliable and valid test of oral reading rate, accuracy, fluency and comprehension. It is appropriate for individuals aged 6 years 0 months (6.0) through to 18 years 11 months (18.11). The GORT-4 has two parallel forms, Form A and Form B, each containing 14 separate stories. Five multiple choice comprehension questions follow each story.

In this test the learner being tested reads a series of graded paragraphs and answers multiple-choice comprehension questions about their content. Performance on the GORT-4 yields rate, accuracy, fluency and comprehension scores as well as an overall reading ability score.

- Rate : the amount of time taken by a learner to read a story
- Accuracy : the ability of a learner to pronounce each word in the story accurately
- Fluency : the combination of a learner's rate and accuracy scores
- Comprehension : the appropriateness of a learner's responses to questions about the content of each story read
- Overall Reading Ability : the combination of a learner's fluency (rate and accuracy) and comprehension scores

Rate, accuracy, fluency and comprehension results are reported as standard scores with a mean of 10 and a standard deviation of 3.

The overall oral reading composite score is reported as a quotient, with a mean of 100 and a standard deviation of 15. Age equivalents, grade equivalents and percentiles are also provided. The GORT-4 evidences a high degree of reliability related to three sources of test error : content sampling, test-retest and scorer differences with reliability coefficients in the upper brackets of **r** values. The

Cronbach coefficient alpha was found to round off or to exceed the α = 0.90 criterion (Wiederholt & Bryant, 2001).

The reading comprehension score represents the dependent variable in this study.

Automated Working Memory Assessment (AWMA) (Alloway, Gathercole & Pickering, 2004).

The AWMA is a computerised tool for assessing working memory (WM) and short-term memory (STM) in children aged 4 to 11 years. The test is presented on a lap-top computer and scoring is fully automated. The automated presentation ensures consistency in presentation of stimuli across participants reducing experimenter errors. The entire AWMA consists of 12 subtests : six involve storage-plus-processing components and are collectively termed WM tasks, whilst the other six involve storage-only components and are referred to as STM tasks. Three of the six measures which relate to WM ("*Odd one out, Mister X,* and *Spatial Span)* measure visuo-spatial ability or VS-WM. The other three (*Listening Recall, Counting Recall* and *Backward Digit Recall')* measure verbal ability or V-WM. The remaining six STM tasks measure verbal ability or V-STM and visuo-spatial ability, or VS-STM. V-STM tasks include *Digit Recall*, *Word Recall* and *Nonword Recall* whilst VS-STM comprise *Dot Matrix, Mazes Memory* and *Block Recall*. Herewith follows a brief description of the individual subtests which test four different aspects of memory.

The verbal short-term memory component measures phonological loop function. The first subtest is *Digit Recall*. In this subtest the child hears a sequence of digits which must be recalled in the same order that they were presented. The child hears a sequence of words in the *Word Recall* task which must then be repeated in the same order. In the *Nonword Recall* task the child hears a sequence of nonwords and has to recall each sequence in the correct order.

The three measures of the verbal working memory component assess verbal central executive function and include the *Listening Recall* subtest where the child is presented with a series of spoken sentences and has to judge the sentence by stating 'true' or 'false' and recalls the final word for each sentence in sequence. In the *Counting Recall* task the child is presented with a visual display of red circles and blue triangles. The child is required to count the number of circles in an array and then recall the tallies of circles in an increasing number of displays. The *Backward Digit Recall* subtest requires the child to recall a series of spoken digits in the reverse order.

The visuo-spatial short-term memory measures provide an account of visuo-spatial sketchpad function. In the *Dot Matrix* subtest the child is shown the position of a red dot in a series of four-by-four matrices and has to recall this position by tapping the square on the computer screen. *Mazes Memory* displays a maze with a red path. The child then traces the same path on a blank maze presented three seconds later. The last test in this batch, is the *Block Recall* subtest where the child is shown a video of randomly placed blocks being touched at a rate of one per second. The child must reproduce this sequence in the correct order by tapping on a picture of the blocks.

Visuo-spatial central executive function is measured by three visuo-spatial working memory subtests. The child views three shapes, each in a box, presented in a row and identifies the odd-one-out shape in the *Odd-one-out* task. At the end of each trial, the child recalls the location of each odd-one-out shape, in the correct order, by tapping the correct box on the screen. In the *Mister X* task the child is presented with 2 cartoon 'Mister X' figures, one with a blue hat and one with a yellow hat. The child must identify whether the Mister X with the blue hat is holding a ball in the same or different hand as the Mister X with the yellow hat. The Mister X with the blue hat may be rotated through 360˚. At the end of each trial, the child has to recall the location of each ball that Mister X with the blue hat had presented, in the same sequence by pointing to a picture with 6 compass points. Finally, the *Spatial-Span* task requires the child to view two shapes, where the shape on the right has a red dot on it. The child must identify whether the shape on the right is the same or opposite of the shape on the left. The shape with the red dot could be rotated through 360˚. At the end of the trial the child has to recall the location of each red dot on the shape in sequence, by pointing to a picture with three compass points.

A computer generated report provides a summary of the performance of a child and includes raw scores, standardised scores, composite scores and percentiles. A graph and learner's profile is supplied. The test-retest reliabilities of the AWMA subtests range from α = 0.64 to α = 0.84 (Alloway, Gathercole & Pickering, 2006).

Verbal short-term memory (V-STM), verbal working memory (V-VM), visuo-spatial short-term memory (VS-STM) and visuo-spatial working memory (VS-VM) represent four of the five independent variables to this study. The fifth is represented by the outcome of the Recalling Sentences Subtest on CELF-4 (Semel, Wiig & Secord, 2006) outlined below.

The Recalling Sentences Subtest on the Clinical Evaluation of Language Fundamentals – Fourth Edition (CELF-4) (Semel, Wiig & Secord, 2006).

The child is presented with sentences which are to be repeated verbatim. Vance (2008) proposes that sentence recall highlights the interaction between short-term memory and the language processing system. She refers to a study conducted by herself and Drake in 2007 that supports the hypothesis that sentence recall reflects both long-term language knowledge and short-term memory skill. Vance (2008) proposes sentence recall error analysis to reflect this relationship. Short-term memory errors include word order errors, where meaning is intact. Conversely, when meaning is altered, or if a sentence is produced that is grammatically or semantically incorrect, then limited language knowledge is implicated. Vance (2008) advocates that a sentence recall test be included in a memory assessment. Alloway, Gathercole, Willis and Adams (2004) also refer to the value of sentence recall tests as they demonstrate the function of the episodic buffer which involves the integration of information from short-term memory subsystems with the products of the language processing system. As the AWMA does not assess episodic buffer function, inclusion of a sentence recall test was essential in this study.

The CELF-4 is an individually administered clinical tool for the identification, diagnosis, and follow-up evaluation of language and communication disorders in students 5 - 21 years old. The CELF-4 provides a flexible, multi-perspective assessment process for pin-pointing a student's language and communication strengths and weaknesses. The CELF-4 comprises 18 subtests administered within a series of designated levels. The *Recalling Sentences S*ubtest is one component of the expressive language index and is a level 2 tool which serves to describe the nature of the disorder. The stated objective of the *Recalling Sentences S*ubtest is to evaluate the student's ability to: (a) listen to spoken sentences of increasing length and complexity and (b) repeat the sentences without changing word meanings, inflections, derivations or comparisons (morphology), or sentence structure (syntax). The authors point out that an ability to imitate sentences has long been used as a tool to discriminate between normal and disordered language development. The student's response indicates if critical meaning or structural features are internalised for recall. Students score a 3 for sentences repeated verbatim. If the response is not an exact repetition then the student is allocated a score of 2, 1, or 0 corresponding to the number of errors in the student's response. A score of 2 corresponds with 1 word error : this is a response with a single word changed, added, substituted or omitted. If 2 - 3 word errors occur they are assigned 1 point : any response with two or three words changed, added substituted, omitted or reversed/transposed. Four+ errors include any response with four or more words changed, added, substituted, omitted or reversed; or an omission or resequencing of phases containing four or more words: these are assigned a score of 0. When scoring special conditions apply: any word that is changed, added, substituted or omitted counts as a single error. However, each transposition that changes the meaning of a sentence counts as two errors. A transposition that doesn't alter meaning is considered as one error. The total raw score for a subtest is the sum of the item scored. Each subtest raw score is converted to a norm-referenced scaled score using the age-appropriate table. Each subtest scaled score can be converted to a percentile rank.

The test-retest reliability for the Recalling Sentences Subtest is considered to be excellent, with the average corrected stability coefficients for all ages at .90 (Semel, Wiig & Secord, 2006).

3.4 Procedure

Permission to carry out this research was obtained from the Human Research Ethics Committee (Non-Medical) of the University of the Witwatersrand (Protocol No: HO91107) and from the Gauteng Department of Education (Refer to Appendix A and B). Principals of the schools participating in the study were advised as to the nature of this study in an interview and were presented with an information letter and consent form (refer to Appendix C and D).

An information letter was sent to parents/guardians via the schools (refer to Appendix E) and this included a consent form to grant permission for their child to participate in this study (refer to Appendix F). On receipt of the signed consent form, each subject was assigned a number code to ensure confidentiality. Prior to commencing the assessment, each child gave written assent (refer to Appendix G) and were advised that they could withdraw at any time during the assessment.

