

**Executive Functions in Early Adulthood: Data for the
Controlled Animal Fluency Test**

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DECLARATION

I, Jacqueline Evans-Barker, declare that the Doctor of Psychology (Clinical Neuropsychology) thesis entitled “Executive Functions in Early Adulthood: Data for the Controlled Animal Fluency Test” is no more than 40,000 words in length, exclusive of tables, figures, appendices, and references. This thesis contains no material that has been submitted previously, in whole or in part, for the award of any other academic degree or diploma. Except where otherwise indicated, this thesis is my own work.

Signature:.....

Date:.....

DEDICATION

This thesis is dedicated to the memory of my father *Graham Evans*, a great man who I love and miss very much.

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I would like to acknowledge the following people, without whom this thesis would never have been completed:

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TABLE OF CONTENTS

DECLARATION	i
DEDICATION	ii
ACKNOWLEDGEMENTS	iii
TABLE OF CONTENTS	iv
LIST OF TABLES	viii
LIST OF FIGURES	ix
LIST OF APPENDICES	x
ABSTRACT	xi
CHAPTER 1. EARLY ADULTHOOD: DEVELOPMENTAL CONTEXT	1
1.1. Executive Functions	2
1.1.1. Brain regions / systems and executive functions	3
1.1.2. Individual differences in neural mechanisms	6
1.2. Theories of Executive Function	8
1.2.1. Lezak	8
1.2.2. Barkley	9
1.2.3. The unity / diversity framework of executive function	12
1.3. Relationship Between Executive Functions and Other Cognitive Functions	13
1.3.1. Intelligence	15
1.3.2. Working memory	18
1.4. Relationship Between Executive Functions and Non-Cognitive Factors	21
1.4.1. Age	21
1.4.2. Education level	23
1.4.3. Socioeconomic status	24

1.5. Executive Functions in Early Adulthood	26
1.5.1. Brain injury	26
1.5.2. Mental illness	28
1.6. Assessing Executive Functions	30
1.7. Verbal Fluency Tests of Executive Function in Clinical Practice	32
1.7.1. Phonemic verbal fluency	35
1.7.2. Semantic verbal fluency	36
1.8. The Controlled Animal Fluency Test	39
1.8.1. CAFT performance in late adulthood	40
1.8.2. CAFT performance in early adulthood	41
1.9. Rationale for the Current Study	43
1.10. Aims and Hypotheses	44
CHAPTER 2. METHOD	46
2.1. Participants	46
2.2. Assessment Instruments	46
2.2.1. Interview protocol	46
2.2.2. Executive function	47
<i>Controlled Animal Fluency Test</i>	47
<i>Controlled Oral Word Association Test</i>	48
<i>Trail Making Test</i>	48
2.2.3. Intellectual functioning	48
<i>Wechsler Abbreviated Scale of Intelligence</i>	48
2.2.4. Attention and working memory	49
<i>Digit Span (WAIS-IV)</i>	49
2.3. Procedure	49

CHAPTER 3. RESULTS	51
3.1. Data Analysis	51
3.2. Demographic Data	51
3.2.1. Gender	52
3.2.2. Language background	53
3.3. Scores for All Dependent Variables	54
3.4. Tests of Hypotheses	55
3.4.1. Hypothesis one	55
3.4.2. Hypothesis two	55
3.4.3. Hypothesis three	56
3.4.4. Hypothesis four	56
3.4.5. Hypothesis five	56
3.4.6. Hypothesis six	57
3.5. Regression Analysis of Cognitive Variables on CAFT Conditions	57
3.5.1. Regression analysis of cognitive variables on CAFT Auto	58
3.5.2. Regression analysis of cognitive variables on CAFT Size	58
3.5.3. Regression analysis of cognitive variables on CAFT Alphabet	58
3.6. Controlled Animal Fluency Test Normative Data	59
CHAPTER 4. DISCUSSION	60
4.1. Hypothesis One	60
4.2. Hypothesis Two	62
4.3. Hypothesis Three	64
4.4. Hypothesis Four	65
4.5. Hypothesis Five	66
4.6. Hypothesis Six	67
4.7. Controlled Animal Fluency Test Normative Data	69

4.8. Strengths and Limitations	70
4.9. Future Directions	72
4.9.1. Demographic issues	72
4.9.2. Cross cultural issues	73
4.9.3. Modern theories of intelligence	73
4.9.4. Neural mechanisms underlying CAFT performance	74
4.10. Conclusion	74
REFERENCES	76

LIST OF TABLES

Table 1.1		5
	<i>Regional Frontal Lobe Specialisation in Neuropsychological Processes</i>	
Table 1.2		7
	<i>Neural Mechanisms of Executive Function and Their Contribution to Cognitive and Affective Domains</i>	
Table 1.3		31
	<i>Executive Function Component and Associated Measures</i>	
Table 1.4		43
	<i>Normative Data Popp (2003)</i>	
Table 3.1		52
	<i>Overall Sample Demographics</i>	
Table 3.2		52
	<i>Demographic Variables on the Basis of Gender for the Whole Sample</i>	
Table 3.3		53
	<i>Language Background of Sample</i>	
Table 3.4		54
	<i>Whole Sample Dependent Variables</i>	
Table 3.5		55
	<i>Correlations Between the CAFT and FSIQ</i>	
Table 3.6		56
	<i>Correlations Between the CAFT and Demographic Variables</i>	
Table 3.7		59
	<i>Controlled Animal Fluency Test Normative Data</i>	

LIST OF FIGURES

<i>Figure 1.1.</i>	11
Barkley's theoretic model of executive	
<i>Figure 1.2.</i>	13
The Unity / Diversity framework of executive function	
<i>Figure 1.3.</i>	19
Baddeley's model of working memory	

LIST OF APPENDICES

APPENDIX A	87
Interview Protocol	
APPENDIX B	89
Controlled Animal Fluency Test (CAFT) Instructions	
APPENDIX C	91
Controlled Oral Word Association Test (COWAT) Instructions	
APPENDIX D	93
Trail Making Test (TMT) part A and part B	
APPENDIX E	99
Research Ethics Approval by Victoria University Human Research Ethics Committee	
APPENDIX F	101
Information to Participants Form	
APPENDIX G	104
Consent Form for Participants	

ABSTRACT

Assessment tools that accurately assess executive functions in early adulthood are important for clinical practice, particularly given factors that can affect the executive functions, such as brain injury and mental illness, are relatively common during this developmental period. The aim of the current study was to investigate a more recently refined measure of executive function, the Controlled Animal Fluency Test (CAFT) in a non-clinical sample of young adults. Relationships between performance on the CAFT and other executive measures and cognitive measures were examined along with the relationship of CAFT measures to demographic factors. Further normative data for the CAFT for young adults were also obtained. Sixty individuals (27 male & 33 female) aged 19 to 40 years ($M = 31.2$ years, $SD = 6.03$) participated. They were screened for brain injury, serious illness, neurodevelopmental disorder, and psychotropic medication according to a structured interview protocol. Participants were tested with the CAFT, the Controlled Oral Word Association Test (COWAT), the Wechsler Abbreviated Scale of Intelligence (WASI), the Trail Making Test (TMT), and the Digit Span subtest from the Wechsler Adult Intelligence Scale – Fourth Edition (WAIS-IV). Results showed significant correlations between the three conditions of the CAFT and FSIQ; CAFT Size and part B of the Trail Making Test; CAFT Alphabet and the COWAT; and all three conditions of the CAFT and the demographic variables of SES and number of years of education. The current findings highlight the interconnectedness of executive functions and other cognitive constructs such as FSIQ and reinforce the importance of accounting for demographic variables when developing normative data sets. Most importantly, however, the results of the current study provide evidence that the CAFT is a clinically useful measure of executive function with the early adulthood population.

CHAPTER 1. EARLY ADULTHOOD: DEVELOPMENTAL CONTEXT

For many individuals early adulthood, which is generally viewed by developmental psychologists as the period from 20 years to 40 years is a time of change, uncertainty, and increasing competency in dealing with their world. For most people this is the period of peak physical fitness and health. Factors such as poor diet, sexually transmitted diseases, and substance use or abuse, however, can negatively impact physical development during this stage of the lifespan. From a social and emotional perspective independence from parental figures is often sought, lifestyle choices are made, education and training are undertaken, and careers embarked upon. The changing nature of relationships with family, friends, and colleagues can be a source of pleasure or sadness as can the development of intimate relationships.

Early adulthood is not generally viewed as a period of life in which major age-related cognitive changes occur. Salthouse (2004) states "it is often assumed that age-related effects on cognitive functioning are small, are limited to aspects of memory, begin relatively late in adulthood, and possibly affect only some people" (p. 140). Salthouse, however, argues that these assumptions may be untrue. Data from several of his studies shows that improvements or increases in some skills are observed as a result of aging, such as in general knowledge and vocabulary. Subtle declines in other skills, however, were seen such as memory functions, cognitive speed, and reasoning. These changes, whether they were improvements or declines were clearly evident before the age of 50 years (Salthouse).

However, it is well recognised that cognitive changes during early adulthood can also occur due to brain disease such as tumours and the associated treatment, degenerative diseases such as Multiple Sclerosis or Huntington's disease, psychological/psychiatric disorders such as depression and schizophrenia, developmental disorders such as cerebral palsy or intellectual disability, toxins such as lead, metabolic conditions or major systemic disease

such as diabetes, and more commonly, acquired brain injury. Cognitive skills that are commonly affected by these processes are the executive functions.

1.1. Executive Functions

'Executive Functions' are commonly referred to in neuropsychological research, literature, and clinical practice. The skills that comprise the executive functions, however, are quite often characterised differently by different authors. Alvarez and Emory (2006) describe executive functions as "higher-level' cognitive functions involved in the control and regulation of 'lower-level' cognitive processes and goal-directed, future-oriented behaviour" (p.17). Banich (2009) lists specific functions or skills that comprise executive function, including sequencing, inhibitory control, task switching, freedom from distraction, appropriate utilisation of feedback, maintaining mental set, and responding appropriately to novel situations. Anderson (2002) suggests that "anticipation, goal selection, planning, initiation of activity, self-regulation, mental flexibility, deployment of attention, and utilisation of feedback" (p.71) are the primary components. One of the more commonly cited definitions of executive functions is that of Lezak (1982) who describes executive functions as "those mental capacities necessary for formulating goals, planning how to achieve them, and carrying out the plans effectively" (p. 281).

Despite a lack of consensus regarding the definition of executive functions there does appear to be some agreement regarding the complex nature of executive functions and their importance in all aspects of human life. It is the executive functions that allow us to plan and execute our day, responding appropriately to unexpected or novel situations. Executive functions enable us to see a complex task through from conception to completion (Jurado & Rosselli, 2007).

1.1.1. Brain regions / systems and executive functions

Executive functions are often referred to in the literature as 'Frontal Functions', that is the group of skills that comprise the executive functions are thought to be mediated by the frontal lobes (Stuss & Alexander, 2000; Stuss & Levine, 2002). Stuss and Alexander, however, point out that there are many difficulties in understanding the relationship between the frontal lobes and executive functions. Furthermore, there is some disagreement in the literature about the relationship between the frontal lobes and the executive functions.

The frontal lobes are thought to be the mediators of executive functions as damage to this area often result in executive deficits (Banich, 2009; Grattan & Eslinger, 1991). Additionally, neuroimaging has demonstrated activation of the frontal lobes during tasks that are executive in nature (Jurado & Rosselli, 2006). However, it is important to note that the frontal lobes can be subdivided into three separate regions, each of which is thought to be functionally different. These are, the primary motor cortex, the premotor cortex, and the prefrontal cortex (Nolte, 2002), with the prefrontal cortex being identified in many studies as the region primarily involved in mediating executive functions (Jurado & Rosselli, 2007).

The prefrontal cortex itself is further divided into three distinct regions based on neuroanatomy and cortical architecture; these are the dorsolateral, ventromedial, and orbitofrontal regions (Stuss & Levine, 2002). These three distinct regions and their corresponding subcortical circuits are suggested to be functionally different from one and other. The dorsolateral prefrontal cortex is largely involved in cognitive processes of memory, attention, (Stuss et al., 2000) spatial skills and reasoning abilities; the skills that comprise the executive functions (Stuss & Levine). The ventromedial area on the other hand is implicated in judgement and decision making, whilst orbitofrontal regions play a role in affective processing.

Stuss and Alexander (2000) present their conceptual review on the relationship between executive functions and the frontal lobes based on information they have gathered in several studies using patients with focal frontal lesions. Their collated data supports the position that there is not a singular executive function nor is there a “frontal homunculus” (p. 291). They contend that distinct areas within the frontal lobes are related to specific processes. They do, however, suggest that the use of complex tasks of executive function may activate several of the processes in multiple frontal areas thereby giving the impression that the frontal lobes are “functionally homogeneous” (p. 296). Stuss and Alexander also suggest that, due to their strong connection to the limbic system, the frontal lobes primary task may not be executive control. The development of personality, self-awareness, consciousness, social and affective functioning may be the key task of the frontal lobes (Stuss & Alexander, 2000).

In order to investigate the concept of executive functions and its relationship to the frontal lobes, Alvarez and Emory (2006) conducted a meta-analysis of studies examining the effect of various brain lesions on neuropsychological test performance. Results indicated that neuropsychological tests that purport to assess executive functions, such as the Wisconsin Card Sorting test (WCST), verbal fluency task, and the Stroop Test, were sensitive to frontal lobe damage but were not specific. The authors conclude that they found “inconsistent support for the historical association between executive functions and the frontal lobes” (p. 33). Alvarez and Emory suggest that the high sensitivity but poor specificity of the neuropsychological measures to frontal lobe damage indicates that other brain regions in addition to the frontal lobes are required for appropriate executive functioning.

Grattan and Eslinger (1991) conducted a systematic review of clinical and experimental studies of frontal lobe damage in both children and adults. One of the purposes of the review was to help clarify the nature of frontal lobe processes, how they develop and change throughout the lifespan whilst

supporting cognitive, emotional, and social functions. The authors contend that there is evidence to support the division of the frontal lobes into superior mesial, orbital, and lateral sectors and that each of these divisions supports different, but interactive, neuropsychological processes, many of which can be identified as executive functions. The frontal lobe regions and their associated neuropsychological processes described by Grattan and Eslinger are shown in Table 1.1.

Table 1.1
Regional Frontal Lobe Specialisation in Neuropsychological Processes
(Grattan & Eslinger, 1991, p. 304).

Neuropsychological Process	Measure	Frontal Lobe Specialisation
Cognitive flexibility	Establish/shift response set tasks of divergent production	Lateral
Self-regulation	Self-ordered pacing, go-no go paradigms conflicting stimuli vigilance-divided attention, motor programming	Lateral, mesial
Environmental judgements	Environmental independence Initiation-motivation Recency discrimination frequency judgement cognitive estimation	Orbital, polar, inferior Mesial lateral
Memory	Contextual memory Spatial-temporal contexts temporal ordering organise-categorise conditional associative learning Vulnerability to interference Activation of self knowledge	Posterior ventromedial Lateral Orbital Mesial
Language	Aspects of encoding Fluency-spontaneity paralinguistic skills Coherence of narrative	Lateral, superior mesial Orbital

1.1.2. Individual differences in neural mechanisms

An increasing trend over the past 10 years in cognitive neuroscience research is to investigate individual differences in neural mechanisms that mediate the cognitive functions. Braver, Cole, and Yarkoni (2010) conducted a review of a number of studies that have employed variety of techniques, such as functional magnetic resonance imaging (fMRI) and electroencephalography / event related potential (EEG / ERP), to examine the neural mechanisms of executive functions, the contribution of these mechanisms to other cognitive and affective domains, and factors that may contribute to the individual differences seen. A summary of Braver et al.'s review of the role of neural mechanisms of executive function across the cognitive and affective domains of working memory, anxiety, and emotional regulation is shown in Table 1.2.