Children were tested individually in a quiet area of the school at a time designated by the teacher and that did not interfere with their school work. Tests were administered over two sessions. The duration of the initial session was approximately 30 minutes during which the GORT-4 and CELF-4 Recalling Sentences Subtest was administered. The second session during which the AWMA was administered lasted 30 to 45 minutes approximately.

Based on their performance on the GORT-4, learners were classified into four ability groups according to specific criteria.

1.	Skilled Reader Group	Learners with **no** *word recognition* ***or*** *comprehension* deficits, who attained accuracy and comprehension scores at or above the 50th percentile
2.	Reading Disabled Group	Learners with deficits in *word recognition* **and** *comprehension*, who attained accuracy and comprehension scores below the 50th percentile

3.	Poor Comprehender Group	Learners with intact *word recognition* **but** a *comprehension* deficit, who attained an accuracy score <u>at</u> or <u>above</u> the 50^{th} percentile but <u>below</u> the 50^{th} percentile for comprehension
4.	Poor Fluency Group	Learners with intact *comprehension*, **but** a *word recognition* deficit, who attained a score <u>at</u> or <u>above</u> the 50^{th} percentile for comprehension but <u>below</u> the 50^{th} percentile for accuracy

3.5 Data Analysis

A key criterion for the use of parametric techniques in statistical data analysis is a normal distribution of scores obtained on each dependent variable (Howell, 2008). Standardisation data from the GORT-4 as reported by Semel, Wiig and Secord (2006) reflect a normal distribution hence it was concluded that the data pertaining to the dependent variable was normally distributed. Parametric statistic measures were therefore considered appropriate for further data analysis (Schiavetti & Metz, 2006) as data resembled the ‘normal’ distribution curve.

A suggested methodology for studying reading development is a correlational research design as this enables the researcher to test a hypothesis that identifies a particular cognitive skill as a significant contributor to reading development. The hypothesis is tested by assessing the strength of the correlation between the hypothesized cognitive skill and the measure of reading ability (Gathercole & Baddeley, 1993). This study followed work in this tradition whereby the relationship between working memory and reading comprehension was investigated in 80 Grade 5 English language learners, classified into four reading ability groups, according to the criteria specified.

To explore the first hypothesis of this study that different working memory components will contribute differently to readers with different comprehension abilities, the mean standard score for the five memory components across the four reading ability groups, was calculated. Then two-tailed t-tests were applied to determine how the four reading ability groups compared on the five memory components.

To determine the outcome of the second hypothesis that differences in working memory components may suggest a 'signature' profile that distinguishes the reading subgroups from each other, the mean standard scores obtained by each of the four reading ability groups on the five working memory components, were compared on a graph. In addition, a series of correlational analysis was conducted between each of the respective reading ability groups and the five memory components. The Pearson Correlation Coefficients method was employed to give a precise index of the strength and direction of the relationships that exist among the working memory variables and the reading comprehension subgroups.

To ascertain whether a general or domain-specific system is involved in reading comprehension Pearson Correlation Coefficients were utilized to determine how the 80 participants reading comprehension scores on the GORT-4 correlated to their V-STM, V-WM, VS-WM and VS-STM on the AWMA and to the Recalling Sentences Subtest's result on the CELF-4. Scatterplots representing intercorrelations between reading comprehension, V-STM, V-WM, VS-STM, VS-WM and Sentence Recall show whether the integration of information in working memory rather than the focus on separate sub-systems plays a significant role in reading comprehension.

The Stepwise Multiple Regression Method was employed to ascertain the predictive value of the variables V-STM, V-WM, VS-STM, VS-WM and Sentence Recall on reading comprehension. This enabled the determination of the role played by the episodic buffer zone in reading comprehension, as proposed in the fourth hypothesis of this study. This method is suggested as a means of testing hypotheses in complex correlational data bases as regressions provide a way of conservatively estimating the strength of the unique relationship between a reading score and the hypothesized predictor of reading (Gathercole & Baddeley, 1993).

CHAPTER 4 : RESULTS

This chapter documents the quantitative analyses conducted in order to ascertain whether significant correlations existed between the various components of working memory and reading comprehension within the specific reading ability groups. If significant correlations were determined, this would point to the existence of 'signature' working memory profiles for specific reading ability groups. Regression analyses were performed to determine the predictive relationship between the working memory components and reading comprehension. The statistical results are reported and where relevant graphs and tables are presented.

As outlined in Chapter 3, the Gray Oral Reading Test-4 (GORT-4) was administered and based on the accuracy/decoding and comprehension scores, participants were assigned to one of four reading ability groups : Skilled Reader Group (SR); Reading Disabled Group (RD); Poor Comprehender Group (PC); or Poor Fluency Group (PF). The comprehension score on the GORT-4 represented the dependent variable in this study.

The Automated Working Memory Assessment Battery (AWMA) is a computerised assessment tool and participants completed all 12 subtests of memory. The scores of these 12 subtests are automatically collapsed by the AWMA programme to reflect 4 composite scores, including: V-STM, V-WM; VS-STM, and VS-WM which relate to memory performance. The Recalling Sentences Subtest score on the CELF-4 provided an additional measure of working memory function, in that its results pointed specifically to the episodic buffer, whilst the measures from the AWMA referred to the central executive, phonological loop and visuo-spatial components of the working memory model.

This chapter is organised as follows : For each hypothesis outlined in Chapter 2, descriptive and inferential statistics based on the analyses conducted, are presented.

Tables and figures are included where necessary to summarise data and to facilitate ease of comparison.

4.1 Comparison of the Memory Components in the Four Reading Ability Groups

Hypothesis 1 : Different working memory components will contribute differently to readers with different comprehension abilities.

The accuracy and comprehension scores obtained on the GORT-4 were used to allocate readers to a specific reading ability group. According to the criteria set the membership of the 80 participants to the specific groups is reflected in Table 4.1. Refer to Appendix H for a spreadsheet where standard scores from the GORT-4, standard scores and composite scores from the AWMA and scaled scores from the Recalling Sentences Subtest of the CELF-4 have been captured.

Table 4.1 : Distribution into different reading ability groups according to GORT-4 accuracy/decoding and comprehension scores.

SKILLED READER (SR)	**READING DISABLED (RD)**	**POOR COMPREHENDER (PC)**	**POOR FLUENCY (PF)**
N=43	N=20	N=12	N=5

Table 4.2 shows a breakdown of the mean standard scores on the four composite measures of the AWMA and the Recalling Sentences Subtest on the CELF-4 for the four different reading ability groups.

Table 4.2 : Summary of mean standard scores for the five memory components across the four reading ability groups

AWMA	SKILLED READER (SR) (N=43)	READING DISABLED (RD) (N=20)	POOR COMPREHENDER (PC) (N=12)	POOR FLUENCY (PF) (N=5)
V-STM	102.51	95	101.75	95.4
V-WM	104.27	93.75	99.08	97
VS-STM	94.30	87.2	92.33	84•
VS-WM	105.83	94.15	105	103
Recalling Sentences CELF-4	10.53	8.05	10.25	9.6

On the AWMA scores are standardised to a mean of 100 with a standard deviation of 15 for each age band. Scores in the 70 - 85 range are below average, scores in the 85 – 100 range are low average; scores in the 100 - 115 range are high average, whilst those in the 115 - 130 range are above average. From the summary of means data it can be seen that the mean standard scores of the four composite measures on the AWMA fall into the low average to high average range for the AWMA in all four reading ability groups, except for VS-STM which fell below average in the Poor Fluency group. On the CELF-4 Recalling Sentences Subtest scores are standardised to a mean of 10 and a standard deviation of 3. Scores in the 10 - 13 range are high average; scores in the 7 - 10 range are low average. From the summary of means data on the CELF-4 Recalling Sentences Subtest the standard score means for all 4 reading ability groups fell in the low to high average range.

In order to determine how the four reading ability groups compared on the five memory components, two-tailed t-tests were applied. This was to establish whether the difference between the sample mean of one group is significant when tested against the sample mean of another group. Howell (2008) points out that by examining the theoretical distribution of differences in means, it can be determined whether an observed difference in means can be judged significant, thereby justifying the conclusion that the two samples are drawn from different populations. The results of the t-tests are presented in Table 4.3 to Table 4.7., in which the t-stat and p-stat values are presented.

Table 4.3 : T-tests and p-stat data comparing V-STM means in each of the four reading ability groups presented in a matrix.

V-STM								
	SKILLED READER (SR) (N=43)		**READING DISABLED (RD) (N=20)**		**POOR COMPREHENDER (PC) (N=12)**		**POOR FLUENCY (PF) (N=5)**	
	t-stat	p-stat	t-stat	p-stat	t-stat	p-stat	t-stat	p-stat
SR		1	-2.36	0.026•	-0.17	0.864	-0.88	0.424
RD				1	1.33	0.197	0.05	0.964
PC						1	-0.70	0.504
PF								1

There is a 2.6% chance that the 2 samples viz. the Skilled Reader and the Reading Disabled group have the same mean and with 5% confidence the null hypothesis can be rejected. The Skilled Reader and Reading Disabled groups are thus significantly different on the variable V-STM.

Table 4.4 : T-tests and p-stat data on V-WM in the four reading ability groups in matrix format.

V-WM								
	SKILLED READER (SR) (N=43)		READING DISABLED (RD) (N=20)		POOR COMPREHENDER (PC) (N=12)		POOR FLUENCY (PF) (N=5)	
	t-stat	p-stat	t-stat	p-stat	t-stat	p-stat	t-stat	p-stat
SR		1	-3.23	0.002•	-1.44	0.166	-1.10	0.324
RD				1	1.27	0.216	0.47	0.657
PC						1	-0.29	0.779
PF								1

There is a 0% chance that the 2 samples viz. the Skilled Reader and the Reading Disabled group have the same mean and with 5% confidence the null hypothesis can be rejected. The Skilled Reader and Reading Disabled groups are significantly different on the variable V-WM.

Table 4.5 : T-tests and p-stat data on VS-STM in the four reading ability groups in matrix format.

VS-STM								
	SKILLED READER (SR) (N=43)		READING DISABLED (RD) (N=20)		POOR COMPREHENDER (PC) (N=12)		POOR FLUENCY (PF) (N=5)	
	t-stat	p-stat	t-stat	p-stat	t-stat	p-stat	t-stat	p-stat
SR		1	-1.98	0.050•	-0.59	0.562	-2.95	0.024•
RD				1	1.17	0.249	-0.71	0.487
PC						1	-1.94	0.077
PF								1

There is a 5% chance that the 2 samples viz. the Skilled Reader and the Reading Disabled group have the same mean and with 5% confidence the null hypothesis can be rejected, indicating that the Skilled Reader and Reading Disabled groups differ significantly on VS-STM.

There is a 2.4% chance that the 2 samples viz. the Skilled Reader and the Poor Fluency groups have the same mean and with 5% confidence the null hypothesis can be rejected, indicating that VS-STM distinguishes the Skilled Reader group from the Poor Fluency group.

Table 4.6 : T-tests and p-stat data on VS-WM in the four reading ability groups in matrix format.

VS-WM								
	SKILLED READER (SR) (N=43)		**READING DISABLED (RD) (N=20)**		**POOR COMPREHENDER (PC) (N=12)**		**POOR FLUENCY (PF) (N=5)**	
	t-stat	p-stat	t-stat	p-stat	t-stat	p-stat	t-stat	p-stat
SR		1	-2.70	0.011•	-0.22	0.831	-0.65	0.542
RD				1	2.07	0.047•	1.57	0.139
PC						1	-0.38	0.713
PF								1

There is a 1.1% chance that the 2 samples viz. the Skilled Reader and the Reading Disabled group have the same mean on VS-WM and with 5% confidence the null hypothesis can be rejected.

There is a 4.7% chance that the 2 samples viz. the Reading Disabled and the Poor Comprehender groups have the same mean and with 5% confidence VS-WM distinguishes the two groups.

Table 4.7 : T-tests and p-stat data on Sentence Recall in the four reading ability groups in matrix format.

SENTENCE RECALL								
	SKILLED READER (SR) (N=43)		**READING DISABLED (RD) (N=20)**		**POOR COMPREHENDER (PC) (N=12)**		**POOR FLUENCY (PF) (N=5)**	
	t-stat	p-stat	t-stat	p-stat	t-stat	p-stat	t-stat	p-stat
SR		1	-3.43	0.001•	-0.31	0.762	-0.49	0.647
RD				1	2.36	0.026•	0.98	0.371
PC						1	-0.32	0.760
PF								1

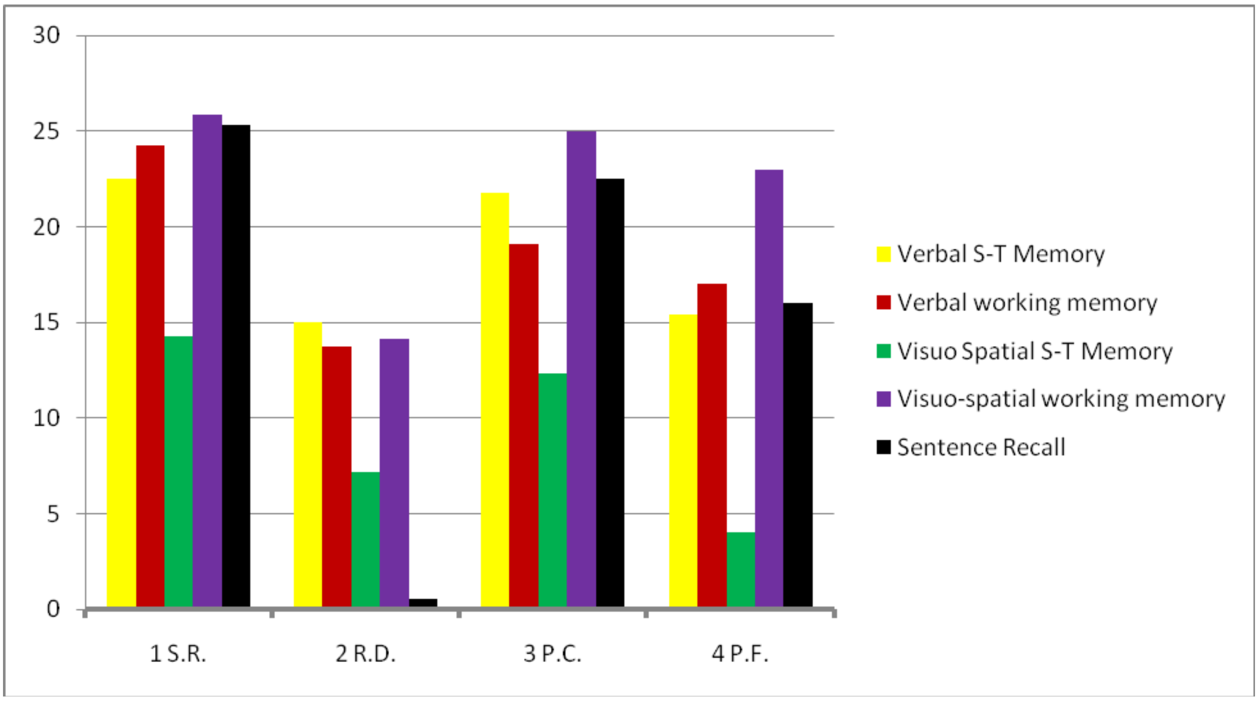
The difference between the means of the Skilled Reader group and the Reading Disabled group as well as the Reading Disabled and the Poor Comprehender groups is statistically significant and with 5% confidence the null hypothesis can be rejected : Sentence Recall distinguishes the Skilled Reader group from the Reading Disabled group and the Reading Disabled group from the Poor Comprehender group.

The t-test data revealed that the Skilled Reader group's standard score means differed significantly from the Reading Disabled group's standard score means on all 5 memory variables i.e. V-STM; V-WM; VS-STM; VS-WM and Sentence Recall. This distinguishes the Skilled Reader group from the Reading Disabled group. The

Reading Disabled group's standard score means were statistically different from the Poor Comprehender group on two of the five variables: VS-WM and Sentence Recall. The Poor Fluency group was distinguished from the Skilled Reader group when their VS-STM standard score means were compared.

The finding that the Skilled Reader group can be distinguished from the Reading Disabled group seems to suggest that there are distinctive working memory profiles between these two ability groups. The standard score means for the Poor Comprehender group on the five memory variables could not be distinguished from the Skilled Reader group standard score means and this suggests that their working memory profiles may be similar, an observation graphically depicted in the graph below. Furthermore, the t-test data showed that the Poor Comprehender group's standard score means were similar to those of the Skilled Reader group on the variables V-STM and VS-WM, hence it is plausible that in these instances the null hypothesis is true, so these two groups perform similarly on these two variables. Of significance too, was the t-stat comparing the Reading Disabled group and Poor Fluency group on V-STM. When comparing the standard score means of the two groups on V-STM, no significant difference could be established. The null hypothesis is true in this case and it can be inferred that the two groups perform similarly on this variable.

Hypothesis 2 : The differences in working memory components may suggest a 'signature' profile that distinguishes the reading subgroups from each other.



<u>Figure 4.1</u>. : Graph depicting the mean standard scores obtained by each of the four reading ability groups on the five working memory components.

The graph depicting the mean standard score performance of the four reading ability groups on the five memory components illustrates that Skilled Readers have a working memory profile which resembles that of Poor Comprehenders. The working memory profile of the Reading Disabled group appears relatively weaker than the other reading ability groups and the Sentence Recall mean for this group is relatively low. The Poor Fluency group had relatively weak V-STM, V-WM and Sentence Recall scores in comparison to the Skilled Reader and Poor Comprehender groups. From the graphic representation it can be seen that all four reading ability groups had relatively weak VS-STM scores in the presence of raised VS-WM scores.

In order to determine the relationship between the five memory components within each reading ability group, a series of correlation analysis was conducted (Howell, 2008). The Pearson Correlation Coefficients calculated are presented below in a correlation matrix. A correlation matrix table is presented for each reading ability group. Schiavetti and Metz (2006) in their interpretive guide for correlation coefficients suggest 0.00 is nil correlation whilst +0.50 is moderate correlation and +1.00 is a significant positive correlation. These guidelines have been used to interpret correlational data.