Table 1.2
Neural Mechanisms of Executive Function and Their Contribution to Cognitive and Affective Domains (adapted from Braver et al., 2010).

Cognitive / Affective Domain	Neural mechanism	Contribution
Working Memory (WM)	Lateral Inferior Parietal Sulcus (IPS)	Core storage system Maintains integrity of WM representations
	Lateral Prefrontal Cortex (PFC)	Attentional filtering Excitatory drive that can increase IPS capacity
	Basal Ganglia & PFC	Increased WM capacity due to dopaminergic modulation
Trait Anxiety	Dorsolateral Prefrontal Cortex (DLPFC)	Anxiety associated with reduction in DLPFC activation
	PFC	Poor cognitive control of anxiety due to reduced sustained but increased transient activation
Emotion Regulation	Lateral PFC	Mechanisms contribute to emotional regulation by providing a top down attentional bias over emotional responses
	PFC-Amygdala relationship	Mediated differently in depressed versus nondepressed individuals, regulate differences in autonomic arousal, and related to regulation success

1.2. Theories of Executive Function

1.2.1. Lezak

Lezak (1982) argues that executive functions are at the core of all human activities that are socially oriented, useful, and creative, that it is the executive functions that allow an individual to set a goal and achieve that goal. With this in mind Lezak conceptualises executive functions as having four major components (1) goal formulation; (2) planning; (3) carrying out activities; and (4) effective performance.

Lezak's (1982) first category of executive functions, goal formulation, is the ability of an individual to set a goal or act with intent. Goal formulation, which was subsequently renamed volition (Lezak, Howieson & Loring, 2004), encompasses an awareness of self, including physical, social, and situational awareness. Lezak makes a clear distinction here between purposive, goal-directed motivation that she views as an executive function, and the instinctive impulses and reflexes of infants and "subhuman animals" (p. 286). The second component identified by Lezak (1982) is planning. Lezak views planning as being comprised of multiple skills including sustained attention, the ability to view the environment and oneself objectively, the capacity for abstract thinking, the ability to generate ideas and think of alternatives, and to make choices in order to carry out a goal.

Carrying out activities, which has been renamed purposive action (Lezak et al., 2004), follows on from planning in that, it is viewed by Lezak (1982) as the "translation of an intention or a plan into self-serving, productive, activity" (p. 290). The capacities involved in this component include the ability to initiate and maintain, switch and stop a complex behavioural pattern in an appropriate manner (Lezak, 1982). The final component in Lezak's model of executive functions is effective performance. This is viewed as an individual's

ability to monitor their behaviour, making corrections where necessary, and to adjust the intensity and pace of the delivery where appropriate.

1.2.2. Barkley

Barkley (2001) proposes an evolutionary view of the development and conceptualisation of executive functions, believing that it's important to understand how executive functions have developed over time from the skills seen in the early primates that evolved into humans. In adopting an evolutionary perspective Barkley attempted to define the executive functions and to answer the question "why is there executive functioning" (p. 2).

The theoretical model of executive function proposed by Barkley (1997; 2001) encompasses many of the abilities noted as executive functions by other researchers previously discussed. Barkley's model, however, is comprised of five major executive functions and their associated component processes, (1) response inhibition; (2) non-verbal working memory; (3) verbal working memory; (4) self-regulation of emotion and motivation; and (5) reconstitution. Barkley (2001) believes that these major executive functions develop throughout an individual's life from being overt forms of behaviour in infancy and childhood to being covert forms of behaviour in adulthood. Moreover, Barkley contends that this overt to covert transition has occurred throughout human evolution as an adaptive mechanism, after all, executive functions are the capacities required for self-directed, goal oriented behaviour.

Response inhibition is the first of the major executive functions outlined by Barkley (2001). It has a role in inhibiting prepotent responses, interrupting ongoing responses, and in providing a form of interference control. Response inhibition enables skills of impulse control, delay of gratification, and appropriate regulation of activity level (Barkley, 2000).

Non-verbal working memory is the second major executive function described by Barkley (2001) and is involved in retrospective and prospective functions. This enables an individual to have some sense of the continuity of time. It also enables a person to be able to hold information, such as events, in mind. Verbal working memory, the third executive function, is involved in covert receptive and expressive language and enables self-talk such as self reflection and instruction, reading comprehension, and assists with rule-governed behaviour (Barkley, 2000; Barkley, 2001).

Barkley (2001) proposes that self-regulation of affect/motivation is, as the name suggests, involved in goal directed behaviour and motivation as well as affective regulation and arousal. These processes contribute to an individual's level of motivation, their ability to persist with a task, and their ability to control their emotions. The fifth major executive function outlined by Barkley is reconstitution. This is involved in the analysis and synthesis of behavioural patterns, fluency, mental flexibility, and the ability to generalise (Barkley, 2000; Barkley, 2001). See Figure 1.1 for Barkley's theoretical model of executive function (1997).

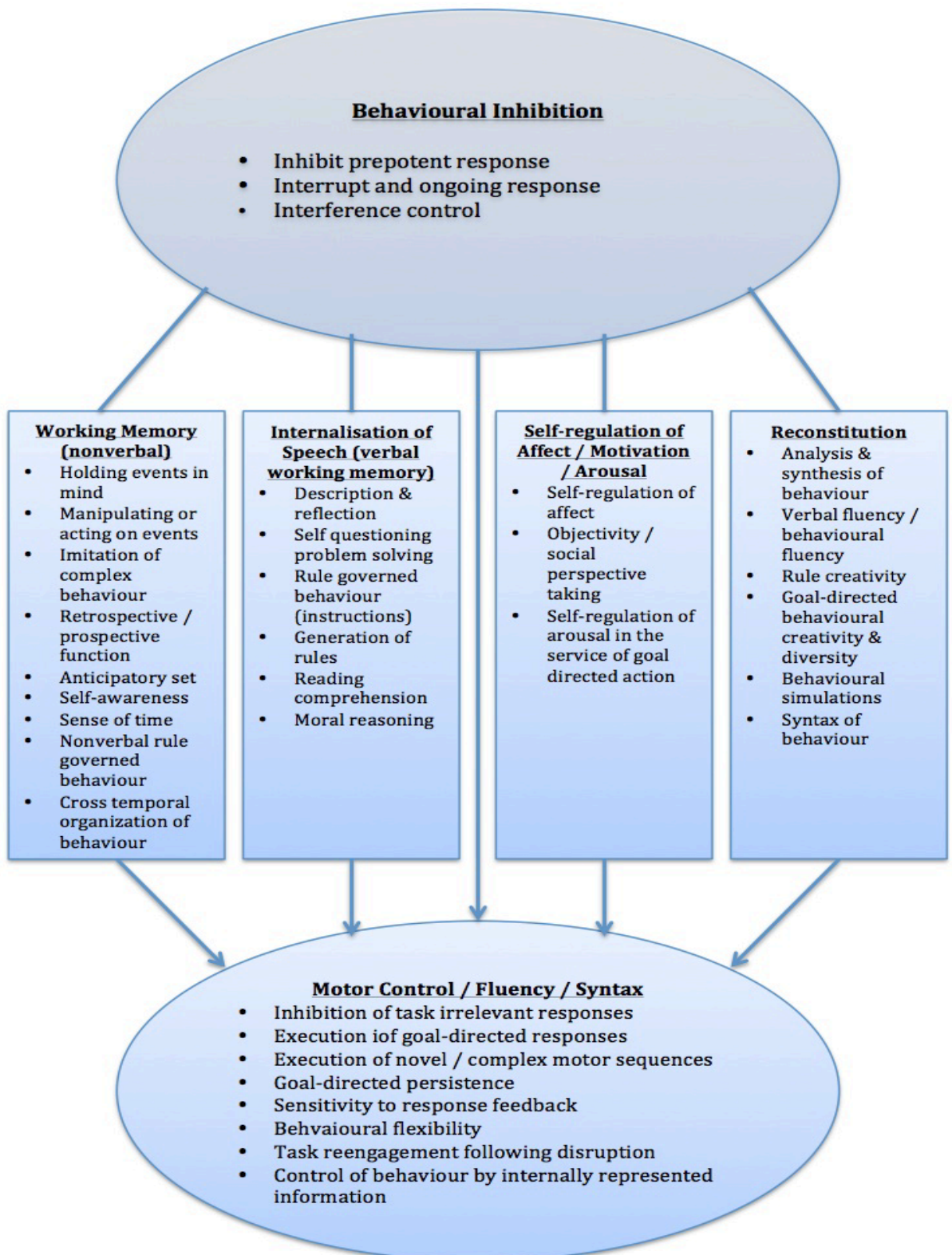


Figure 1.1. Barkley's theoretical model of executive function (Barkley, 1997).

1.2.3. The unity / diversity framework of executive function

Miyake et al. (2000) recognised the need to provide evidence for a theory of executive function that explains how executive functions are organised and what contribution is made by specific skills, the executive subcomponents, to the whole. With a focus on three specific executive functions, these being shifting, defined as the ability to switch between tasks, updating is defined as the ability to add or delete information in working memory, and inhibiting, defined as the ability to suppress a dominant or automatic response Miyake et al. employed an individual differences approach to “examine the extent of unity or diversity of these three executive functions” (p. 54).

Miyake et al. (2000) tested 137 participants on a variety of commonly used executive function tasks and on tasks that were thought to specifically measure the three target executive functions. The results revealed that the three target executive functions of shifting, updating, and inhibiting are separable functions but are correlated. Miyake et al. suggest that this finding supports the view that executive functions have both unity and diversity.

Since the original Miyake et al. (2000) study, Friedman et al. (2006), Friedman et al. (2008), and Friedman, Miyake, Robinson and Hewitt (2011) have further explored individual differences in executive functions, using a range of samples including twin studies, with a particular focus on shifting, updating, and inhibiting. They have sought to identify the underlying cognitive and biological factors that contribute to the individual differences seen in executive functions and provide further support for the view that executive functions have both unity and diversity. Miyake and Friedman (2012) provide a review of these past studies and provide four main conclusions. Firstly, the authors conclude that executive functions do have both unity and diversity, “that is, different EFs correlate with one another, thus tapping some common underlying ability [unity], but they also show some separability [diversity]” (Miyake & Friedman, 2012). This conclusion lends support for a new

framework of executive function, the Unity / Diversity framework which is depicted in Figure 1.2.

The second conclusion drawn by Miyake and Friedman (2012) in their review is that genetics is a significant contributor to individual differences seen in executive function. Thirdly, they conclude that the “unity” component of executive function may be a good predictor of differences seen in socially oriented behaviours. Finally, Miyake and Friedman found that individual differences seen in executive functions have some constancy throughout development.

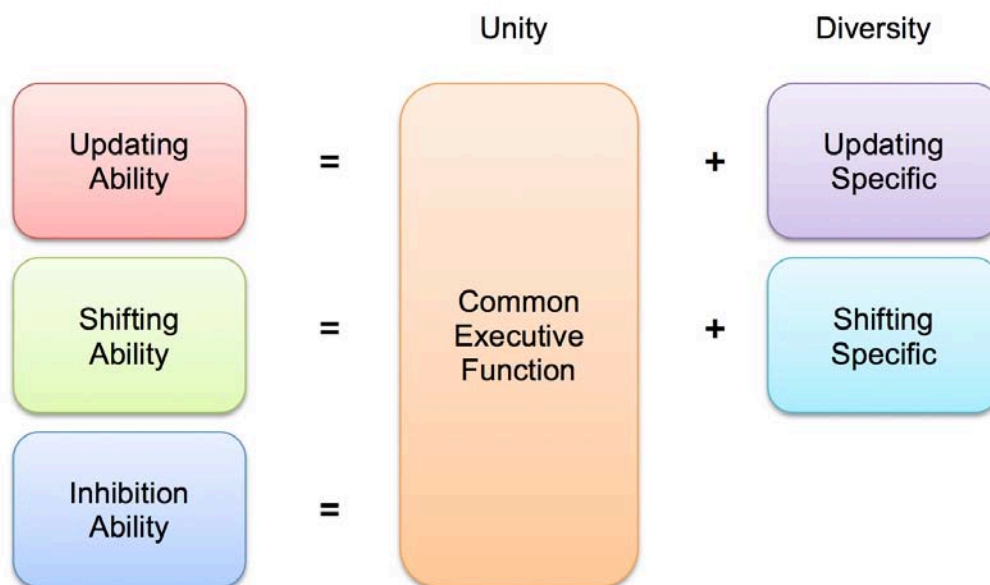


Figure 1.2. The Unity / Diversity framework of executive function. (Miyake & Friedman, 2012, p. 11).

1.3. Relationship Between Executive Functions and Other Cognitive Functions

There appears to be some difference of opinion as to whether executive functions should be considered cognitive functions or whether they should be viewed as a separate but interrelated concept. Reynolds and Horton (2008),

for example, believe that executive functions differ somewhat from other cognitive functions as they represent a group of mental functions rather than a single construct. They suggest that executive functions can be viewed as being more 'active' than other cognitive functions as executive functions are involved in carrying out a goal directed task. Put simply, executive functions are employed when we are actively doing something. Conversely, other cognitive functions tend to be more passive and involved with general knowledge and retaining facts.

Lezak et al. (2004) subscribes to a similar view to Reynolds and Horton (2008) in their conceptualisation of executive functions and how they are related to other cognitive functions. Lezak et al. suggest that executive functions are involved in the "how or whether a person goes about doing something" (p. 35) whilst other cognitive functions are generally concerned with "what or how much" (p. 35). Lezak et al. explain their position further by describing the functional impairments that are likely seen in individuals with a specific cognitive deficit in comparison to executive dysfunction. Lezak et al. contend that cognitive deficits usually result in a specific impairment and that as long as the executive functions are still intact the individual can continue to function relatively well. On the other hand, executive deficits generally present globally, given their role in coordinating or directing the specific cognitive functions. Impaired executive functions may result in clinically significant impairments in adaptive behaviour despite intact cognitive functions.

Alvarez and Emory (2006), however, refer to executive functions as high-level cognitive functions. These high-level cognitive functions or "supervisory cognitive processes" (p. 17) are involved in directing and organising lower-order cognitive functions in the implementation of a goal-directed task. Furthermore, these high-level cognitive functions, the executive functions, are reliant on the sound functioning of the lower-level cognitive functions such as attention, visuospatial processing, and memory.

1.3.1. Intelligence

Executive functions are conceptualised as a group of interrelated functions that are involved in the performance of goal-directed, problem solving tasks and have been identified as being imperative for independent, adaptive functioning in all aspects of life (Lezak et al., 2004). Given their relationship to other aspects of cognition some authors (Obonsawin et al., 2002; Piguet et al., 2002; Salthouse, 2005; Unsworth et al., 2009) have investigated the relationship between executive functions and another important cognitive concept, general intellectual functioning or intelligence.