Table 4.8 : Correlation Matrix for Skilled Reader Group

SKILLED READER GROUP (N=43)					
	V-STM	**V- WM**	**VS-STM**	**VS-WM**	**SENTENCE RECALL**
V- STM	1	0.37	0.16	0.27	0.64•
V- WM		1	0.55•	0.61•	0.64•
VS-STM			1	0.71•	0.27
VS-WM				1	0.37
Sentence Recall					1

From this correlation matrix it can be seen that VS-STM has a moderately strong correlation (r = 0.71) with VS-WM in the Skilled Reader group. V-STM and V-WM are moderately correlated with Sentence Recall at r = 0.64. V-WM is moderately correlated to VS-STM in the Skilled Reader group at r = 0.55 and to VS-WM at r = 0.61 respectively.

Table 4.9 : Correlation Matrix for Reading Disabled Group.

READING DISABLED GROUP (N=20)					
	V-STM	**V- WM**	**VS-STM**	**VS-WM**	**SENTENCE RECALL**
V- STM	1	0.59•	0.23	0.39	0.61•
V- WM		1	0.60	0.81•	0.26
VS-STM			1	0.71•	0.006
VS-WM				1	0.097
Sentence Recall					1

From this correlation matrix V-WM has a moderately strong correlation with VS-WM in the Reading Disabled group at r = 0.81. VS-STM has a moderately strong correlation with VS-WM at r = 0.71. V-STM is moderately correlated to V-WM and Sentence Recall at r = 0.59 and r = 0.61 respectively.

Table 4.10 : Correlation Matrix for Poor Comprehender Group.

POOR COMPREHENDER GROUP (N=12)					
	V-STM	**V- WM**	**VS-STM**	**VS-WM**	**SENTENCE RECALL**
V- STM	1	0.76•	0.35	0.44	0.37
V- WM		1	0.62•	0.77•	0.20
VS-STM			1	0.79•	0.01
VS-WM				1	0.14
Sentence Recall					1

In the Poor Comprehender group, VS-STM has a moderately strong correlation with VS-WM at r = 0.79. V-WM is moderately correlated to VS-STM and VS-WM at r = 0.62 and r = 0.77 respectively. V-STM has a moderately strong correlation with V-WM at r = 0.76.

Table 4.11 : Correlation Matrix for Poor Fluency Group

POOR FLUENCY GROUP (N=5)					
	V-STM	**V- WM**	**VS-STM**	**VS-WM**	**SENTENCE RECALL**
V- STM	1	0.49	0.56•	0.35	0.76•
V- WM		1	0.50•	0.53•	0.81•
VS-STM			1	0.71•	0.36
VS-WM				1	0.17
Sentence Recall					1

This correlation matrix for the Poor Fluency Group reveals that V-STM and V-WM have a moderately strong correlation with Sentence Recall, at 0.76 and 0.81 respectively. V-STM is moderately correlated to the VS-STM at 0.56, whilst VS-STM has a moderately strong correlation with VS-WM at 0.71 in this group. Finally, V-WM is moderately correlated to VS-STM and VS-WM at 0.50 and 0.53 respectively.

Hypothesis 3 (a) : A general system is involved in reading comprehension. It is assumed that the central executive will play a significant role in reading comprehension as it is involved in the *processing* of material being stored in the phonological loop and the visuo-spatial sketchpad.

To consider this hypothesis it is necessary to consider how all 80 participants' reading comprehension scores on the GORT-4 correlated to their V-STM and V-WM performance, as well as to their VS-STM and VS-WM performance on the AWMA and to the Sentence Recall result on the CELF-4. Pearson Correlation Coefficients were calculated and are recorded in Table 4.12.

Table 4.12 : Pearson's Correlation between V-STM, V-WM, VS-STM, VS-WM, Sentence Recall and Reading Comprehension (GORT-4) for all 80 participants.

PEARSON CORRELATION COEFFICIENTS (READING COMPREHENSION) n=80				
V-STM	**V-WM**	**VS-STM**	**VS-WM**	**Sentence Recall**
0.23	0.29	0.16	0.24	0.30

From this table it can be seen that reading comprehension was only weakly correlated to V-STM, V-WM, VS-STM and VS-WM. The weakest correlation of r = 0.16 was that of comprehension and VS-STM whilst the 'strongest' was between reading comprehension and V-WM at r = 0.29. This table of data indicates that reading comprehension was not strongly correlated to V-WM and VS-WM which draw on central executive functioning, nor was reading comprehension strongly correlated to V-STM and VS-STM which indicate a domain-specific relationship. Rather, it appears that every component of Baddeley's (2000b) model is weakly implicated in reading comprehension. The Pearson Correlation data between reading comprehension and Sentence Recall revealed a r = 0.30. Of all the correlational data between reading comprehension and the five memory components, this correlation statistic was the highest, but it too represents a weak correlation with reading comprehension. All of Baddeley's (2000b) components of memory appear to play some role in reading comprehension, implicating a domain-general system that appears not to be restricted to a working memory system for language.

Hypothesis 3 (b) : The integration of information in working memory rather than the focus on separate sub-systems is expected to play a significant role in reading comprehension. Including a Poor Fluency group may yield valuable information in this regard, as these readers are deficient in bottom-up processes but successful comprehenders.

Scatterplots are graphically presented to illustrate intercorrelations. These scatterplots are represented in a correlation matrix, whereby the relationships between variable pairs in a multivariate study (such as this one), can be found by locating the desired variable pairs in the row and column headings (Schiavetti & Metz, 2006). Reading comprehension, V-STM, V-WM, VS-STM, VS-WM and Sentence Recall were the six variables entered. Schiavetti and Metz (2006) refer to a diagonal plot as being indicative of a strong positive or negative correlation between two variables.

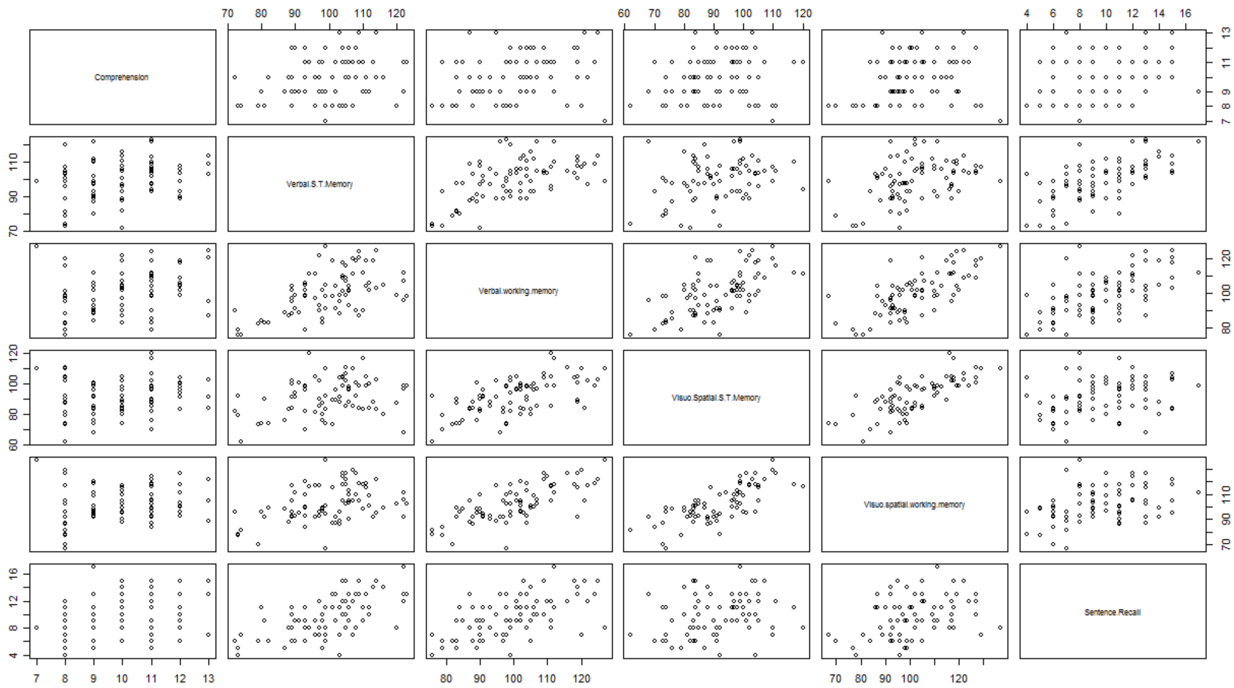


Figure 4.2 : Scatterplots representing intercorrelations between Reading Comprehension, V-STM, V-WM, VS-STM, VS-WM and Sentence Recall

The scatterplots reveal moderately positive relationships between :

- V-STM and V-WM
- V-WM and VS-STM
- V-WM and VS-WM
- VS-STM and VS-WM
- Sentence Recall and V-STM
- Sentence Recall and V-WM

Reading comprehension was not strongly correlated with any of the variables. Moderately positive intercorrelations existed between the short-term and working memory systems in both the verbal and visuo-spatial domains. A moderately positive correlation was also detected between the verbal and visuo-spatial working memory system. V-WM was also moderately correlated to VS-STM. Sentence

Recall was moderately correlated to verbal short-term and working memory. These intercorrelations demonstrate an interplay between the subsystems.

The correlation matrix presented below gives a more precise account of the intercorrelations between the variables Reading Comprehension, V-STM, V-WM, VS-STM, VS-WM and Sentence Recall.

TABLE 4.13 : Correlation Matrix for Reading Comprehension, V-STM, V-WM, VS-STM, VS-WM and Sentence Recall.

	READING COMPREHENSION	V-STM	V-WM	VS-STM	VS-WM	SENTENCE RECALL
Reading Comprehension	1	0.23	0.29	0.16	0.24	0.30
V-STM		1	0.55•	0.29	0.40	0.65•
V-WM			1	0.60•	0.71•	0.59•
VS-STM				1	0.73•	0.27
VS-WM					1	0.41
Sentence Recall						1

The strongest positive correlation was between VS-STM and VS-WM. Thereafter the strength of the intercorrelations are ranked as follows: V-WM and VS-WM, Sentence Recall and V-STM, V-WM and VS-STM, V-WM and Sentence Recall, followed by V-STM and V-WM.

The inclusion of the Poor Fluency group (i.e. those participants who scored above the 50th percentile on comprehension, but below the 50th percentile on accuracy on the GORT-4), who despite their low number, n = 5, revealed some additional insights : only VS-STM distinguished this group from the other reading ability groups. T-test data revealed that when VS-STM was compared across the four groups, it distinguished the Poor Fluency group from the Skilled Reader group. It had been anticipated that Sentence Recall might be a distinguishing factor between this group and Poor Comprehenders and/or the Reading Disabled group but the low sample size may account for this lack of evidence.

Hypothesis 4 : The episodic buffer zone is expected to play an important role in reading comprehension as it integrates information from the subsidiary working memory system and long-term memory.

This hypothesis is concerned with the predictive value of the independent variables V-STM, V-WM, VS-STM, V-WM and Sentence Recall on reading comprehension. The Stepwise Multiple regression method was employed since the aim was to determine which of the afore-listed variables predicted reading comprehension. Howell (2008) points out that the Stepwise model is a combination of simultaneous forward selection and backward elimination. At the outset, the variable with the largest variance is selected from the set of possible predictor variables. Thereafter, the significance of the remaining predictor variables is recalculated and the next variable with the largest significance is added. As each variable is added, variables already selected are considered for elimination if they no longer contribute significantly. This process continues until the only variables remaining are those that make a significant contribution and all those that do not have been eliminated.

Significance levels were set to the default values of 0.5 for entry and 0.1 for elimination.

The results of the regression analysis to determine which variables were significant predictors of reading comprehension showed that Sentence Recall accounted for 16% of the variance in reading comprehension. This substantiates the role played by the episodic buffer in reading comprehension.

When Sentence Recall was excluded and only V-STM, V-WM, VS-STM and VS-WM entered as the predictor variables and the GORT-4 comprehension score as the predicted criterion variable, the best predictor of reading comprehension in the prediction equation was V-WM. This confirms that V-WM does indeed play an important role in reading comprehension and that the central executive is involved in the *processing* of material being stored in the phonological loop as suggested in Hypothesis 3 (a).

CHAPER 5 : DISCUSSION

This study investigated the role working memory played in reading comprehension in 80 Grade 5 English language learners in order to explore the relationship between working memory and reading comprehension and to determine the nature of working memory deficits in less skilled readers. The 80 learners were classified into four reading ability groups to ascertain whether 'signature' working memory profiles were identifiable and which could serve to distinguish the four reading ability groups. The Gray Oral Reading Test-4 (GORT-4) (Wiederholt & Bryant, 2001), The Automated Working Memory Assessment (AWMA) (Alloway, Gathercole & Pickering, 2004) and the Recalling Sentences Subtest on the Clinical Evaluation of Language Fundamentals - Fourth Edition (CELF-4), (Semel, Wiig & Secord, 2006) were administered to assess the 80 learner's reading comprehension and working memory.

The results obtained from the standardised assessment tools were presented in the previous chapter. It is the function of this chapter to provide a more in-depth discussion of the results of this study and to contextualise the results with reference to the specific aims of this study and within the broader framework of research into reading comprehension and working memory. The theoretical and practical implications of the findings of this study will be discussed and the limitations of this study will be presented to facilitate perspective and the scientific endeavour of this research.

This chapter is organised as follows: The results of this study will be discussed with specific reference to the four hypotheses which operationalised the aims of the study, followed by an overview of the theoretical and practical implications of the results. A section relating to the limitations of this study, will precede the conclusion.

5.1 Hypothesis 1: Different working memory components contribute differently to readers with differing reading comprehension capabilities.

Swanson and Siegel (2001), in their review of studies concerning learning disabilities as a working memory deficit, concluded that working memory processes have been implicated in reading failure in childhood, adolescence, and adulthood. However, Vukovic and Siegel (2006) point out that less is known about how working memory is involved in reading comprehension.

In this study, where the 80 participants were classified into four reading ability groups based on their reading accuracy and reading comprehension scores, the means of the four composite standard scores on the AWMA fell into the low average to high average range in all four reading ability groups, except for VS-STM which fell below average in the Poor Fluency group. Means data from the CELF-4 Recalling Sentences Subtest yielded the same finding of means within the low to high average range. The standard score means data for the five memory components across the four reading ability groups suggests that working memory alone does not account for comprehension deficits in reading disabled learners and poor comprehenders. This finding is corroborated by Vukovic and Siegel (2006) who concluded, after a review of research into the role of working memory in children's reading comprehension abilities, that lower-level (e.g. phonological awareness, short-term memory) and higher-order (i.e. language) processes, in addition to working memory, may contribute to problems with reading comprehension. This points to the complexity of the reading comprehension process alluded to in previous chapters, where simultaneous decoding and processing of print occurs, whilst meaning is being constructed within the context of the reader's personal world, prior knowledge and previous experience. As Gathercole and Baddeley (1993) pointed out over a decade ago, working memory alone could not claim to provide a complete account of any particular aspect of language processing for e.g. reading comprehension, as there is much more to reading and comprehension, and each of these areas of language processing is represented by areas of extensive research activity.

Further examination of the interface between working memory and reading comprehension in the four reading ability groups revealed eight significant inter-group comparisons of difference. The Skilled Reader group differed significantly from the Reading Disabled group on all five working memory components. This implies that working memory can distinguish these two groups from each other and this has implications for the assessment and remediation of reading disabled learners. This is in accordance with the suggestion of Pickering (2006) that different patterns of working memory functioning occur in children with different learning problems, such as dyslexia.

The Skilled Reader group was also distinguished from the Poor Fluency group on the VS-STM component and the Reading Disabled group was distinguished from the Poor Comprehender group on VS-WM and Sentence Recall. These findings refer to the role of the visual-spatial sketchpad in reading comprehension. Baddeley (2010) makes reference to recent advances in the study of the visuo-spatial domain which indicate that the principal function of VS-STM is to create and maintain a visuo-spatial representation that persists across the irregular pattern of eye movements that characterises our scanning of the visual world, whilst VS-WM combines the temporary storage and manipulation of visual images in the service of cognition. The significance of the role played by the visuo-spatial system in reading comprehension is underscored by the finding of this study referred to above. It punctuates the importance of considering the role played by the visuo-spatial system, and not only that of a working memory for language, when referring to reading comprehension. Baddeley (2003) indicated that imagery is useful when reading a descriptive passage. Reduced access to the visual-spatial domain therefore appears to be a constraining factor in achieving reading competency. The Skilled Reader group, who attain fluent, accurate decoding of text are contrasted with readers from the Poor Fluency group whose reading accuracy and fluency are compromised, on the variable VS-STM. The Reading Disabled group are distinguished from Poor Comprehenders on VS-WM, with Poor Comprehenders outperforming the Reading Disabled group on this measure. This highlights the value of examining both the verbal and non-verbal domains of working memory and has particular relevance when considering remediation methods for weak decoders of text. The role of rapid automatic naming (RAN) and the visuo-spatial domain need further investigation as successful decoding relies on phonological awareness (the verbal domain) and RAN which operates independently of phonology and is pre-supposed to have a non-verbal, visuo-spatial basis.

The significance of the finding pertaining to Sentence Recall will be discussed at length in a later section (see 5.5) of this chapter. With regards to this first hypothesis, it confirms that different components of working memory appear to contribute differently to readers with differing comprehension abilities.

5.2 Hypothesis 2: Differences in working memory components may suggest a 'signature' profile that distinguishes the reading subgroups from each other.

The data from this study did not yield distinguishable 'signature' working memory profiles for each of the four reading ability groups. Based on the t-test data, the Skilled Reader group was distinct from the Reading Disabled group on all five working memory components, suggesting that working memory is a cognitive skill that distinguishes the Skilled Reader from the Reading Disabled. The profile of the Skilled Reader reflects standard score means in the high average range in four of the five memory components viz. V-STM, V-WM, VS-WM and Sentence Recall, with VS-STM in low average range, whilst the Reading Disabled group's standard score means fall in the low average range for V-STM, V-WM, VS-STM, VS-WM and Sentence Recall. These two profiles are commensurate with Swanson's (2006) finding that the reading disabled have smaller general working memory capacity than their normal achieving counterparts.