A contemporary theory of intelligence is the Cattell-Horn-Carroll theory of cognitive abilities (CHC theory). The CHC theory is an amalgamation of the Cattell-Horn, *Gf*, *Gc* model of intelligence, which proposed that fluid intelligence included skills such as novel reasoning and problem solving and that crystallised intelligence constituted acquired knowledge, with the more recent three-stratum theory by Carroll (1993).

The CHC theory has undergone a number of modifications in the years since its inception with the current CHC model consisting of nine broad abilities, these being: crystallised intelligence (*Gc*); fluid intelligence (*Gf*); quantitative reasoning (*Gq*); reading and writing ability (*Grw*); short-term memory (*Gsm*); long-term storage and retrieval (*Glr*); visual processing (*Gv*); auditory processing (*Ga*) and processing speed (*Gs*). The CHC theory assumes that the exact nature of intelligence can be derived through analysing scores obtained on variety of cognitive tests, therefore, this theory is considered a psychometric theory of intelligence (McGrew, 2004).

In their study of 234 young adults, Friedman et al. (2006) examined the relationships that exist between executive functions and intelligence, as measured by the Wechsler Adult Intelligence Scale – Third Edition (WAIS-III; Wechsler, 1997) FSIQ, and considered the abilities of fluid intelligence (*Gf*)

and crystallised intelligence (*Gc*) as originally described in the dichotomous Cattell-Horn model of intelligence and more recently by the CHC theory. Specifically, Friedman et al. investigated three distinct executive functions, of inhibiting, updating, and shifting. Friedman et al. found that inhibiting, updating, and shifting were related to the three different measures of intelligence with updating being the most closely related. However, when correlations between the three executive measures were considered, only updating was still found to be significantly related to intelligence. The authors also found no difference in association between *Gf*, *Gc* and WAIS-III FSIQ with the three executive measures. These findings highlight the importance of working memory (updating) with regard to intelligence and also suggest that *Gf* is not more closely related to executive functions than overall intelligence or *Gc*. The findings of Friedman et al. with regard to the relationship between *Gf* and executive functions are in contrast to those of Decker, Hill, and Dean (2007).

In order to investigate the association between executive functions and *Gf*, or fluid reasoning abilities, Decker et al. (2007) administered three executive tasks, the Category Task (CT), the Trail Making Test part B (TMT-B), and the Wisconsin Card Sorting Test (WCST), and three subtests of the Woodcock Johnson – Revised Fluid Reasoning Cluster, to individuals aged from 19 to 45 years. Their findings strongly support an association between executive functions and fluid reasoning and indicate that executive function tests and tests of fluid reasoning may be measuring the same skills (Decker et al.,). These findings have significant implications from a theoretical perspective. If these measures are in fact tapping into the same processes it suggests that executive functions and what we view as intelligence may be better conceptualised as the same construct. The finding that measures of executive function and fluid reasoning may be interchangeable also has implications from a clinical practice perspective. The time it takes to assess a patient may be greatly reduced if the same assessment tools can be used to measure aspects of executive functions and intelligence.

In a recent study Davis, Pierson, and Finch (2011) contend that there is still some uncertainty within the literature regarding the relationship between executive functions and intelligence. In order to help clarify this they administered the Delis Kaplan Executive Function System (D-KEFS) and the Wechsler Adult Intelligence Scale – Third Edition (WAIS-III) to 63 participants aged between 18 and 38 years. Their findings revealed a strong association between performance on the D-KEFS and WAIS-III suggesting an overlap in those skills thought to be executive in nature and those that are thought to represent intelligence. Despite this strong association, however, the D-KEFS was found to measure skills not accounted for by the intelligence measure. The authors conclude that in clinical settings executive functions should be independently assessed “although it may be possible to extrapolate an idea of broad executive functioning from the WAIS-III” (Davis et al., p. 67).

In considering many of the individual subtests that make up the WAIS-III and the skills that are required to undertake these tasks one could argue that as item difficulty increases in many subtests performance relies more heavily on the executive functions. For example, although the Block Design subtest is viewed as a measure of visuospatial and construction skills, executive skills are necessary for successful performance as an individual has to plan, arrange, and organise the blocks according to a particular pattern. Good performances on the processing speed tasks are dependent on the ability to sequence and order visual information and are also reliant on good planning and monitoring skills. Persistence and motivation are also required to undertake the processing speed tasks. The Similarities and Matrix Reasoning subtests, on the other hand, require cognitive flexibility, which is also viewed as an executive function. The Digit Span and Arithmetic subtests, which form a measure of working memory, are thought to be particularly reliant on the executive functions.

1.3.2. Working memory

In 1974 Baddeley and Hitch set out to investigate memory, which at the time was viewed as a dichotomous system comprised of short-term memory (STM) and long-term memory (LTM). More specifically, Baddeley and Hitch's initial question was "what is short-term memory for?" (Baddeley & Hitch, 1974, p. 86). From this study Baddeley and Hitch proposed a three-component model of working memory that replaced the existing STM model. This resulted in a working memory-LTM view of human information processing rather than the existing STM-LTM model.

Baddeley (1992) defines working memory as "a brain system that provides temporary storage and manipulation of information necessary for such complex cognitive tasks as language comprehension, learning, and reasoning.....Working memory has been found to require the simultaneous storage and processing of information" (p. 556). The original model of working memory as proposed by Baddeley and Hitch (1974) included an attentional control system that they termed the 'central executive'. Two subsystems, the phonological loop, which held speech-based information, and the visuospatial sketchpad, which held visual information, aided this central executive. Since Baddeley and Hitch originally proposed this three-component model of working memory there have been a number of modifications, the most recent by Baddeley in 2000.

In an effort to account for a number of factors that were not captured by the original Baddeley and Hitch (1974) model of working memory, Baddeley (2000) proposed a revised model that incorporates a fourth component, the episodic buffer. Baddeley states that the episodic buffer is "a limited-capacity temporary storage system that is capable of integrating information from a variety of sources" (p. 421). The episodic buffer is controlled by the central executive and provides a means of communication or a point of interaction between the visuospatial sketchpad and the phonological loop, which are

viewed as slave systems, and episodic long-term memory (LTM). See Figure 1.3 for Baddeley's (2000) model of working memory.

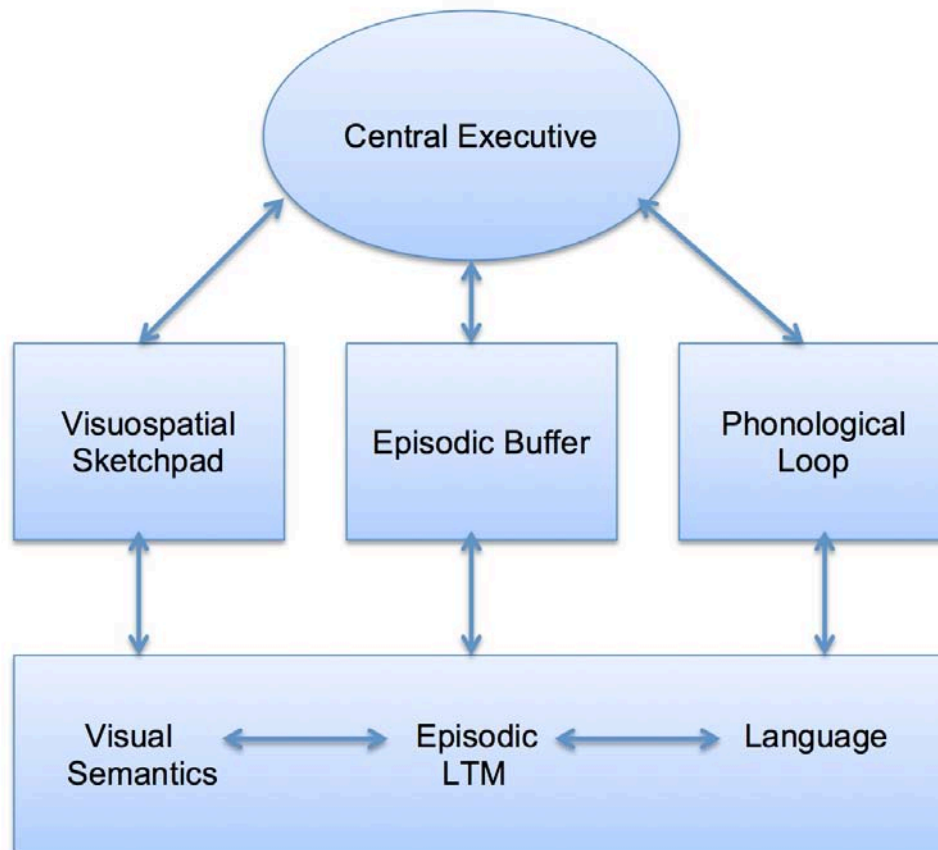


Figure 1.3. Baddeley's model of working memory (Baddeley, 2000).

The relationship between executive functions and working memory was investigated by Rende, Ramsberger, and Miyake (2002). The aim of their study was to examine the contribution of different working memory components, based on the Baddeley and Hitch (1974) model, on the performance of phonemic and semantic verbal fluency tasks. The results of this study suggest that it is not only the central executive component of the Baddeley & Hitch model of working memory that plays a key role in the successful performance of verbal fluency tasks but that the subcomponents of visuospatial sketchpad and phonological loop also play an important supporting roles.

Specifically, Rende et al. (2002) found that the visuospatial sketchpad was particularly associated with performance of semantic fluency tasks. Rende et al. suggest that this is due to individuals commonly using visualisation strategies to complete this task. Therefore, the ability to temporarily store and manipulate visual information is important for successful completion of semantic verbal fluency tasks. Conversely, the working memory component of phonological loop was found to be particularly associated with performance on phonemic fluency tasks. Again the authors propose that this is due to the search-by-initial-letter strategy commonly employed by individuals undertaking phonemic verbal fluency tasks and the need for individuals to be able to temporarily store and manipulate verbal information for successful completion.

In clinical practice and in research, span tasks, such as operation span, counting span, and reading span are commonly used as measures of working memory (Conway et al., 2005; Engle, 2002; Hill et al., 2010; Kane et al., 2004). Conway et al. (2005) suggest that span tasks of working memory have been designed with Baddeley and Hitch's (1974) model of working memory in mind. They have been designed to assess immediate memory capacity, or short-term memory, whilst actively engaging in ongoing mental activity (Conway et al.). One of the most frequently used span tasks is the Digit Span test which is purported to be a measure of auditory-verbal attentional capacity and working memory (Ostrosky-Solís & Lozano, 2006).

The Digit Span test has two components, Digits Forward and Digits Backward. In the Digits Forward condition individuals are asked to repeat back strings of numbers that increase in length from two digits to nine digits. In the Digits Backwards condition individuals are asked to repeat back strings of numbers in the reverse order that increase in length from two to eight digits. In both conditions the task is discontinued if two trials of a number sequence are failed (Wechsler, 1997, 2008). In considering Baddeley and Hitch's (1974) model of working memory, the Digits Forward condition, the measure of

immediate memory capacity, would be subserved by the phonological loop whilst the Digits Backward condition, the measure of working memory, would utilise the central executive in addition to the phonological loop (Ostrosky-Solís and Lozano, 2006).

1.4. Relationship Between Executive Functions and Non-Cognitive Factors

Understanding the impact that demographic variables can have on cognitive functions and neuropsychological test performance is vitally important to ensure accurate and appropriate collation of normative data (Lezak, 2004; Mitrushina, Boone, Razani & D'Elia, 2005). Some of the demographic variables that are reported to affect executive functions in particular include age, education level, and socioeconomic status (Coman et al., 1999; Gladsjo et al., 1999; Saykin et al., 1995; Sherrill-Pattison, Donders & Thompson, 2000; Unverzagt et al., 1996; Welsh-Bohmer et al., 2009; Wiederholt et al., 1993).

1.4.1. Age

In 'normal' aging, the structural and functional efficiency of the brain changes. There is grey and white matter volume loss, neuronal numbers decrease, as do the number of neuronal connections, whilst ventricular volume and intracranial space increase (Vinters, 2001). Alterations in neurotransmitter activity are also seen (Ferrier & McKeith, 1991). Whilst these changes occur throughout the brain they are particularly seen within the prefrontal cortex (Treitz, Heyder & Daum, 2007). As the frontal lobes are particularly implicated in 'normal' aging it is logical to assume that changes in executive functioning would also be noted over time. Whilst numerous studies (e.g., Nathan, Wilkinson, Stammers & Low, 2001; Yuspeh, Vanderploeg, Crowell & Mullan, 2002; Caccappolo-Van Vliet et al., 2003; Buckner, 2004) have highlighted a decline in executive functions as a consequence of pathological aging the

literature investigating executive functions in 'normal' or nonpathological aging is somewhat lacking in comparison. Therefore, the nature and course of executive changes in normal aging is less clear (Treitz et al.).

Collie, Shafiq-Antonacci, Maruff, Tyler, and Currie (1999) investigated the relationship between age and neuropsychological test performance using the battery developed by the Consortium to Establish a Registry for Alzheimer's Disease (CERAD), which includes the domain of executive function, on a healthy Australian sample aged 44 years and above with a mean age of 63.1 years (SD = 9.02). Age was found to have a significant effect on neuropsychological test performance with individuals in the older age group performing more poorly on executive measures than individuals in the younger age group.

Hester, Kinsella, Ong, and McGregor (2005) also investigated the impact of demographic variables, including age, on performance on the Trail Making Test, which is said to assess the executive component of cognitive flexibility/set shifting (Kortte, Horner & Windham, 2002). As with Collie et al. (1999), age had a significant influence on test performance, specifically, older participants performed more poorly than their younger counterparts (Hester et al.).

In a more recent and comprehensive study investigating executive changes during normal aging, Treitz et al. (2007) employed a cross-sectional approach utilising four successive age groups encompassing the 20 to 75 year age range. Participants were assessed using a variety of tasks that are said to measure the executive components of strategic memory processing, verbal fluency, reasoning, inhibition, and task management, a self-report measure of executive functioning was also administered. Results reveal that the various subcomponents of executive functioning assessed were differentially affected (supporting the view that executive functions are multifaceted), however, the general pattern seen was that of increased decline after the age of 60 years.

The authors contend “the results of the present study are generally consistent with the idea of age-associated executive dysfunction” (Treitz et al., p. 384).

1.4.2. Education level

Education level is another factor that has been shown to have an impact on cognitive and executive abilities throughout the lifespan. Hester et al. (2005) found, as with age, that education level influenced performance on the Trail Making Test part B in their study involving 363 community dwelling individuals aged between 60 and 89 years. The results of this study revealed a small but significant relationship between age and performance on the Trail Making test part B with individuals that have 12 or more years of education performing significantly better on this test than individuals with 11, or fewer than 11 years of education (Hester et al.).

Ganguli et al. (2010) conducted a study involving 1413 individuals grouped according to education level (i.e., less than high school; high school graduate; more than high school). These results also revealed an association between education level and cognitive and executive functioning. Ganguli et al. demonstrated that lesser education was associated with poorer performance in all cognitive domain assessed, these being attention, executive, language, memory, and visuospatial skills.