Of significance in this study, is not only the finding of contrasting profiles between the Skilled Reader and Reading Disabled groups on working memory components, but the similarities found between the profiles of the Skilled Reader and Poor Comprehender groups. Skilled Readers could not be distinguished from Poor Comprehenders on two of the five memory components viz. VS-STM and VS-WM. Vukovic and Siegel (2005) also found that poor comprehenders tended to perform more similarly to typical readers than to poor readers across tasks, although in contrast to this study, they found poor comprehenders to be characterised by V-WM deficits. In this study, the Poor Comprehender group's performance was significantly different to the Reading Disabled group on VS-WM and Sentence Recall, when the visuo-spatial domain and episodic buffer zone's binding function are drawn upon.

In this study, the short-term memory system played a significant role in the Poor Fluency group. VS-STM distinguished the Poor Fluency group from Skilled Readers (as discussed previously). Furthermore, the Poor Fluency and Reading Disabled groups performed similarly on the V-STM system, indicating that both groups experience difficulty with phonological short-term memory processes and have restricted storage capacity. This finding confirms that of Swanson et al (2006) that children with reading disability suffer deficits in storage. Deficits in lower-level processes characterise these readers and this has important ramifications for remediation of readers in these two groups. In addition, the Poor Fluency group data highlights the importance of higher-order processes in reading comprehension and underscores the need to include these, as well as more traditional methods in a comprehensive reading programme and not to place an exclusive emphasis on lower <u>or</u> higher order processes. Vukovic and Siegel (2005), make reference to a longitudinal study they conducted whereby the co-ordination of many lower and higher level skills were considered important in explaining the development of reading comprehension ability. They point out that this very co-ordination, which is a function of the working memory system, may be deficient in poor comprehenders. The data obtained from the Poor Fluency group is considered of value as the Poor Fluency and Poor Comprehender groups demonstrate converse accuracy/decoding and comprehension skills. Findings from the one group shed insights into the functioning of the other. Further investigation of these group's reading comprehension and working memory ability will clarify the co-ordinating role of lower-and higher-order processes.

In order to further investigate the differences in the working memory components across the four reading subgroups, within group inter-correlations of the five memory components were calculated. In all four reading ability groups the following inter-component correlations were recorded :

- VS-STM correlated with VS-WM
- V-STM correlated with VS-WM
- V-WM correlated with VS-STM

In three of the four ability groups, the additional inter-correlations occurred :

- V-STM correlated with V-WM (the Reading Disabled was excluded)
- V-STM correlated with Sentence Recall (the Poor Comprehender group was excluded)

In the Skilled Reader and Poor Fluency groups V-WM was also correlated with Sentence Recall, whilst V-STM was correlated with V-WM in the Reading Disabled and Poor Comprehender groups only.

These inter-correlations permit the following observations that the short-term memory system of storage is correlated with the working memory system of manipulation in the visuo-spatial domain in all four reading ability groups but short-term memory and working memory were not correlated within the auditory-verbal domain across the four ability groups.

V-STM correlated with Sentence Recall in the Skilled Reader, Reading Disabled and Poor Fluency groups, whilst V-WM was moderately correlated with Sentence Recall in the Skilled Reader and the Poor Fluency groups. This finding verifies a theoretical position put forward by Baddeley (2010) that the episodic buffer should be regarded as a passive store and that the process of binding which it undertakes does not depend crucially on executive control as previously thought, hence the relationship of Sentence Recall with V-STM and V-WM.

The findings from the data discussed above can be summed-up as follows: the Skilled Reader group can be distinguished from the Reading Disabled group on the basis of their working memory performance, whilst the Skilled Reader group resembles the Poor Comprehender group on two of the working memory components. Inter-correlations confirmed that the Skilled Reader and Poor Fluency group members' Sentence Recall, V-STM and V-WM components correlate within their respective subgroup and this finding is of relevance as it pertains to the relationship between the components of the verbal memory domain, long-term knowledge, and successful comprehension. The findings also suggest the importance of the interplay between the lower-order (short-term memory system) and higher-order (working memory system) in reading comprehension.

5.3 Hypothesis 3(a): A general working memory system is involved in reading comprehension as opposed to deficits restricted to the verbal domain. The central executive's role in reading comprehension is assumed to be vital.

In this study, the findings revealed only a weak correlation between the five memory components and reading comprehension. When ranked, Sentence Recall achieved the 'strongest' correlation (r = 0.30), followed by V-WM (r = 0.29), VS-WM (r = 0.24), V-STM (r = 0.23) and finally VS-STM (r = 0.16). These results do not lend credence to a strong link existing between reading comprehension and working memory. In the studies that were reviewed by Vukovic and Siegel (2005), their findings indicated that working memory is an important variable in explaining reading comprehension in children from the ages of 7 to 11. Of the 80 participants in this study, the mean age of the sample was 10.7 years.

The results from this study suggest that the relationship between reading comprehension and working memory is dynamic and that further investigations with learners in the age range 11 - 14 years, may provide unique insights into the changing status of the relationship between working memory and reading comprehension as learners grow older. Vukovic and Siegel (2005), in their study of learners in the later elementary grades, found V-WM deficits to characterise poor comprehenders. In this study, when Sentence Recall was excluded and only

V-STM, V-WM, VS-STM, and VS-WM entered as predictor variables in the regression analysis, V-WM was the best predictor of reading comprehension. V-WM appears to be an important component of reading comprehension in Grade 5 learners.

Despite the fact that this study did not reflect that reading comprehension and working memory share a strong relationship, it is necessary to consider the correlations of the five memory components with reading comprehension. The 'strongest' correlation was Sentence Recall ($r = 0.30$) followed by V-WM ($r = 0.29$). This suggests that the relationship between reading comprehension and working memory reflects not only a domain-based, language system, but a general working memory system is implicated by the role played by the episodic buffer. Vukovic and Siegel (2006), refer to a study by Daneman and Merkle as early as 1996, who found that reading comprehension tended to be more strongly correlated with working memory measures that involved verbal information, than with numerical working memory tasks. A study by Swanson and Siegel (2001), showed that reading comprehension is more strongly related to verbal working memory, than to visuo-spatial working memory and the findings of Vukovic and Siegel's (2005) longitudual study confirm that a working memory system for language accounts for the relationship between working memory and reading comprehension. In addition, the central executive's storage and processing roles and its connections with LTM through the episodic buffer, appear to play an important role in reading comprehension.

The determination of this relationship is important. The implication that a working memory system for language is involved in reading comprehension requires that learners with specific comprehension difficulties need to be taught strategies for processing and remembering verbal information and that the link with crystallised knowledge is crucial.

Before summing up this section, it must be noted that the studies cited predominantly used typically achieving readers ranging in age from 7 to 11 years. This study used participants of mixed reading abilities, falling at the upper-end of the age spectrum reported in other studies. Though weak, the correlation between V-WM ($r = 0.24$) and reading comprehension is noted. In a study by Swanson and Howell (2001) with children aged 9 - 14 years, overlapping variance between linguistic and visuo-spatial components was found to explain variance in reading comprehension. This led the authors to conclude that both a general working memory system, as well as a language-based working memory system may be involved in reading comprehension. In this study, all of Baddeley's (2000) components of working memory appear to play some role in reading comprehension, implicating a general working memory system with greater reliance on verbal codes.

5.4 Hypothesis 3(b): The integration of information in working memory rather than the focus on sub-systems is expected to play a significant role in reading comprehension.

Inter-correlations between the variables reading comprehension, V-STM, V-WM, VS-STM, VS-WM and Sentence Recall revealed a number of relationships. As discussed in the preceding section, a weak link existed between working memory and reading comprehension, but stronger correlations were evident between other variable pairs, as presented in the previous section. This indicates that information within the phonological loop and visuo-spatial domain are inter-correlated, and that the short-term store and working memory processing mechanisms are also linked. The verbal domain of V-STM and V-WM are connected to Sentence Recall. The findings suggest an interplay of information within and between the sub-systems, central executive and episodic buffer, indicating that the integration of information appears necessary. By including the Poor Fluency group, it had been hoped that a strong correlation with reading comprehension and sentence recall would emerge as these readers are successful comprehenders with intact higher-order processes, and who appear to integrate information successfully to overcome their deficit lower-order skills. The low sample size (n=5), may account for a lack of evidence, in this regard. Future studies targeting this group are suggested to uncover more of the complex relationship between working memory and reading comprehension.

5.5 Hypothesis 4 : The episodic buffer zone is expected to play an important role in reading comprehension as it integrates information from the subsidiary working memory system and long-term memory.

Regression analysis revealed Sentence Recall to be the best predictor of reading comprehension when V-STM, V-WM, VS-STM and VS-WM were entered into the regression equation. Sentence Recall makes a significant contribution to reading comprehension. This is an important finding as the role of the episodic buffer has not been explored in relation to reading comprehension. Literature searches revealed no available data. This finding supports the notion that reading comprehension requires the binding function of the episodic buffer zone which enables the reader to simultaneously store and process the content of the text read, whilst concurrently activating prior knowledge from the crystallised long-term memory store. This collation of information enables the reader to construct a situation model which facilitates access to the full meaning of the text. The episodic buffer appears to play a critical part in the reading comprehension process. Difficulty experienced by the Reading Disabled group on Sentence Recall provides further evidence for this claim. Further investigations will yield more information of this role and in-turn this will extend our knowledge of the episodic buffer itself. According to Westby (2004) mental models are central to comprehension and the redintegration process where long-term knowledge is used, to ‘fill-in’ or ‘reconstruct’ meaning (Vance, 2008). This finding of Sentence Recall playing an important role was not supported by Alloway and Gathercole (2005) in their investigation of working memory and Sentence Recall in young children, nor in their study of the role of Sentence Recall in reading and language learning disabled children. Their studies provided limited evidence that children’s Sentence Recall performance is significantly associated with language learning and literacy. The finding in this study supports the need for further exploration of this aspect of working memory. The ‘strong’ correlation of Sentence Recall to reading comprehension, when compared to that of V-STM, V-WM, VS-STM and VS-WM adds additional credence to future research into this area.