In a fairly recent study Meijer, van Boxtal, Van Gerven, van Hooren and Jolles (2009) investigated the interactions between education and health status (i.e., physical, social and psychological functioning) with regard to cognitive functioning and change over a six-year period in two groups of individuals aged 24 to 47 years and 49 to 77 years. The results reveal that level of education does have a significant impact on cognitive test performance for the younger group only and that the specific cognitive domain affected differs with respect to health status component. A significant positive association between education level and physical functioning was found with regard to

initial performance on tasks of working memory, speed, and executive functioning. At the six-year follow-up, however, education level and physical functioning were positively related to performance on tasks that assess cognitive speed whilst education and psychological functioning were associated with performance on executive functioning tasks. In addressing the question as to why significant findings were revealed only for the younger group of participants the author suggest that as one ages the “protective effects” of education lessen. They go on to state “Educational experience may therefore only serve as a counter-weight to health-related cognitive deterioration in younger persons, who still benefit from direct effects of education on brain structure and function” (Meijer et al., 2009, p. 527).

1.4.3. Socioeconomic status

The relationship between executive function performance and socioeconomic status is a little unclear. In their study of 340 individuals that ranged in age from seven to 21 years Krikorian and Bartok (1998) found no significant relationship between socioeconomic status, as determined by parental level of education and occupation, and performance on a non-verbal measure of executive functioning, the Porteus Maze Test. Coelho (2002) categorised participants into one of three SES groups, professional, skilled worker, and unskilled worker. This was based on a modified version of the Hollingshead Four Factor Index of Social Status (1972), which uses number of years of education and occupation to determine social status. Unlike Krikorian and Bartok (1998) Coelho’s results did show a significant, positive relationship between socioeconomic status and discourse performance, which has found to be a correlate of executive functioning.

This difference in findings between Krikorian and Bartok (1998) and Coelho (2002) may well be due to the considerable differences in tests of executive functions these authors used. The Porteus Maze Test was developed as a nonverbal test of intelligence but has been viewed by some, such as Krikorian

and Bartok, as a measure of executive function as it requires good planning skills and inhibitory control for successful performance. The Porteus Maze Test, however, is not primarily used as a measure of executive function and some authoritative sources, such as Strauss, Sherman and Spreen (2006) do not list it as a test of executive function. In contrast, the Coelho study examined the relationship between socioeconomic status and discourse performance, which arguably involves a broader range of executive skills including initiation, verbal fluency, monitoring, and organisation. Coelho's finding of a significant relationship between a verbal executive function task and socioeconomic status in comparison to Krikorian and Bartok's nonsignificant finding using a visual task may reflect the cognitive modality.

Kaplan et al. (2001) investigated the association between performance on tests of executive function, including the Trail Making Test and a test of verbal fluency, and childhood socioeconomic status in a study involving 496 Finnish men. In this study childhood socioeconomic status was determined on the basis of parental (father and mother) education and occupation. The results were fairly consistent revealing poorer executive function performance in those individuals with lower childhood socioeconomic status. When the participants own level of education was accounted for (e.g., did not complete elementary school; completed elementary or elementary plus some junior high school; completed elementary plus some vocational training; completed junior high school and more) poorer executive function performance was still observed in those participants with lower childhood socioeconomic status (Kaplan et al.,).

The contrasting findings in the literature regarding the relationship between executive function performance and socioeconomic status may be, in part, the result of the lack of uniformity in the way in which socioeconomic status is operationalised. Furthermore, in the past determining SES on the basis of number of years of education and occupation may have been sufficient as education pathways after secondary school were limited to university and

skills training generally occurred on the job. Today, however, there are a wide variety of education pathways and further training past secondary school including Tafe and online courses. Additionally, it is not unusual for individuals to change jobs on a more regular basis and to work across a variety of industries. These factors are important to consider if a uniform operationalisation of SES is to be determined.

1.5. Executive Functions in Early Adulthood

Despite some debate as to whether there is age-related cognitive change during the early adulthood stage of life there are some factors that do affect cognitive skills, in particular the executive functions, which are relatively common during this stage of life.

1.5.1. Brain Injury

There are many causes of brain injury including, but not limited to stroke, tumour, poisoning, suffocation, and various diseases such as Parkinson's disease, Alzheimer's disease, and Multiple Sclerosis. Brain injuries also occur due to physical trauma to the head. A report on hospitalisations due to traumatic brain injury (TBI) in Australia in 2004-2005 found that youth and young adults were particularly vulnerable to this type of brain injury (Helps, Henley & Harrison, 2008). Furthermore, individuals who have experienced a TBI are at significant risk for disability. An estimated 43.3% of TBI survivors, that were hospitalised, in the United States were found to be suffering from a long-term or life-long disability (Langlois Orman, Kraus, Zaloshnja & Miller, 2011). Given the prevalence of brain injury within the adolescent and early adulthood age range, and potential long-term consequences, understanding the way in which cognitive and executive functions are affected as a result of brain injury is vital.

Functional and neuropsychological outcomes following a brain injury vary greatly and are dependent on several factors including injury severity, the location of damage within the brain, the individuals age at the time of injury, the circumstances of the injury, and even the possibility of bias due to compensation, litigation, and secondary gain (Fleminger, 2009). Nevertheless, despite there being a wide variety of neuropsychological outcomes following brain injury, given the nature of executive functions and that they are mediated by the frontal lobes, and their interconnectedness with other cognitive functions, deficits in the functions that are commonly viewed as being executive in nature, such as planning, organising, idea generation, and inhibition, are a common consequence of brain injury.

Although it is accepted that attention, memory, processing speed, and executive function deficits are common sequelae of brain injury, Serino et al. (2006) were interested in understanding whether these deficits were primarily the result of a unique impairment in the Central Executive System (CES) as described in Baddeley's (2002) model of working memory or the result of deficits in information processing speed. Using a cohort of 37 TBI patients with an age range of 14 to 69 years Serino et al. results support the involvement of the CES in cognitive outcome following TBI, rather than a general slowing of information processing speed. This is because working memory was primarily affected as were other functions such as divided attention and long term memory which are said to be dependent on the CES.

Deficits in executive functions as a result of brain injury are not limited to a short period of time post injury. Draper and Ponsford (2008) investigated the cognitive functioning of 60 participants ten years post TBI and compared their performance on a range of cognitive and executive measures, (including the Trail Making Test, Digit Span subtest from the WAIS-III, and the COWAT) to a group of 43 demographically similar controls. Draper and Ponsford set out to obtain a better understanding of the long-term cognitive outcomes following TBI and to determine which assessment measures are best able to detect

impairments. The results revealed significantly poor performance by the TBI group in comparison to controls across the domains of processing speed, memory, and executive function. Two less commonly used tests of executive function, namely the Sustained Attention to Response Task (SART), a computerised task that is said to measure response inhibition over a sustained period, and the Hayling Sentence Completion Test, also a task of response inhibition, were found to be the most sensitive executive measures.

A recent study by Senathi-Raja, Ponsford and Schönberger (2010) examined the impact that age at time of injury, injury severity, and time post injury has on long-term cognitive function, including executive function, five to 22 years post TBI. One hundred and twelve participants, aged 16-81 years at the time of their injury were matched with 112 healthy controls. Injury severity in the TBI participants, as determined by length of post traumatic amnesia (PTA) duration, ranged from mild to very severe. On average, TBI participants were seen 11.22 years post injury and were assessed using a range of cognitive and executive tasks including a measure of verbal fluency.

Results of the aforementioned study clearly demonstrate persistent basic cognitive and executive deficits in long-term TBI survivors (Senathi-Raja et al., 2010). The level of long-term impairment was found to be significantly associated with TBI severity and age at time of TBI, with older age at time of injury associated with poorer long term outcomes. TBI in adolescence or early adulthood was found to be associated with less severe long-term cognitive and executive deficits than in older age groups, however, increased time post injury was not found to have a positive impact on cognitive and executive functioning, even in the younger age groups (Senathi-Raja et al.).

1.5.2. Mental Illness

According to an Australian Bureau of Statistics (ABS; 2006) report of mental health in Australia, mental illness (i.e., anxiety disorders, mood disorders,

alcohol use disorders & drug use disorders) is one of the leading causes of disability and reduced productivity across the lifespan. More importantly, however, mental illness was found to significantly reduce individuals overall quality of life. This report by the ABS (2006) also demonstrated that the prevalence of mental illness within the Australian population generally increased with age until approximately 44 years of age and then declined with the highest proportion of mental illness seen within the early adulthood age range. Given the prevalence of mental illness, particularly amongst individuals within the early adulthood age range, the impact that mental illness has on an individuals everyday functioning, and the wider societal consequences, it is important to examine the effect that mental illness has on cognitive functioning.

Chepenik, Cornew and Farah (2007) suggest that we intuitively know that mental illness, such as a mood disorder, affects the way in which we think and how effectively we are able process information. Torres, Boudreau and Yatham (2007) conducted a meta-analysis investigating the neuropsychological functioning of euthymic bipolar disorder patients with the aim of determining whether these patients display cognitive deficits as seen in their symptomatic counterparts. The results of the meta-analysis revealed a pattern of impairment of moderate to large effect size across the cognitive domains of attention/processing speed, episodic memory, and executive functions. This is similar to what has been observed in symptomatic bipolar disorder patients. Therefore, the authors suggest that their meta-analysis provides evidence that the neuropsychological deficits in the domains of attention/processing speed, memory, and executive function are trait-related, that is, these deficits are independent of symptomatology.

Porter, Bourke and Gallagher (2007) state that “neuropsychological impairment is well established as a feature of major depressive disorder (MDD)” (p.115). In their review they sought to clarify the pattern of neuropsychological impairment seen in various phenotypes of MDD (e.g.,

melancholia, psychotic depression, unipolar, and bipolar depression) with a particular focus on the neuropsychological domains of attention, verbal and non-verbal learning and memory, and executive function. The authors also examined the affect of other factors such as age, gender, and comorbid diagnoses on neuropsychological impairment. Although their findings were largely inconclusive, that is a distinct pattern of neuropsychological deficit in MDD was not seen, Porter et al. suggest that impairments in executive functions are more commonly seen in elderly patients with MDD, those with severe melancholia, those with psychotic depression, and those with bipolar disorder.

1.6. Assessing Executive Functions

Given the term executive function describes range of cognitive skills rather than a singular construct it is not surprising that there is a broad range of neuropsychological tests that reportedly assess these different facets of executive functions. These varied tests of executive functions have been developed for, and used in both clinical and research studies for people of all ages. In clinical practice measures of executive function are used for a variety of reasons including assisting with diagnostic clarification, to obtain a better understanding of an individual's behavioural difficulties, and for rehabilitation and intervention purposes. In an aged population tests of executive function are used for diagnostic clarification, particularly with regard to dementia and to discriminate between normal, mildly, and severely cognitively impaired individuals (Bryan & Luszcz, 2000; Whelihan, Thompson, Piatt, Caron & Chung, 1997).

As with other cognitive measures it is important to determine whether tests of executive function assess what they purport to assess. Furthermore, it is important to determine whether there is an association between performances on tasks that assess different facets of executive function. The issue of cognitive congruence compounds this problem. Bryan and Luszcz (2000)

describe the phenomena of cognitive congruence as the widely acknowledged finding that performance on virtually any cognitive task is positively correlated with performance on any other cognitive task. Bryan and Luszcz do, however, suggest that the relationships between different measures of executive function are generally greater than what would be accounted for by the phenomena of cognitive congruence alone.

Some of the more commonly used tests of executive function and the component of executive function they purport to assess as described by Strauss et al. (2006) and Pennington and Ozonoff (1996) are shown in Table 1.3. This 'compendium' of executive function tests focuses on measures that are used clinically; it does not include those developed for laboratory research and not widely available to practising psychologists.

Table 1.3
Executive Function Component and Associated Measures (adapted from Strauss et al., 2006 & Pennington and Ozonoff, 1996)

Executive Function Component	Test
Set shifting	Wisconsin Card Sorting Test
	Trail Making Test, part B
	Contingency Naming Test
Planning and organisation	Tower of London
	Porteus Mazes
	Rey-Osterrieth Complex Figure Test
Working Memory	Sentence Span
	Counting Span
	Digit Span
Inhibition	Stroop Test
	Hayling Test
	Go-No Go
Fluency	Controlled Oral Word Association Test
	Category Fluency
	Thurstone Word Fluency
	Design Fluency

1.7. Verbal Fluency Tests of Executive Function in Clinical Practice

Verbal fluency, like all executive functions, is said to be mediated by the frontal lobes but more specifically is related to left hemisphere function (Goldstein, Obrzut, Cameron, Hunter & Armstrong, 2004). Verbal fluency tests of executive function are designed to measure the speed and ease at which an individual can produce words according to certain rules. Successful completion of verbal fluency tasks is reliant on many cognitive processes including initiation, being able to respond to a novel request (Monsch et al., 1994), retrieval of information from long-term memory, immediate memory and working memory capacity to generate category cues and monitor words already retrieved (Unsworth, Spillers & Brewer, 2011), inhibitory control to be able to inhibit a response that does not comply with the stated rule (McDowd et al., 2011), and vocabulary (Unsworth et al., 2011). Typically, two rules sets or conditions can be used with tasks of verbal fluency, these being phonemic fluency or semantic fluency (Jurado & Rosselli, 2007; Lezak, 2004).

Troyer, Moscovitch and Winocur (1997) propose a theoretically based, two component model of fluency performance in an effort to understand more about underlying cognitive processes involved in undertaking both semantic and phonemic verbal fluency tasks. The first component they propose is clustering, which Troyer et al. view as the generation of words within either phonemic or semantic categories. In their study Troyer et al. defined phonemic clusters as groups of words, given in succession, that start with the same two letters (e.g., art, arm), that have the same structure with the exception of a different vowel sound (e.g., fit, fat), that are homonyms (e.g., some, sum), or that are rhyming words (e.g., sand, stand). Troyer et al. used animals as their semantic category and defined clusters as animals generated in succession that belong to the same semantic subgroup, for example African animals, farm animals, Australian animals, and pets. Given this description of clustering and examples, Troyer et al. suggest that clustering is

reliant on verbal memory and word storage and is thereby subserved by temporal lobe processes.

The second component proposed by Troyer et al. (1997) is switching which is the ability to shift or change response from one cluster to another. To be able to successfully switch from one response set to another an individual must be able to initiate a strategic search, they must be cognitively flexible, and possess the ability to shift, therefore, switching is view by Troyer et al. to be mediated by frontal lobe processes. Overall, the results of the Troyer at al. study support the view that clustering and switching are separate and important components of both phonemic and semantic verbal fluency performance. Switching was found to be the more important of the two for performance on phonemic fluency tasks with clustering found to be equally important for both phonemic and semantic fluency tasks.

In a recent study involving a group of young adults, aged 18 to 35 years, Unsworth et al. (2011) examined the processes involved in word generation that allow for successful performance on both phonemic and semantic verbal fluency tasks using the two-component, clustering and switching, model proposed by Troyer et al. (1997). Additionally, these authors sought to examine verbal fluency performance in relation to other cognitive processes of working memory capacity, inhibition, vocabulary size, and processing speed.