5.6 Limitations of the Study and Threats to Validity

It is important to take cognisance of the fact that although every effort has been made to make the study as representative as possible, generalisability or external validity of the research findings may be compromised by certain factors.

Firstly, the relatively small sample (n=80) is less accurate as an estimation of the population than a larger sample would be. This is further compounded by the second factor, namely convenience sampling, which was the preferred sampling method for this study. A purposive non-probability sampling method, as utilised in this study, cannot guarantee that the sample is representative of the whole/heterogeneous population (Babbie, 2004) and findings of this study are thus not generalisable to the whole population. In an effort to make the sample as representative as possible, learners were drawn from four different schools of similar socio-economic status. Learners for whom English was a primary home language were selected and exclusion criteria were rigorously applied. The results of this study are therefore generalisable to the population from which it was drawn.

The third factor, which posed a limitation to this study also related to the sample size. The 80 participants were categorised into reading ability groups on the basis of their accuracy in decoding and reading comprehension. Four ability groups resulted but these groups did not have an equal number of subjects: The Skilled Reader group comprised 43 members, the Reading Disabled group had 20 members, whilst the Poor Comprehender and Poor Fluency groups had 12 and 5 members respectively. The low numbers of participants in each reading ability group posed a threat to the internal validity of the study as between-group comparisons were central to the aims of this study, hence the low numbers, particularly in the Poor Comprehender and Poor Fluency groups may have compromised the reliability and validity of the results. Furthermore, the low numbers in the Poor Comprehender group and Poor Fluency group prevented the researcher from performing additional within-group regression analysis. A larger sample size would have permitted this analysis and it would have been of scientific interest to establish which of the five memory variables best predicted reading comprehension in each group.

The fourth factor refers to the AWMA as an assessment tool for use in the South African context. The subtest instructions are presented by a female voice with a British accent. All the test items presented in the V-STM and V-WM subtests are presented by this voice. The AWMA test session commences with the V-STM component, before progressing to the other subtests. The researcher is of the opinion that this may have had a negative effect on the results for the V-STM and V-WM component, due to unfamiliarity with the accent, and rather than the V-STM tasks being short-term storage and recall tasks only, a processing component may have been introduced as a result of the presenter's accent. This factor was not predicted prior to data collection and only became apparent during testing, but it should be noted for any future research in the South African context where the AWMA battery is employed. Furthermore, standardisation of the AWMA is based on children recruited from primary schools in North-East England hence the application of standard scores as a way of describing a learner's performance with respect to the performance of children of the same age, may be inappropriate to the South Africa context.

The fifth factor relates to the language employed in this study. Since English has a deep orthography, it is incumbent on the researcher to point out that the findings should not be generalised to other languages with highly transparent orthographies. Should this be done caution must then be exercised, as reading achievement rates can be different (as outlined in an earlier chapter).

Finally, the GORT-4 (Wiederholt & Bryant, 2001) was selected as the reading assessment measure. The GORT-4 makes use of a series of graded, narrative passages. An assessment tool which provided narrative and expository passages may have placed greater demands on working memory. Westby and Watson (2004) point out that because expository texts generally have a less familiar structure and content than narrative tests, they place greater processing demands on working memory. A more fine-tuned reading measure may have supplied more discriminating reading comprehension results and this would have enhanced the intrinsic value of this study. In addition, the standardisation issues relating to the AWMA, apply also to the GORT-4 and CELF-4.

5.7 Theoretical and Practical Implications of the Research

This study concerned itself with the relationship between working memory and reading comprehension with the intention of leading to an improved understanding of the nature of working memory and how working memory may contribute to reading comprehension failure.

The findings from this study revealed that the five components of working memory as outlined in Baddeley's (2000) model, were only weakly correlated with reading comprehension. The components that were more 'strongly' linked included Sentence Recall and V-WM. This outcome of the role of V-WM is in accordance with other studies concerning this topic. Nation et al (1999), Cain et al (2000), Seigneuric et al (2000), Vukovic and Siegel (2005, 2006) are proponents of the notion that the verbal domain of working memory is implicated in reading comprehension. In particular, these researchers refer specifically to the importance of V-WM in reading comprehension. The finding that Sentence Recall was the 'strongest' correlate of reading comprehension and that this variable best predicted reading comprehension, is a significant finding that reinforces the role of the episodic buffer zone and suggests that the interface of incoming information with long-term information is critical in the reading comprehension process. The roles of the central executive and episodic buffer are emphasised in the reading comprehension process. This is verified by Westby and Watson (2004) who outline that comprehension of text requires efficient working memory since the reader must process information online whilst retrieving information from long-term memory. This enables the reader to build a mental model that is a representation of a situation or world described in the text. Greater understanding and the ability to recall facts and make inferences are associated with more elaborate mental representations (Zwaan & Radvansky, 1998). V-WM is considered to be internalised language that is used to talk to oneself, to provide reflection, description, instruction and questioning, which in turn facilitate problem-solving, the development of rules, and moral reasoning (Westby & Watson, 2004). When these are linked with prior knowledge and past experiences, accessed through the episodic buffer, fuller comprehension is afforded. Consideration of this link between simultaneous storage and processing and long-term memory in reading comprehension has important educational implications. Vance (2008) advocates reducing the processing load as a way of targeting central executive functioning, but since the service of the episodic buffer must also be called into action, educationalists and clinicians must promote long-term memory retrieval by accessing prior knowledge about the topic to be read and forging links with this information. Methods advocating such links have been proposed by Wallach and Butler (1994) and the findings of this research gives impetus to the inclusion of such methods in reading teaching pedagogy.

When attempting to establish whether a pattern of working memory deficits or ‘signature’ working memory profiles exist that distinguish the four different reading ability groups from each other, it was determined that the working memory profile of the Skilled Reader group was significantly different from that of the Reading Disabled group, but similar to that of the Poor Comprehender group. This finding corresponds with Swanson et al's (2006) claim that skilled readers out-perform the reading disabled on working memory measures. Their finding that poor comprehenders are stronger on working memory measures than reading disabled readers is in concert with this study's finding. As the Reading Disabled group performed in the low average range on all five working memory components, enhancing working memory would be beneficial. Phonological awareness, verbal rehearsal, the promotion of visualisation, reducing the processing load and encouraging long-term memory access are suggested methods. Vance (2008) and Gathercole and Alloway (2008) provide an outline of some of these strategies and Westby (2004) stresses the importance of links with incoming and existing information and global organisation for a particular text so that readers can 'center' (make each of their comments refer to the topic) and 'chain' (place ideas in a logical sequence) when undertaking reading comprehension.

As the working memory profile of the Poor Comprehender group resembled the Skilled Reader group, the five components of working memory do not offer a distinctive profile between these groups, but reinforced their similarities. As in this study, Swanson et al (2006) found too, that poor comprehenders have an advantage over children with reading disability on working memory measures. They attributed this advantage to the storage system of children with comprehension-only deficits to be more intact than in reading disabled learners. In this study, the Poor Comprehender group was found to perform in a similar manner to Skilled Readers on V-STM and this supports Swanson's et al (2006) claim of an adequate phonological system. In their study, V-WM was comparable in poor comprehenders and the reading disabled, showing executive system dysfunction in these readers. This finding was not repeated in this study, where VS-STM and Sentence Recall distinguished the two groups. When considered together these findings point to the need for on-going research with poor comprehenders to clarify and disentangle the interaction between the components of working memory during the act of reading comprehension.

As clear and distinctive patterns of working memory deficits did not emerge in this study in accordance with a learner's reading comprehension deficit, the notion can be forwarded that working memory performance is not a consequence of reading skill. Engle, Kane and Tuholski (1999a) proposed this notion and suggested that individual differences on various cognitive tasks (e.g. reading comprehension) are due to the total level of activation in a general working memory system. They go as far as to argue that the amount of activation is a constant characteristic of an individual and changes little with increases or decreases in reading ability. Swanson et al (2006) add that working memory is a general skill that underlies various cognitive domains. This leads the researcher to draw an inference relevant to the South African context, where educators are confronted daily with the plight of learners whose achievement in reading is poor. The PIRLS (2006) report highlighted the fact that South African Grade 4 and 5 learners achieved the lowest literacy score in 45 education systems. In this report a learner's background, home factors, the school and the characteristics of the individual learner e.g. home language, were cited as having an impact on a learner's literacy achievement. Given the extent of low literacy levels in South Africa, educational development initiatives must be a priority. Because working memory appears to be a general skill underlying various cognitive domains, its value cannot be underestimated. Alloway and Alloway (2010) when investigating the predictive power of working memory and IQ in learning, found that a child's success in all aspects of learning related to how good their working memory is, regardless of IQ score. This issue is important because distinguishing between the cognitive skills underpinning success in learning is crucial for early screening, identification, intervention, promoting best educational practices and allocating resources. Their research found that working memory contributed to learning beyond practice effects and that it is not linked to the parent's level of education or socio-economic status. Alloway (2009) asserts that working memory is a relatively stable construct that has powerful implications for academic success. She is of the opinion that early intervention in working memory could lead to a reduction in the number of those learners failing in schools and help address the problem of under-achievement in schools. This would be of particular relevance in the South African context where the vast majority of learners at a Grade 5 level fare poorly in literacy achievement. Working memory could serve as a measure to assist educators in differentiating education practices. To this end, speech and language therapists need to be utilised in education settings to assist in the differentiation of 'difference' from 'disorder' and to inform educators of and to promote evidence-based practices.