Unsworth et al. (2011) demonstrate that switching, or the ability to generate category cues, and clustering, the production of words within phonemic or semantic subcategories, were found to be related successful performance on both phonemic and semantic verbal fluency tasks with switching found to be the more important of the two. With regard to the relationship between switching and clustering and other cognitive processes, working memory capacity was found to be an important contributor to both switching and clustering and was found to be more strongly related to successful performance on both phonemic and semantic verbal fluency tasks than the

other cognitive processes examined. Vocabulary was found to be related to clustering and the number of words generated, however, no significant relationship was found between vocabulary and switching. Processing speed, however, was found to be significantly related to switching rather than clustering, and was also found to be related to successful performance for both semantic and phonemic verbal fluency tasks. Finally, inhibition was not found to be related to either switching or clustering, although, it was found to be related to number of words produced. On further examination, however, this relationship was found to be the result of variations in working memory capacity, with the authors concluding that inhibition was not related to successful performance on tasks of verbal fluency (Unsworth et al.,)

Although the study by Unsworth et al. (2011) suggests that phonemic and semantic verbal fluency tasks are mediated by the same processes, other studies, such as that undertaken by Monsch et al. (1994) have found difference in performance between phonemic and semantic verbal fluency in various patient groups. Specifically, Monsch et al. compared phonemic and semantic verbal fluency performance in patients with dementia of the Alzheimer type and patients with Huntington's disease. The Huntington's patients were found to perform poorly on both fluency tasks whereas the Alzheimer's group showed far greater impairment on the semantic fluency task. Melinder, Barch, Heydebrand & Csernansky, (2005) suggest that one of the reasons why differences are observed in phonemic and semantic verbal fluency performance between patient groups is that whilst successful performance on both fluency tasks rely on the same underlying cognitive processes, semantic fluency performance is reliant on an intact semantic system whereas phonological fluency tasks are not.

Gladsjo et al. (1999) assessed 768 'normal' adults ranging in age from 20 to 101 years on the COWAT and an animal fluency tasks with an aim of investigating the influence of demographic variables including age, educational level, ethnicity, and gender on phonemic and semantic verbal

fluency performance and developing further norms for these tests. Educational level and ethnicity were found predict phonemic fluency performance whilst age, educational level, and ethnicity explained the largest variance in semantic fluency performance (Gladsjo et al.,).

1.7.1. Phonemic verbal fluency

Phonemic verbal fluency tests require participants to produce as many words as they can during a specific time frame (usually one minute) beginning with a specific letter, most commonly F, A, and S. The Controlled Oral Word Association test (COWAT) (Benton, Hamsher & Rey, 1994) is one commonly used example of a phonemic verbal fluency test.

Despite the wide use of phonemic verbal fluency tasks across a range of neuropsychological settings the utility of phonemic verbal fluency tasks in diagnosis and/or detection of frontal lobe deficits is contentious. Cerhan et al. (2002) conducted a study of the utility of phonemic fluency tasks in predicting Alzheimer's disease. The results of the study demonstrated that phonemic fluency tasks were useful in predicting Alzheimer's disease but not as good as semantic fluency tasks.

In their study of low-grade brain tumour patients Goldstein et al. (2004) hypothesised that patients with left hemisphere tumours would perform more poorly on verbal fluency tasks (phonemic and semantic) than right hemisphere patients as verbal fluency is more particularly associated with the left hemisphere. Results of this study showed significant findings with regard to semantic verbal fluency but no significant findings in relation to phonemic verbal fluency. These findings suggest that phonemic verbal fluency is not a particularly sensitive indicator of left hemispheric lesions.

Jurado, Mataro, Verger, Bartumeus and Junque (2000) attempted to clarify the sensitivity of phonemic and semantic verbal fluency tasks in detecting

frontal lobe dysfunction in a traumatic brain injury (TBI) population. In contrast to the results of Goldstein et al. (2004), Jurado et al. found greater impairment on phonemic verbal fluency, but not semantic verbal fluency, in patients with frontal lobes lesions in comparison to matched controls. The authors conclude that their results are “consistent with the idea that phonemic and semantic fluency tasks have different brain-based substrates, and that phonemic fluency is more sensitive to frontal lesions than semantic fluency” (p.792).

1.7.2. Semantic verbal fluency

Semantic fluency tasks involve asking the participant to produce as many items/objects as possible, within a certain time frame (usually one minute), according to a specific category. Common categories include fruit and vegetables, clothing, things in the supermarket, or the most common category, animals (Strauss et al., 2006). Successful performance on tasks of semantic verbal fluency relies on intact semantic knowledge rather than letter-sound knowledge which means that temporal brain regions are involved in addition to frontal structures (Kavé, Heled, Vakil & Agranov, 2011).

Semantic fluency tasks have been found to be useful in detecting executive function deficits in a variety of clinical settings and across a variety of patient groups (Cerhan et al., 2002; Goldstein et al., 2004; Raskin & Rearick, 1996). Kavé et al. (2011) sought to clarify which verbal fluency task, semantic or phonemic, was more helpful in determining executive deficits after TBI. Their cohort of 30 Hebrew speaking TBI patients and 30 controls, aged between 18 and 35 years, were assessed on a phonemic fluency task using the letters b, g, and s and three semantic categories of animals, fruits and vegetables, and vehicles. These authors examined their findings in relation to Troyer et al's. (1997) clustering and switching model of verbal fluency as a means of determining the contribution of the executive functions (frontal lobe processes) versus verbal memory and word storage (temporal lobe processes).

Although Kavé et al. (2011) predicted, based on previous research, that TBI patients would perform more poorly on phonemic fluency tasks the opposite was found to be true. The TBI patients performed more poorly on the semantic fluency tasks. In analysing their results they found that this was a result of deficits in switching, an executive function, and not due to poor clustering, a temporal lobe function.

One of the benefits of using semantic verbal fluency tasks rather than phonemic verbal fluency tasks is that they don't rely as heavily on letter-sound knowledge, therefore, they may be more appropriate to use in illiterate individuals. A study conducted by Manly et al. (1999) investigated the effect of literacy on neuropsychological test performance in a group of education-matched literate and illiterate individuals. Verbal fluency tasks included in the study were the COWAT and category fluency (animals, food and clothing). The results show that many of the illiterate individuals were unable to complete the phonemic fluency task, the COWAT, as they were unable to generate any words for specific letters and those that were able to generate words were found to perform more poorly than their literate counterparts. Conversely, no significant difference was found between the literate and illiterate group on semantic verbal fluency performance.

da Silva, Petersson, Faisca, Ingvar & Reis (2004) explored the usefulness of semantic verbal fluency tests for the assessment of illiterate individuals using two criteria, animals and supermarket items. The results revealed no significant difference between the literate and illiterate subjects on the performance of the semantic verbal fluency test using supermarket items. A significant difference was found, however, between the two participant groups on performance of the semantic verbal fluency test utilising animal criteria. Specifically, the illiterate group performed significantly worse on this task in comparison to their literate counterparts. Although the authors did not investigate the reasons behind this finding they suggest that the difference

seen between the two groups may be due to the positive impact that reading has on acquiring knowledge (da Silva et al., 2004).

Ardila, Ostrosky-Solís and Bernal (2006) contend that semantic verbal fluency using animals as the designated category has some significant benefits in comparison to other categories that are commonly used. Firstly, it is a category that is easily defined across cultures and languages. Ardila et al. use the example of “vegetable” to highlight the ambiguity that can exist in defining a semantic field between culture and languages. They suggest that “vegetable” in Spanish, for example, is not as clear and defined a category as it is in English. “Vegetable” in Spanish may include trees and grass where this is clearly not the case in English.

Another benefit that Ardila et al. (2006) see in using animals as category is its relative consistency and stability across countries, educational attainment, and time. They suggest that there are only small differences seen between individuals living in different countries using the category of animals in comparison to other categories and in comparison to phonemic cues. Time, or generational differences may be seen in individuals from the same culture for example the category of “tool” may produce vastly different responses in a 80 year old in comparison to a 30 year old (Ardila et al.,).

Research conducted by Pekkala et al. (2009) further supports the usefulness of using semantic verbal fluency tasks, particularly with the category of animals, cross-culturally. Pekkala et al. investigated semantic verbal fluency performance in monolingual American English-speaking individuals and monolingual Finnish-speaking individuals, with English and Finnish being two unrelated languages. When education was accounted for, no significant difference was found between the two groups in the number of correct words produced. Interestingly, however, a difference was observed in the order of the type of animals produced. The English speaking participants tended to produce pets and then zoo animals whilst the Finnish speaking individuals

produced farm animals, pets, and then zoo animals. The authors suggest this finding may be due to the different socio-cultural backgrounds of these two groups. In summary, Pekkala et al. suggest that semantic verbal fluency tasks are a useful assessment tool that may be “relatively culture-free” (p. 442).

1.8. The Controlled Animal Fluency Test

The Controlled Animal Fluency Test (CAFT) was originally devised by Jan Monti (Ewing) (1984) and further developed by Tucker (Tucker, Ewing, and Ross, 1996; Tucker, personal communication, 2008). The CAFT was developed as a verbal fluency type measure of executive functions, similar to the Controlled Oral Word Association Test (COWAT) but utilising semantic criteria and phonemic criteria in separate conditions (trials).

The CAFT consists of three conditions and involves asking participants to name as many animals (defined broadly) as possible within 60 seconds according to three distinct conditions. Condition 1 is Animals Automatic in which participants are asked to name as many animals as they can. A point is awarded for every correct response. This procedure is the most commonly used semantic verbal fluency task and is commonly referred to as Animal Fluency (Strauss et al., 2006). The benefit of this task in comparison to the COWAT is that successful performance does not rely on phonological knowledge and, as mentioned above, cultural effects appear to be minimal.

The second condition of the CAFT is Animals by Size. In this condition participants are asked to name as many animals as they can in order from smallest to largest. Points are awarded for every animal named that is larger than the previous one. Points are not awarded, however, for animals named that are clearly out of size order.

This condition of the CAFT is considered the most demanding of executive functions as it relies, not only on the ability to produce words according to a

novel rule, but also involves other executive skills. For example, successful completion of the Animals by Size condition of the CAFT requires self regulation and monitoring (the participant has to keep track of their responses), inhibitory control (the participant has to inhibit responses that do not conform to task rules), and sequencing (the participant has to be able to order their responses correctly, according to the rule). An individual can draw on their linguistic knowledge for the animal label but must use their visual processes to successfully complete this trial. Arguably, the task demands of the Animals by Size condition of the CAFT and the skills required to successfully complete it draw on similar skills to those required for part B of the Trail Making Test (TMT-B).

Condition 3 of the CAFT, Animals by Alphabet, is the most similar to the COWAT as successful performance requires sound phonemic and planning skills. In this condition participants are asked to generate an animal name for each letter of the alphabet in alphabetical order. Points are not awarded for omitted or misused letters (e.g., F for Pheasant). As with the COWAT, individuals who have impaired phonemic abilities, for example a developmental dyslexia, may perform poorly on this trial in the absence of executive deficits.

1.8.1. CAFT performance in late adulthood

Two previous studies, Ruvceska (2003) and Evans-Barker (2004), investigated performance on the CAFT in a late adulthood sample. Both Ruvceska and Evans-Barker examined the relationship between performance on the CAFT and other measures of executive function, cognitive function, and demographic characteristics. Normative data for the CAFT in this age range was also gathered by both authors.

Ruvceska (2003) assessed 46 nonclinical, community dwelling individuals aged between 60 and 83 years on the CAFT and a range of other executive

and cognitive measures. Whilst it was anticipated that significant relationships would be found between performance on the Auto, Size and Alphabet conditions of the CAFT and performance on other executive and cognitive measures, no significant relationships were revealed.

In contrast to Ruvceska (2003), Evans-Barker (2004) did find significant relationships between performance on the CAFT and other tasks of executive and cognitive function in her study involving 29 nonclinical individuals from the late adulthood age range. Specifically, significant positive relationships were revealed between all three conditions of the CAFT and the COWAT, the CAFT Auto and Alphabet conditions with a task of memory and learning, the Rey Auditory Verbal Learning Test (RAVLT), and the CAFT Auto and Alphabet conditions with FSIQ. With regard to demographic characteristics, performance on the three conditions of the CAFT was also found to be significantly and positively correlated with number of years of education and the CAFT Auto and Alphabet conditions significantly related to SES.

Whilst the Ruvceska (2003) and the Evans-Barker (2004) studies involved participants from the same age-range several differences in the demographic information are noted that may be contributing factors to the contrasting findings. The most prominent difference seen is that more than half of the Ruvceska sample were from non-English speaking backgrounds whereas the Evans-Barker sample are all of English speaking origin. In addition, the Evans-Barker sample has a higher mean FSIQ, a higher mean number of years of education, and a higher mean socioeconomic status.

1.8.2. CAFT performance in early adulthood

One previous study investigating performance on the CAFT in an early adulthood sample was reported by Popp (2003). Popp assessed a cohort of 59 healthy adult men and women on the CAFT and other tests of executive function and cognitive functioning including the COWAT and the Wechsler

Adult Intelligence Scale – Third Edition (WAIS-III) Vocabulary, Digit Span, Block Design, and Symbol Search subtests.

One of the main aims of Popp's (2003) study was to gather normative data for the CAFT in the early adulthood age range as no such data existed at that time. Popp also examined the relationship between performance on the CAFT and performance on other executive and cognitive tasks with the belief that "the establishment of such relationships will allow for increased understanding when comparing the profile performance of neuropsychologically compromised individuals against unimpaired peers" (p. 47). A general examination of other factors that may impact or be related to executive task performance such as age, gender, level of education, and intelligence was also carried out.

The overall results of the Popp (2003) study revealed significant, positive correlations between the CAFT Animals Automatic condition and the COWAT and the CAFT Animals Alphabet condition and the COWAT. Interestingly, a gender difference was detected with females performing significantly better on the CAFT Animals Alphabet condition than their male counterparts. Furthermore, a gender difference was detected with performance on the CAFT Animals Automatic and Animals Alphabet conditions correlating with performance on the COWAT for females only, not for males. The normative data gathered by Popp are summarised in Table 1.4.

Table 1.4
Normative Data Popp (2003) (N = 59)

Sample	CAFT Condition	Mean	SD
Total sample (N = 59)	CAFT Animals Automatic	23	5.4
	CAFT Animals by Size	12.3	3.0
	CAFT Animals by Alphabet	13.5	3.7
Male (N = 24)	CAFT Animals Automatic	23.4	5.9
	CAFT Animals by Size	12	3.5
	CAFT Animals by Alphabet	12.1	3.2
Female (N = 35)	CAFT Animals Automatic	22.7	5.2
	CAFT Animals by Size	12.5	2.8
	CAFT Animals by Alphabet	14.5	3.7

1.9. Rationale for the Current Study

The continued development and refinement of measures that can accurately assess executive functions in an early adulthood population is needed to assist in the assessment and rehabilitation of individuals experiencing executive dysfunction that may be due to TBI, alcohol and drugs, infection, toxic exposure, or other causes. Moreover, given the patient group and the setting in which the neuropsychologist is likely to assess them, for example a rehabilitation facility post TBI, tests that are time efficient, uncomplicated, portable, and that simultaneously assess multiple components of executive function are highly desirable.

The CAFT is a brief, uncomplicated assessment tool that assesses multiple components of executive function including verbal fluency and inhibitory control, as does the Controlled Oral Word Association Test (COWAT). Although the CAFT is a verbal fluency type measure of executive function, similar to the COWAT, it does have some significant advantages over the COWAT. Performance on the CAFT also requires skills of self-regulation, sequencing, and monitoring. Additionally, when looking at the CAFT in comparison to the COWAT, it requires participants to produce words according to semantic criteria mainly, rather than phonemic criteria alone. This reduces the likelihood of confounding deficits in letter-sound abilities with

those that are executive in nature. In clinical practice the capacity of the test instrument to make this distinction is important to differentiate these individuals with executive function impairments from those with dyslexia.

The CAFT is a more recently refined test of executive function and its ability to assess executive functions in individuals within the early adulthood age range has not been comprehensively established. Moreover, there is only one prior study of the CAFT with young adults, Popp (2003) and this found a gender effect. Given that normative data are required to accurately detect executive dysfunction, gathering additional normative data for individuals in the early adulthood age range will be one of the focuses of the current study in addition to exploring the CAFT in relation to other executive, cognitive, and non-cognitive factors.

1.10. Aims and Hypotheses

The primary aim of the present study is to investigate how performance on the CAFT relates to performance on other established tests of executive function, cognitive function and non-cognitive factors in the early adulthood age-range. Specifically it is hypothesised that: (i) performance on the three conditions of the CAFT will be positively correlated with FSIQ, (ii) performance on CAFT Size will be positively correlated with performance on part B of the Trail Making Test (a higher score on CAFT Size and a shorter completion time on part B of the Trail Making Test will be seen) (iii) performance on CAFT Size will be positively correlated with performance on the Digits Backwards test, seen as a working memory task, (iv) performance on CAFT Alphabet will be positively correlated with performance on the COWAT, (v) performance on the three conditions of the CAFT will be correlated with demographic variables of socioeconomic status, age, and years of education.

In light of the findings by Popp (2003) a second aim of the current study will be to test whether performance on the CAFT varies according to gender.

Specifically, it is hypothesised that: (vi) a significant difference will be seen between males and females performance on the three conditions of the CAFT. A third aim will be to produce further normative data for the CAFT in the early adulthood age-range.

CHAPTER 2. METHOD

2.1. Participants

The current sample comprised 60 healthy community dwelling individuals, 27 males and 33 females aged between 19 and 40 years ($M = 31.2$, $SD = 6.03$). Participants were recruited from educational institutions, workplaces, and through personal networks of the researcher in urban and regional areas of the state of Victoria (Australia) on the basis of availability. To ensure that the sample was a non-clinical one, potential participants were assessed using a semi-structured interview protocol to screen out individuals with a significant history of medical conditions that could affect cognition (e.g., uncorrected sight and hearing deficits, brain diseases, major systemic disease, history of psychological disorder, significant head trauma with a loss of consciousness of greater than five minutes), developmental disorders, drug abuse or dependence, and participants who did not have conversational English language skills. (See Tables 3.1, 3.2, and 3.3 for participant demographic information).

2.2. Assessment Instruments

2.2.1. Interview protocol

A structured interview was developed by the researcher in order to obtain the demographic and medical information necessary to carry out the present study. Information obtained through the interview protocol includes demographic information such as age, gender, educational history, and marital status. Current occupation was also requested to determine socio-economic status based on McMillian, Bevis and Jones (2009) Australian Socioeconomic Index 2006 (AUSEI06). The language background of participants was also obtained with individuals being classified as being of English speaking background (ESB) or of non-English speaking background

(NESB). A participant was defined as being from an ESB if both their parents' first language was English, whilst participants were defined as being from a NESB if one or both of their parents was born in a country other than Australia and first spoke a language other than English. This categorisation was adapted from criteria used by Carstairs, Myors, Shores, and Fogarty (2006).

Relevant medical information was also required to ensure that the sample was of a non-clinical type. Individuals found to have uncorrected sight and hearing deficits, brain diseases, major systemic disease, history of psychological disorder, significant head trauma with a loss of consciousness of greater than five minutes, developmental disorders, drug abuse or dependence, and participants who lack basic English language skills were excluded from the study. Participants were also asked to give details of any current medication (prescription or otherwise) to ensure that it would not impact upon their cognitive or executive function abilities. (See Appendix A).

2.2.2. Executive function

Controlled Animal Fluency Test (CAFT)

The CAFT has been constructed to assess executive functioning without confounding letter-sound problems. It comprises three conditions, each of which draws on different aspects of executive functions. For each condition participants are to name as many animals as possible in 60 seconds. The first condition is Animals Automatic, where participants are to name as many animals as they can in any order. The second condition is Animals Size, where participants are asked to name as many animals as they can in order from the smallest to largest. In the third condition, Animals Alphabet, participants are asked to name an animal for each letter of the alphabet. In each condition a point is awarded for every correct response (See Appendix B).

Controlled Oral Word Association Test (COWAT)

The COWAT (Benton et al., 1994) is an established test of executive functioning that assesses the ability of a participant to generate words according to a specific rule and their ability to keep track of earlier responses. The COWAT requires participants to produce as many words as possible beginning with the specified letters of the alphabet, allowing 60 seconds for each letter. (See Appendix 3). The standard administration and scoring procedure for the COWAT as outlined in Strauss et al., (2006) were used.

Trail Making Test

The Trail Making Test (TMT) is a well-established assessment tool that will be used in the present study as a measure of executive functioning. This test is comprised of two parts, Part A and Part B. Part A requires participants to connect, using a pencil, 25 numbers, that are randomly arranged on a page, in the correct order. Part B requires participants to connect, using a pencil, 25 numbers and letters that are randomly arranged on a page, in alternating order. The standard administration and scoring procedure will be used for the TMT as given in Strauss, et al., (2006). (See Appendix D).

2.2.3. Intellectual functioning***Wechsler Abbreviated Scale of Intelligence (WASI)***

The WASI is a brief test of intelligence that is based on the measurement of both verbal and non-verbal abilities. The WASI is comprised of four subtests, Vocabulary, Similarities, Block Design, and Matrix Reasoning. Vocabulary and Similarities combine to form a measure of verbal intelligence (VIQ) and Block Design and Matrix Reasoning form a measure of non-verbal intelligence (PIQ). Together VIQ and PIQ produce a measure of overall intellectual functioning or full scale intelligence (FSIQ). Administration and scoring procedures were carried out according to the WASI manual (Wechsler, 1999).

2.2.4. Attention and working memory

Digit Span subtest (WAIS-IV)

The Digit Span subtest is a well-established measure from the Wechsler Adult Intelligence Scale (WAIS-IV) that was used in the current study for measuring the span of immediate recall and working memory. Whilst the test is comprised of three parts, Digits Forward, Digits Backward, and Sequencing, only the Digits Forward and Digits Backwards components were used in the current study. Digits Forward was used in the current study as a measure of immediate memory capacity whilst Digits Backwards was used as a measure of working memory.

The Digits Forward and Digits Backward both consist of eight sets of digit sequences, each sequence one digit longer than the last. The digit sequences are verbally presented to the participant at a rate of approximately one digit per second, the participants are then required to verbally repeat the digit sequence exactly as presented in the Digits Forward test and in the reverse order in the Digits Backwards test. Administration and scoring procedures are carried out according to the WAIS-IV manual (Wechsler, 2008).

2.3. Procedure

Approval to conduct the current study was received from the Victoria University Human Research Ethics Committee (see Appendix E). Potential participants were sought through personal contacts of the researcher and provided with an 'Information to Participants' form (see Appendix F). Individuals interested in participating in the current study were provided with the researcher's telephone and email contact details and asked to contact her if they wished to participate in the study. Potential participants were also provided with the opportunity to consult with the researcher or supervisor via telephone or email prior to their participation.

Participants selected the date, time, and location of their assessment provided it was a venue suitable for testing. Participants were again given opportunities to clarify the study's methods and aims. Participants were then asked to read and sign and a 'Consent Form for Participants' (see Appendix G).

To reduce testing effects such as fatigue and learning, participants were assessed using one of two counterbalanced test orders. Assessment order A was; Interview Protocol, CAFT, Digit Span, WASI, COWAT, and TMT. Assessment order B was; Interview Protocol, COWAT, TMT, WASI, Digit Span, and the CAFT. These assessment orders were distributed as evenly as possible across the demographic characteristics of age and gender. The time of day that each participant was assessed was recorded (am = 8am to 1pm; pm = 1pm to 6pm) with this also being distributed as evenly as possible across the demographic characteristics of age and gender.

The assessment protocol for each participant was administered over a 60-minute period approximately by the researcher in a standardised manner. All participants were able to complete the test protocol in one session.

CHAPTER 3. RESULTS

3.1. Data Analysis

All data obtained were analysed using the Predictive Analytic Software Statistics for Windows (PASW), version 17, formerly known as Statistical Package for the Social Sciences (SPSS). A range of statistical techniques were employed to test hypotheses including independent samples t-tests, MANOVA's and Pearson's bivariate correlation. Where pairwise statistical tests are employed, such as t-tests, a common approach to adjusting for Type 1 error inflation is to use the Bonferroni correction, however, this can increase the risk of a Type 2 error to an unacceptable level. Accordingly, the Type 1 error rate has been set at .05. Where significant differences were found standard cut-offs were used to characterise effect size (Cohen, 1992).

3.2. Demographic Data

The final sample comprised 27 males and 33 females that ranged in age from 19 years to 40 years ($M = 31.2$, $SD = 6.03$) recruited from urban and regional areas of the State of Victoria (Australia). Potential participants were assessed with a semi-structured interview to screen out individuals with a significant history of medical conditions that could affect cognition, developmental disorders, drug abuse or dependence, and participants who lacked basic English language skills. Means and standard deviations for the demographic characteristic of the whole sample are shown in Table 3.1.

Table 3.1
Overall Sample Demographic Variables

		N	Mean	SD	Range
Gender:	Male	27	N/A	N/A	N/A
	Female	33	N/A	N/A	N/A
Age, years		60	31.2	6.03	19 – 40
Education, years		60	16.6	2.7	11 – 26
Socioeconomic Status		60	70.0	19.7	27.7 - 100
FSIQ		60	109.6	10.8	86 – 131
English Speaking		60	N/A	N/A	N/A
Second Language		8	N/A	N/A	N/A
Place of Residence:	Capital City	34	N/A	N/A	N/A
	Regional City	26	N/A	N/A	N/A

The above summary for the sample reveals that they had a relatively high education level and, socioeconomically, were above the midrange of socioeconomic status by McMillian et al., (2009) rankings. There was a very good range of SES scores in the sample. The sample was seen to have a mean FSIQ in the upper end of the average range.

3.2.1. Gender

A comparison between males and females on the basis of age, education, socioeconomic status, and FSIQ is shown in Table 3.2.

Table 3.2
Demographic Variables on the Basis of Gender for the Whole Sample

	Gender	N	Mean	SD
Age, years	Male	27	32.7	5.9
	Female	33	29.9	6.0
Education, years	Male	27	15.7	2.7
	Female	33	17.2	2.6
Socioeconomic Status	Male	27	68.4	20.1
	Female	33	71.3	19.5
FSIQ	Male	27	109.4	11.1
	Female	33	109.7	10.7

With alpha set at .05, independent t-tests (2-tailed) revealed no significant differences between males and females for chronological age at the time of testing, $t(58) = 1.83$, $p = .073$, socioeconomic status, $t(58) = -.55$, $p = .58$, or FSIQ, $t(58) = -.11$, $p = .91$. A significant difference was, however, observed between males and females for number of years of formal education, $t(58) = -2.26$, $p = .03$, with females having a small but significantly higher number of years of education than males.

3.2.2. Language background

Scores obtained for cognitive and non-cognitive measures were also analysed in relation to language background. Demographic characteristics of participants with English speaking and non-English speaking backgrounds with means and standard deviations can be seen in Table 3.3.

Table 3.3
Language Background of Sample

	Language Background	N	Mean	SD
Age, years	ESB	52	31.1	6.2
	NESB	8	31.8	5.1
Education, years	ESB	52	16.5	2.8
	NESB	8	17.1	2.1
Socioeconomic Status	ESB	52	69.2	20.6
	NESB	8	74.9	12.1
FSIQ	ESB	52	108.7	11.3
	NESB	8	115.5	4.2

With alpha set at .05, independent t-tests (2-tailed) revealed no significant differences between participants from English speaking and non-English speaking backgrounds on the basis of age in years at the time of testing, $t(58) = -.28$, $p = .78$, socioeconomic status, $t(58) = -.76$, $p = .45$, or years of formal education, $t(58) = -.64$, $p = .53$. A significant difference was, however, observed between participants from English speaking and non-English speaking backgrounds on the basis of FSIQ, $t(26.43) = -3.17$, $p = .004$, with

participants from non-English speaking backgrounds having a significantly higher FSIQ than participants from English speaking backgrounds. Levene's test for equality of variance was found to be significant, therefore, the t-test was interpreted by assuming unequal variance. Inspection of the data revealed that some non-English speaking participants were statistical outliers; accordingly it was not justified to pursue this issue in the present study.

3.3. Scores for All Dependent Variables

Means and standard deviations of scores for all dependent variables are depicted in Table 3.4.

Table 3.4
Whole Sample Dependent Variables

Measure	Mean	SD
CAFT Animals Auto condition	26.4	4.7
CAFT Animals by Size condition	14.5	2.7
CAFT Animals Alphabet condition	15.8	3.4
COWAT Total Score	44.8	10.8
FSIQ	109.6	10.8
VIQ	106.1	11.6
PIQ	109.7	11.1
Longest Digit Forward	6.7	1.4
Longest Digit Backward	5.6	1.3
Trail Making Test part A	30.6	8.3
Trail Making Test part B	49.0	12.1

The mean scores obtained were found to be normally distributed across all measures according to the published norms (Strauss et al., 2006; Wechsler, 1997; Wechsler, 1999) relating to the appropriate age groups. The mean scores obtained for the CAFT are comparable to those reported by Popp (2003).

A multivariate analysis of variance (MANOVA) was conducted to determine whether assessment order and time of day had an effect on performance of all dependent variables. Results revealed no significant effect for assessment order ($F(14, 43) = 1.25, p = .28$; Wilks' Lambda = .71; partial eta squared =

.29) or assessment time ($F(14, 43) = .92, p = .54$; Wilks' Lambda = .78; partial eta squared = .23), and revealed no significant interaction between assessment order and time ($F(14, 43) = .86$; Wilks' Lambda = .78; partial eta squared = .22).

3.4. Tests of Hypotheses

3.4.1. Hypothesis one

It was hypothesised in the current study that performance on the three conditions of the CAFT would be positively correlated with FSIQ (see Table 3.5).

Table 3.5
Correlations Between the CAFT and FSIQ

	CAFT Auto	CAFT Size	CAFT Alphabet
FSIQ	.60**	.44**	.59**

Note:

** $p < .01$ (1-tailed).

* $p < .05$ (1-tailed).

CAFT Auto = Controlled Animal Fluency Test, Animals Auto condition; CAFT Size = Controlled Animal Fluency Test, Animals Size condition; CAFT Alpha = Controlled Animal Fluency Test, Animals by Alphabet condition; FSIQ = WASI Full Scale IQ.