The finding of this study that working memory is not strongly correlated to reading comprehension, either its achievement or failure, endorses Wolf and O'Brien's (2004) claim that multiple factors are involved in the reading process and their interactions are complex. The cognitive architecture of reading is multidimensional, hence speech and language therapists need to involve themselves in the screening, identification and remediation of reading comprehension difficulties.

According to Roth and Troia (2009) speech-language pathologists can play a substantive and proactive part in school-wide language and reading disability prevention and intervention efforts. They suggest that within a collaborative working paradigm, speech-language pathologists can assist with instructional targets in the area of oral language, phonemic awareness, metacognition and reading comprehension. They point out that speech-language pathologists could apply their deep understanding of language and literacy in diverse sociolinguistic populations to serve as a professional resource and nexus for intervention providers. Given the dire levels of literacy attainment in South Africa and the complexity of the reading comprehension process, the national education authority needs to consider speech-language pathologists as integral members in a professional collaborative partnership.

5.8 Directions for Future Research

This study points to the need for on-going research in the area of working memory and reading comprehension. Of particular interest, would be further investigation of the role of Sentence Recall in reading comprehension as this study found it to predict reading comprehension, whilst other studies with younger children provided limited evidence of its relationship with literacy learning. This will add clarity to the role of the episodic buffer zone in the multi component model of working memory as it pertains to reading comprehension and will clarify the link between fluid and crystallised cognitive systems in reading comprehension.

This study sampled readers across the reading spectrum. Future studies should focus on the relationship between working memory and reading comprehension in poor comprehenders and those who fall in the poor fluency classification. These two groups of readers, with their converse decoding and comprehension skills, should yield additional insights into the relationship between working memory and reading comprehension.

Since the Reading Disabled group was distinguishable from the Skilled Reader group in this study by having smaller general working memory capacity (a finding corroborated in the literature), it would be of value to implement a working memory training programme, such as Jungle Memory, endorsed by Psychological Corporation. This programme trains working memory in the context of key learning activities in eight-weeks following which both working memory and reading comprehension could be re-assessed to determine if evidence of any beneficial effect occurred in reading comprehension. An alternative programme, Robomemo, produced by CogMed, which is a six week computerised training programme designed to enhance working memory through intensive practice, could be implemented as an alternative remediation measure.

Many of the studies reviewed focussed on working memory and reading comprehension in younger children. There is a dearth of studies investigating this relationship in older children (10 – 14 years) when literacy demands increase, to enable the reader to become critical, evaluative and hypothetical. Future studies should aim to target this age range to assess if working memory is a stable or dynamic construct in reading comprehension. It is suggested that a reading assessment tool, more sensitive to inferential or high-order thinking skills be used, as this would tap into the processing component of working memory and may yield more conclusive results. A measurement tool such as the Qualitative Reading Inventory (Leslie & Caldwell, 2001) is recommended, as the inferring required to comprehend oral and written texts is assessed in narrative and expository passages from pre primary to high school levels.

As the Qualitative Reading Inventory (Leslie & Caldwell, 2001) has an oral component, comprehension can be compared across listening and written modalities. Assessing working memory in learners and relating working memory to comprehension of oral and written texts, is anticipated to be a study which could yield interesting results.

The relationship between RAN, working memory and reading comprehension is also a topic of interest since RAN appears to rely on the visuo-spatial domain.

Finally, Alloway et al (2008) have recently devised a working memory rating scale for children. It would be of value to determine whether South African teachers correctly identify working memory deficits in their learners. When the data for this study was collected, educators in the participating schools expressed a willingness to learn more about working memory. Implementing a working memory rating scale would determine whether formal teacher-training is required in this area.

5.9 Conclusion

The field of working memory has been an area of active research since the 1970's when Baddeley and Hitch (1974) coined the term *working memory*, which involves short-term storage, as well as processing, manipulation, and transformation of stored information. Two major frameworks have been proposed to explain the functioning of working memory: the multi component model proposed by Baddeley and Hitch in 1974 and revised in 2000, adopted and reformulated by Gathercole and Pickering (2000). The second line of research, by proponents such as Just and Carpenter (1992) and Engle (1999a) have emphasised the M-capacity, which is particularly useful in explaining the complexity of tasks: the more pieces of information to be held in mind and manipulated, the more complex the task; the less automatic any component of a task is, the more space will need to be devoted to it in working memory. Though different in composition, these two models are viewed as complementary. Evidence of this was found in the current research, which concerned itself with the relationship between working memory and reading comprehension. It has been established that students with working memory problems perform below age expected levels in reading and maths, suggesting that low working memory skills constitute a high risk factor for educational underachievement. In addition, Alloway (2009) points out crucially, that evidence suggests that working memory is even more important to learning than other cognitive skills, such as IQ. The particular role that working memory plays in reading comprehension is a relationship that has not been extensively researched and findings concerning this relationship have been inconclusive. This study investigated the role played by working memory in reading comprehension in Grade 5 learners, whose reading ability varied, as it was the intention of this study to ascertain whether it was possible to identify distinct working memory profiles associated with different reading ability groups. The 80 Grade 5 English language learners were categorised into four reading ability groups based on their GORT-4 results and their working memory assessed, using the AWMA and CELF-4 Recalling Sentences Subtest.

The findings of this study revealed that working memory plays a role in reading comprehension. The Skilled Reader group displayed intact working memory profiles, attaining low to high average mean standard scores in the five memory components, whilst the Reading Disabled group performed in the low average range on V-STM, V-WM, VS-STM and VS-WM and below average on Sentence Recall. The Poor Comprehender group's performance resembled that of the Skilled Reader group and strong similarities in results were attained on V-STM and VS-WM. The Poor Fluency group experienced particular difficulty with VS-STM and Sentence Recall, scoring below average in these memory components, but the very small number of participants in this group affected the power of the analysis and the validity of comparative or correlational results with this group.

These findings gave evidence of the interplay between Baddeley's (2000) memory components and stressed the role of domain-specific and domain-general components of working memory in the complex task of reading comprehension. In addition, the findings highlighted the predictive role of Sentence Recall in reading comprehension, as well as that of V-WM. This pointed to reading comprehension being more reliant on the verbal domain of memory, drawing on the central executive and episodic buffer to allow for the full meaning of a text to be extracted, thereby involving a general working memory system also. Furthermore, the findings reflect the complementary nature of the two frameworks used to describe working memory. The results suggested that reading comprehension was affected by a learner's memory capacity. Learners with reduced memory capacity, as in the Reading Disabled group, performed poorly on decoding and comprehension. Learners in the Poor Comprehender group resembled the performance of Skilled Readers on two of the working memory components, when deficits were hypothesised, and this indicates that capacity differences account for individual variations.

As working memory alone did not account for variations in performance, the findings of this study confirm not only the complex nature of reading comprehension but also that the interaction of lower-order and higher-order cognitive processes is central to the achievement of successful reading comprehension. In addition, the interplay of fluid and crystallised forms of knowledge appears essential to authentic reading as demonstrated by the important role of the episodic buffer.

The findings have implications for assessment and intervention. The role of the speech and language therapist in an integrated, interdisciplinary team within the educational environment, is stressed. The use of working memory measures for assessment is validated, as a tool such as the AWMA, can be used to distinguish between groups of learners and can assist educators in differentiating ‘difference’ from ‘disorder’. On-going research into working memory remediation tools is necessary but Gathercole (2008) indicates that cognitive approaches to learning can bring exciting opportunities, not only for the experimental laboratory, but for practical application in the classroom context.

The area of working memory and reading comprehension will continue to be an area of active research. Dissecting the act of authentic reading into components promotes our conceptualisation of the comprehension process. This research has shown however, that one cannot lose perspective on the dynamic complexity of reading and in the words of Lundberg (1999: 27) “the full complexity and its difficulties can only be understood if a multitude of levels are recognised ranging from genes, brain structures, brain functions, sensory systems, phonological modules, and cognitive systems to early socialization, motivation, cultural capital and historical contexts”.

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APPENDICES

A. Clearance Certificate & Protocol No: HO 91107 from the Human Research Ethics Committee (Non-Medical) of the University of the Witwatersrand

B. Department of Education's Approval Form in respect to Conduct Research

C. Information Letter issued to the school principals

D. School Principal's Consent Form

E. Parent/Guardian Information Sheet

F. Parent/Guardian Consent Form

G. Minor Assent Form

H. Spreadsheet of Standard Scores from the GORT-4; Standard Scores and Composite Scores from the AWMA; and Scaled Scores for the Recalling Sentences Subtest on the CELF-4