With alpha set at .05, Pearson's bivariate correlation (1-tailed) revealed a significant, strong positive relationship between CAFT Auto and FSIQ, accounting for 36% of the variance ($r^2 = .36$), a significant, moderate positive relationship between CAFT Size and FSIQ, accounting for 19% of the variance ($r^2 = .19$), and a significant, strong positive relationship between CAFT Alphabet and FSIQ, accounting for 35% of the variance ($r^2 = .35$).

3.4.2. Hypothesis two

It was hypothesised that performance on CAFT Size would be significantly and positively correlated with performance on part B of the Trail Making Test. With alpha set at .05 a Pearson's bivariate correlation (1-tailed) revealed a significant, weak negative relationship between CAFT Size and the Trail

making test part B, ($r = -.231$, $p = .05$). This indicates that as the number of words produced on the CAFT Size condition increased the time taken to complete the Trail Making Test part B decreased.

3.4.3. Hypothesis three

It was hypothesised that performance on CAFT Size would be positively correlated with performance on Longest Digit Backwards, from the Digit Span test, which was used as a working memory task. With alpha set at .05, a Pearson's bivariate correlation (1-tailed) revealed no significant relationship between these variables ($r = .14$, $p = .15$).

3.4.4. Hypothesis four

It was hypothesised that performance on CAFT Animals Alphabet would be positively correlated with performance on the COWAT. With alpha set at .05 a Pearson's bivariate correlation (1-tailed) revealed a significant, strong positive relationship between the COWAT and CAFT Alphabet, $r(58) = .65$, $p < .01$.

3.4.5. Hypothesis five

It was hypothesised that performance on the three conditions of the CAFT would be correlated with demographic variables of socioeconomic status, age, and years of education (see Table 3.6).

Table 3.6
Correlations Between the CAFT and Demographic Variables

	SES	Age	Education
CAFT Auto	.27*	.15	.29*
CAFT Size	.37**	.19	.35**
CAFT Alpha	.45**	.24	.43**

Note:

** $p < .01$ (2-tailed).

* $p < .05$ (2-tailed).

CAFT Auto = Controlled Animal Fluency Test, Animals Auto condition; CAFT Size = Controlled Animal Fluency Test, Animals Size condition; CAFT Alpha = Controlled Animal Fluency Test, Animals by Alphabet condition; SES = Socioeconomic status; Age = Age at time of testing; Education = Number of years formal education.

With alpha set at .05, a Pearson's bivariate correlation (2-tailed) revealed several significant relationships between variables. Significant, weak positive relationships were observed between CAFT Auto and SES, accounting for 7% of the variance ($r^2 = .07$), and CAFT Auto and education, accounting for 8% of the variance ($r^2 = .08$). Significant, moderate positive relationships were observed between CAFT Size and SES, accounting for 14% of the variance ($r^2 = .14$), and CAFT Size and education, accounting for 12% of the variance ($r^2 = .12$). Significant, strong positive relationships were revealed between CAFT Alphabet and SES, accounting for 21% of the variance ($r^2 = .21$), and CAFT Alphabet and education, accounting for 19% of the variance ($r^2 = .19$).

3.4.6. Hypothesis six

It was hypothesised that a significant difference would exist between males and females performance on the three conditions of the CAFT. With alpha set at .05, independent t-tests (2-tailed) revealed no significant differences between males and females performance on the CAFT Automatic condition, $t(58) = -.73$, $p = .36$, CAFT Size condition, $t(58) = -.04$, $p = .30$, or the CAFT Alphabet condition, $t(58) = -.57$, $p = .96$.

3.5. Regression Analysis of Cognitive Variables on CAFT Conditions

A series of regression analyses were conducted to determine the predictive value of the executive and cognitive factors on each condition of the CAFT. The variables of COWAT, FSIQ, Trail Making Test part B, and Longest Digit Backward were entered into the model using the simultaneous or Enter method (Field, 2009). This ensures that all variables are treated equally as the analyses were exploratory and not based on any prior assumptions or a theoretical model.

3.5.1. Regression analysis of cognitive variables on CAFT Auto

A multiple regression analysis was conducted for CAFT Auto using the COWAT, FSIQ, Trail Making Test part B, and Longest Digit Backwards from the Digit Span subtest as predictor variables. Using the simultaneous or Enter method, a significant model emerged ($F(4, 55) = 13.80, p < .0005$), Adjusted $R^2 = .47$. The COWAT significantly predicted CAFT Auto performance, $\beta = .44, t(55) = 3.90, p = <.0005$, as did FSIQ, $\beta = .32, t(55) = 2.40, p = .02$.

3.5.2. Regression analysis of cognitive variables on CAFT Size

A multiple regression analysis was conducted for CAFT Size using the COWAT, FSIQ, Trail Making Test part B, and Longest Digit Backwards from the Digit Span subtest as predictor variables. Using the simultaneous or Enter method, a significant model emerged ($F(4, 55) = 6.91, p < .0005$), Adjusted $R^2 = .29$. The COWAT significantly predicted CAFT Size performance, $\beta = .44, t(55) = 3.38, p = .001$.

3.5.3. Regression analysis of cognitive variables on CAFT Alphabet

A multiple regression analysis was conducted for CAFT Alphabet using the COWAT, FSIQ, Trail Making Test part B, and Longest Digit Backwards from the Digit Span subtest as predictor variables. Using the simultaneous or Enter method, a significant model emerged ($F(4, 55) = 15.70, p < .0005$), Adjusted $R^2 = .50$. The COWAT significantly predicted CAFT Alphabet performance, $\beta = .50, t(55) = 4.60, p = <.0005$, as did FSIQ, $\beta = .30, t(55) = 2.35, p = .022$,

3.6. Controlled Animal Fluency Test Normative Data

The data obtained for the current study provides additional normative data for the CAFT for individuals in the early adulthood age range. Means and standard deviations, for the entire sample for the total number of words

produced in each condition of the CAFT are presented in Table 3.7.

Table 3.7

Controlled Animal Fluency Test Normative Data (N = 60)

Sample	CAFT Condition	Mean	SD
Total sample (N = 60)	CAFT Animals Automatic	26.4	4.7
	CAFT Animals by Size	14.5	2.7
	CAFT Animals by Alphabet	15.8	3.4

CHAPTER 4. DISCUSSION

The present study sought to examine aspects of executive functioning in the early adulthood age range with a specific focus on a more recently refined test of executive function, the Controlled Animal Fluency Test (CAFT). The CAFT is a brief, uncomplicated verbal fluency measure of executive function that requires the additional skills of self-regulation, monitoring, and inhibitory control for successful performance. The primary aim of the current study was to investigate how performance on the CAFT relates to performance on other established tests of executive function, cognitive function and non-cognitive factors in the early adulthood age-range. A further aim was to investigate whether performance on the CAFT varies according to gender as a prior study, conducted by Popp (2003), found such as difference. In addition the study sought to establish norms for early adulthood.

4.1. Hypothesis One

The results obtained for the current study support the first hypothesis that performance on the three conditions of the CAFT will be positively correlated with FSIQ. Specifically, the results revealed significant, strong relationships between FSIQ and the CAFT Auto and Alphabet condition and a significant, moderate relationship with the CAFT Size condition.

This finding is consistent with previous research that has also investigated the relationship between intelligence and executive functions (Davis et al., 2011; Decker et al., 2007). One such study that particularly looked at the relationship between intelligence and the performance on executive tasks including those of semantic and phonemic fluency was conducted by Piguet et al. (2002). These authors tested individuals on several executive measures and investigated their performance in relation to the sociodemographic variables of level of education, occupation, and estimated FSIQ. Results revealed that only estimated FSIQ played a significant contributing role with regard to

performance on executive measures with the authors commenting that “this finding is consistent with the view that tasks of EFs [executive functions] are closely related to measures of general intelligence” (Piguet et al., p. 152).

In making this comparison between the current findings and those by Piguet et al. (2002) it must be noted that there is a vast difference in participant age between the two studies with Piguet et al.’s. participants being aged 81 years and over. Nevertheless, given that intelligence is said to be a relatively constant phenomena throughout the lifespan this suggests that intelligence may be a protective factor for executive functions into old age.

In considering past research examining the relationship between executive functions and intelligence there has some efforts to determine which aspects of intelligence, as described by the CHC theory of cognitive ability, are most closely related to executive functions (Decker et al., 2007; Friedman et al., 2006). There have been mixed findings with Decker et al. suggesting that fluid reasoning abilities, or *Gf*, are associated with executive functions to the extent that they may be measuring the same construct. By contrast, Friedman et al. (2006), reported a relationship between executive functions and *Gf* but contend that this relationship is no stronger than the relationship seen between executive functions and crystallised abilities of *Gc*. Although the current study has revealed a significant positive relationship between FSIQ and performance on a task of executive functioning, the CAFT, it was beyond the scope of the current study to examined in detail which specific aspects of intelligence contribute most to this relationship.

In their study of 123 healthy individuals Obonsawin et al., (2000) also found strong associations between performance on seven tests of executive function, including the COWAT, and general intellectual ability (*g*). It was also reported that performance on the different tasks of executive function share significant variance which is again consistent with the current study. Obonsawin et al. contend that these results demonstrate that many of the

most frequently used tasks of executive function are similar to the extent that they are related to general intellectual ability and more specifically, that these tests of executive function, as a battery, may provide an accurate assessment of general intellectual ability.

There are clear implications for clinical practice when considering the results of the current study in light of Obonsawin et al's. (2000) contention. If tests of executive function, such as the CAFT, and those of general intellectual ability, or FSIQ are able to measure the same skills it may be possible to shorten the often lengthy neuropsychological assessment process. This would be particularly desirable in situations in which time is limited.

4.2. Hypothesis Two

The second hypothesis stated that performance on CAFT Size condition would be positively correlated with performance on part B of the Trail Making Test, this hypothesis was also supported. The findings show a weak but significant relationship in that as performance on the CAFT Size condition increases, with more animals being recalled, so does performance on part B of the Trail Making Test, with less time taken to complete the task.

Part B of the Trail making test is a well established, widely used measure of executive function, specifically, it's seen as a test of mental flexibility or task switching, which is the ability to switch from one response set to another. Successful completion of part B of the Trail Making Test requires accurate visual scanning, attention, and sound motor skills including speed and dexterity (Lezak et al., 2004; Strauss et al., 2006). In their study of 121 individuals Kortte et al., (2002) found support for the contention that performance on part B of the Trail Making Test is sensitive to cognitive inflexibility.

The finding in the current study of a significant relationship between

performance on the CAFT Size condition and part B of the Trail Making Test provides support for the assumption that these two tests rely on the same underlying cognitive process. It also supports the belief that the CAFT Size condition is not only a measure of the executive function verbal fluency, but may be useful as a measure of other executive skills known to be captured by part B of the Trail making Test such as mental flexibility or task switching.

This particular finding is consistent with previous studies examining the underlying components required for verbal fluency performance (Troyer et al., 1997; Unsworth et al., 2011). Troyer et al. suggest that the ability to group, or cluster, words generated according to phonemic or semantic criteria and then shift or switch between these groups is important for successful verbal fluency performance.

The finding that performance on the CAFT Size condition is significantly related to performance on part B of the Trail Making Test has some important clinical implications. If these two tests are reliant on the same underlying processes and the CAFT Size is also a measure of other executive functions that are traditionally assessed by part B of the Trail Making Test it may be possible to replace the Trail Making Test with the CAFT in assessment protocols. Furthermore, performance on the CAFT Size is not reliant on intact letter and number knowledge, good visual acuity, or good graphomotor skills, therefore, it can be used in patient groups that may be unable to undertake the Trail Making Test such as illiterate individuals, stroke patients or the visual impaired. Finally, the CAFT Size may be a more appropriate tool than the Trail Making Test for bedside assessments as it avoids the problems of posture required for the graphic response and does not rely on good graphomotor skills. Furthermore, a stable surface on which the patient completes the test is not required.

4.3. Hypothesis Three

The hypothesis that performance on CAFT Size will be positively correlated with performance on the longest digit backward task a working memory task was not supported. This finding is not only in contrast to past research (Rende et al., 2002) demonstrating a relationship between working memory and executive functions but is inconsistent with what would logically be expected given the inherent demands of these tasks.

Successful performance on the Digits Backward task is reliant on the ability to 'hold' information in immediate memory while actively engaging in online processing (Conway et al., 2005). The CAFT Size also relies on this ability in being able to 'hold' a particular animal in mind whilst actively searching for another that is marginally bigger. Furthermore, the ability to sequence is required in order to undertake both tasks. In Digits Backward, numbers must be 'held in mind' and repeated back in reverse sequence. Similarly, in the CAFT Size condition animals must be held in mind and ordered, or sequenced according to size.

The finding of the current study regarding these variables is also inconsistent with the broader view of Baddeley's (2000) model of working memory in which the Central Executive plays a major role. However, in considering Baddeley's model of working memory more closely, successful performance on digit span tasks has been found to be highly reliant on the phonological loop (Baddeley, 2001). 'Holding' the digits, the auditory-verbal information, in immediate memory is reliant on phonological loop process, whilst the online manipulation of that information, the reversing of the digits, utilises the central executive (Ostrosky-Solís & Lozano, 2006).

The CAFT Size condition is also somewhat reliant on auditory-verbal working memory and, therefore, the phonological loop, however, the CAFT Size is very much a visually mediated task. An individual must be able to visualise an

animal and hold that representation in their mind and then visualise another animal that is slightly bigger in order to successfully complete this task. As suggested by Rende et al. (2002), this process is mediated by the visuospatial sketchpad rather than the phonological loop and may help explain, to some extent, why no significant relationship was revealed for this hypothesis.

Any future investigation of the CAFT Size in relation to working memory as conceptualised by Baddeley's model of working memory should consider using a visuospatial working memory task rather than an auditory-verbal working memory task. One example of a visuospatial working memory task would be a spatial span task in which the participant observes the examiner tapping a sequence of blocks and then repeats the same sequence forwards and in another trial, backwards. This may help clarify whether performance on the CAFT Size is correlated to working memory performance but is reliant on the visuospatial sketchpad rather than the phonological loop.

4.4. Hypothesis Four

A significant, strong positive relationship was found between performance on CAFT Alphabet condition and performance on the COWAT, thereby supporting the fourth hypothesis. This finding is consistent with past studies conducted by Popp (2003) and Evans-Barker (2004) and was expected given the phonological demands of this CAFT condition. Although the CAFT Alphabet condition has a semantic structure, successful performance does rely on intact letter-sound knowledge as does performance on phonemic verbal fluency tasks such as the COWAT.

The highly significant finding in this case is important in the context of the current study as it demonstrates that the Animals Alphabet condition of the CAFT is a clinically useful verbal fluency type measure of executive function that may be suitable for use across the same populations as the COWAT. More broadly, this finding adds to the existing research regarding the

relationship between various verbal fluency measures of executive function and the ability of these tests to assess the same general construct despite differing task structure and demands.

4.5. Hypothesis Five

It was hypothesised that performance on the three CAFT conditions would be correlated with demographic variables of age, years of education, and socioeconomic status; the results partially support this hypothesis.

In contrast to some past studies (Collie et al., 1999; Gladsjo et al., 1999; Hester et al., 2005) which have demonstrated a significant relationship between age and cognitive task performance, the current study data showed no significant relationship between the variable of age and performance on each of the three conditions of the CAFT. That is, performance on the three conditions of the CAFT did not decrease as a function of age. This non-significant finding, however, may be due to the participants in both the Collie et al. and Hester et al. studies being older and a wider range. Examining performance on the CAFT across a much wider age range may reveal an age effect as it is quite possible that cognitive changes occur to a greater extent in middle and late adulthood.

The number of years of education was found to be significantly correlated with performance on all three CAFT conditions, again with a weak relationship being revealed between years of education and the CAFT Auto, a moderate relationship with CAFT Size and a strong relationship with CAFT Alphabet. As with SES, the results show that performance on the CAFT improves with increasing education. The finding of a significant relationship between number of years of education and verbal fluency performance is consistent with the findings of Evans-Barker (2004) and the study reported by Gladsjo et al. (1999).

Gladsjo et al. (1999) assessed 768 individuals ranging in age from 20 to 101 years on a large neuropsychological test battery that included letter and category fluency tasks. Consistent with the current study, Gladsjo et al. found that number of years of education was significantly related to performance on the category verbal fluency task with the higher number of years of education leading to better performance.

Socioeconomic status (SES) was also correlated with all three conditions of the CAFT with weak relationship being revealed between SES and the CAFT Auto, a moderate relationship between SES and CAFT Size and a strong relationship between SES and CAFT Alphabet. In each case, as SES increases so too does performance on the CAFT condition. These findings are, in part, consistent with those of Evans-Barker (2004), who found weak significant relationships between SES and performance on the CAFT Auto and CAFT Alphabet conditions were found.

The importance of considering the impact of demographic variables on cognitive test performance is well recognised (Carstairs et al., 2006; Collie et al., 1999; Ganguli et al., 2010; Gladsjo et al., 1999; Hester et al., 2005; Kaplan et al., 2001; Meijer et al., 2009). Understanding the impact that variables such as age, years of education, and SES have on cognitive test performance is essential in the development of norms to help ensure that they are reliable and valid. (Lezak, 2004). Developing norms for individual tests, such as the CAFT, that are applicable to different demographic subgroups within the population is particularly important in countries that are as diverse, ethnically, socioeconomically, and educationally, as Australia.

4.6. Hypothesis Six

Popp's (2003) findings showed a gender difference in CAFT scores. Accordingly, it was hypothesised that a significant difference would be seen between males and females scores on the three conditions of the CAFT. The

results of the current study do not support this hypothesis.

The effect of gender on cognitive test performance has been widely studied (Collie et al., 1999; Gladsjo et al., 1999; Hester et al., 2005; Saykin et al., 1995; Unverzagt et al., 1996; Wiederholt et al., 1993) with varied results. Hester et al. for example found that gender had a small but significant effect on performance on part A of the Trail Making Test. They concluded, however, that this difference was so small that corrections on the basis of gender were not warranted when developing a normative data set.

In their study involving 131 individuals aged 18 to 49 years, Saykin et al. also found a gender difference in the performance on certain neuropsychological tests. Specifically, they found that males performed better on the Information subtest of the Wechsler Adult Intelligence Scale – revised, and had faster finger tapping scores than females. However, Saykin et al. suggest that demographic factors such as gender “infrequently account for more than 10% of the variance for many neuropsychological test scores” (p. 79).

Conversely, other studies have revealed no significant difference in performance as a function of gender (Coman et al., 1999; Sherrill-Pattison et al., 2000; Welsh-Bohmer et al., 2009) In considering executive function tests of verbal fluency in particular, Gladsjo et al. (1999) indicates that gender differences are inconsistently found for phonemic fluency tasks but not for semantic fluency tasks. The results of their study, involving 768 individuals found no gender difference for either fluency task, stating “similar to the results of most previous normative studies, gender did not significantly influence fluency performance” (Gladsjo et al., p. 156).

When considering the CAFT in particular, past studies by Ruvceska (2003) and Evans-Barker (2004) did not find a difference in performance as a function of gender. These results, with participants in late adulthood, coupled with past research suggests inconsistent, or no, difference in verbal fluency

performance on the basis of gender. Therefore, it is possible that Popp's finding was the result of "sampling error" or it may reflect the inconsistency of effects as pointed out by Gladsjo et al. (1999) in relation to verbal fluency tasks that are largely phonemic in nature.

4.7. Controlled Animal Fluency Test Normative Data

A comparison of the normative data obtained in the current study with those reported by Popp (2003) shows that the current sample performed better across all conditions of the CAFT. Past literature has shown a positive association between the participant's level of education and cognitive test performance (Hester et al., 2005; Meijer et al., 2009). This difference in mean scores may be explained in part by the difference in mean number of years of education between the two samples with the mean number of years of education in the current sample at 16.6 (2.7) compared to 13.8 (1.68) years in the Popp study.

Past research has also shown a positive association between performance on tasks of executive function and FSIQ (Davis et al., 2011; Decker et al., 2007; Friedman et al., 2006). Therefore, when comparing the normative data for the current study with the data from Popp's (2003) study one might expect that the study with the higher overall mean CAFT scores across the three conditions would also have the higher overall mean FSIQ. Interestingly, this is not the case since Popp had a group mean FSIQ of 113.7 (SD = 19) and in the current study the group mean FSIQ = 109.6 (SD = 10.8). A detailed analysis of this discrepancy was beyond the scope of the current study. Nevertheless, on face value the standard deviation in the Popp study is nearly twice that of the current study indicating a greater variation in performance across his group. Closer examination of Popp's data reveals that the FSIQ range for his participants varied from 76 to 155, a much broader range of FSIQ scores than seen in the current study. Without Popp's outlier FSIQ of 155 his groups mean FSIQ would have been much closer to the mean FSIQ

of the current study.

Mean age of a sample is an important factor to consider when developing a normative data set, particularly when you're considering a relatively wide and diverse age group such as early adulthood. The current sample is comprised of participants that span the entire age range, with the youngest at 19 years of age and the oldest at 40 years of age. The mean age of the current sample, 31.2 years (SD = 6.03), falls roughly in the middle of the early adulthood age range which indicates that the normative data obtained for the CAFT in the current study are more likely to be representative of the specified population than if the mean age was concentrated at one end of the age range.

When examining the mean age of the current sample in comparison to that of Popp (2003) a discrepancy is again observed. The mean age of Popp's sample, 23.3 years (SD = 3.74) is younger than that of the current and does not encompass such a wide age range with the oldest participant being 32 years of age. Although age has been shown to have a significant impact on cognitive test performance, including measures of executive function, this has been found to be the case for older individuals, not those in the early adulthood age range (Collie et al., 1999; Treitz et al., 2007). Therefore, it's unlikely that the difference seen in mean age between the current sample and that of Popp has contributed to the difference seen in mean performance across all three CAFT conditions.

4.8. Strengths and Limitations

The primary aim of the current study was to investigate how performance on the CAFT relates to performance on other established tests of executive function, cognitive factors, and non-cognitive factors in the early adulthood age-range, with an additional aim being to gather further normative data for CAFT in this age group. As is inherent in any applied research a number of methodological issues that may have impacted upon the current findings.

In order to achieve the aims of the current study, a convenience sampling method for participant selection was the most practicable recruitment method. Whilst random sampling is viewed as the 'gold standard' of participant recruitment it involves the establishment of a defined population (e.g., all adults on the electoral role) and a truly randomised method of selecting potential participants. Such a methodology requires very substantial personnel and financial resources that were not available to this study and are often not available. Convenience sampling ensured that the desired sampling characteristics were obtained (i.e., early adulthood age-range, non-clinical type, normal FSIQ range, sound English skills) and was found to be most appropriate given the need to have direct contact with the participants in order to assess them.

A sample that was much larger than the current 60 participants would have been preferable, particularly given the number of variables and correlations. However, given the desired sampling characteristics, the need for face-to-face contact with each participant, the 60-minute assessment session and the very considerable involvement of time in recruiting the sample the total of 60 participants is consistent with some other data sets (Strauss et al., 2006).

Moreover, the sample obtained for the current study encompasses a wide range of ages within the early adulthood age-range (19-40 years), is fairly evenly matched with regard to gender distribution (27 males and 33 females), encompasses a wide range of education levels (11 to 26 years), and a broad socioeconomic range from manual labourer to medical practitioner. The sample was also found to be of normal cognitive functioning status according to the age-appropriate published norms (Strauss et al, 2006; Wechsler, 1999; Wechsler, 2008) for the standard measures used including a mean FSIQ within the upper average range, and was fairly evenly matched with regard to place of residence with 34 being from a capital city and 26 from a regional city.

A final limitation with regard to sampling was the large discrepancy in the number of participants from an English speaking background (N = 52) compared to those from a non-English speaking background (N = 8). The magnitude of this discrepancy was such that a comparison of performance on the CAFT according to language background was not pursued in the current study. This may limit the generality of the findings of the current study to individuals from English speaking backgrounds only.

4.9. Future Directions

There are several avenues of future research that should be pursued with regard to the CAFT. One focus should be on gathering further normative data for the CAFT for individuals in the early adulthood age range. The development of a robust set of normative data for the CAFT is essential not only to provide a “uniform frame of reference for test users” (Nelson, 1994, p. 283) but also to encourage the use of the CAFT in clinical settings.

4.9.1. Demographic issues

One factor to consider when gathering further normative data for the CAFT in the early adulthood age range is to ensure that the sample is representative of the broader population with regard to FSIQ and number of years of education. Although the current sample’s overall mean FSIQ was within the average range it was seen to be within the very upper limits of that range whilst Popp’s (2003) mean overall FSIQ was above average. In both the current and the Popp study mean number of years of education is elevated. Ensuring that the mean FSIQ of any future studies falls within the mid-average range and that the mean number of years of education is not elevated will help ensure that the CAFT norms are derived from a truly ‘normative’ sample.

4.9.2. Cross cultural issues

The influence of culture and language on cognitive test performance is important to consider when developing new assessment tools. As pointed out by Stolk (2009) there is “potential for diagnostic errors when Western standardised assessments are used in education and mental health settings to assess children, adults and aged persons from cultures in which those measures have not been validated” (p. 1). Past literature indicates that semantic verbal fluency tasks, such as the CAFT, may be more useful cross culturally and in assessing illiterate individuals than phonemic verbal fluency tasks such as the COWAT (Ardila et al., 2006; Manly et al., 1999; Pekkala et al., 2009). This suggests that the CAFT may be useful and more accurate across a broader range of individuals than the COWAT and not as subject to differences in culture or reading ability. Obtaining a sample with a broader range of cultural and language background was beyond the scope of the present study but is an important issue to consider, especially in Australia given the continually increasing rate of migration from a wide variety of cultural and linguistic backgrounds (ABS, 2011).

4.9.3. Modern theories of intelligence

Further research regarding the CAFT could also focus on better understanding the relationship between performance on the CAFT and intelligence as described by the Cattell-Horn-Carroll theory of cognitive abilities (CHC theory). The current study has shown significant positive relationships between performance on all three conditions of the CAFT and intelligence, or FSIQ that is comprised of verbal and nonverbal intellectual abilities as described by Wechsler (1999). The contemporary CHC theory encompasses skills such as fluid intelligence (*Gf*) that has been found to be strongly associated with executive functions (Decker, et al., 2007). Investigating whether performance on the CAFT is strongly associated with performance on tasks that are said to assess *Gf* may provide further

information regarding the range of skills the CAFT assesses. Furthermore, it may provide valuable insight into whether *Gf* and executive functions should be viewed as separate or interchangeable constructs.

4.9.4. Neural mechanisms underlying CAFT performance

In line with current trends in cognitive neuroscience a future avenue of research may be to investigate the underlying neural mechanisms involved in performance on the CAFT. The CAFT is a brief, easy to administer, auditory-verbal task of executive function that is not reliant on physical ability. Therefore, the CAFT is well suited to be used in imaging studies such as those described in Braver et al. (2010).

4.10. Conclusion

Using an early adulthood sample, the current study investigated a more recently refined measure of executive function, the Controlled Animal Fluency Task (CAFT) with the aim of determining whether a relationship exists between this test and other well-established measures of executive function, overall intellectual functioning (FSIQ), and demographic factors. Further aims of the study were to investigate whether gender differences exist in performance of the CAFT, as a past study by Popp (2003) revealed such a difference, and to gather further normative data for the CAFT in this age range.

The findings of the current study demonstrate that performance on CAFT Alphabet condition is significantly and positively correlated with the Controlled Oral Word Association Test (COWAT) and that the CAFT Size condition is significantly and positively correlated with part B of the Trail Making Test. Both the COWAT and part B of the Trail Making Test are well-established measures of executive function. These findings provide support for the contention that the CAFT is a useful and valid measure of executive function.

Consistent with past research, the current findings also revealed a significant positive relationship between performance on the three conditions of the CAFT and FSIQ, thereby highlighting the important relationship that exists between these cognitive variables. The well understood need to take into account demographic variable in the development of normative data was reinforced in the current study with performance on the CAFT related to the participants' number of years of education a person has had and their socioeconomic status.

Overall, the results of the current study provide evidence that the CAFT is a useful measure of executive functions in the early adulthood age-range. Its ease of administration, brevity, the fact that performance is not as reliant on letter-sound knowledge as phonemic fluency tasks, and the assumption, based on previous research, that it may be suitable to use cross-culturally make it an attractive assessment tool suitable for use in a variety of setting.

Executive functions are widely regarded in research literature, and clinical practice as a complex set of mental skills or capacities that are important in all aspects of human life (Alvarez & Emory, 2006; Anderson, 2002; Lezak, et al., 2004). There are many factors that can negatively impact the executive functions throughout the lifespan with brain injury and mental illness being two factors that are particularly pertinent during the early adulthood stage of life. Therefore, continued research in this area, including the development of measures, such as the CAFT, that can easily and accurately assess executive functions is crucial.

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APPENDIX A

Interview Protocol

Interview Protocol

Personal Information

Gender:

Date of birth:

Primary language spoken at home:

Number of years of formal education:

Marital status:

Current or former occupation:

Developmental History

Past or current history of developmental disorder?

Medical Information

Any major medical conditions in the past or currently that may affect cognition. Did a medical practitioner formally diagnosed this/these condition/s?

Psychological History

Any history of psychological disorder in the past or currently?

Medication

Prescribed or non-prescribed medication currently taking, include dose and frequency

APPENDIX B

Controlled Animal Fluency Test (CAFT) Instructions

Controlled Animal Fluency Test (CAFT)

For each of the following three conditions allow 60 seconds for the participant to complete the task. If the participant is silent for 15 seconds or more, repeat basic instructions. Write down each animal name in the order said. – If queried, animals include reptiles, birds, and fish.

1. **Animals Auto:** Tell me as many different animals as you can, in any order and keep going until I say stop.

2. **Animals Size:** I want you to tell me as many different animals as you can but this time I want you to put them in order of their size. That is, I want you to tell me the smallest animal you can think of first, then one just a little bit bigger, and a little bit bigger and so on, making sure that each one is bigger than the one before it. Don't get too big too quickly or you'll run out of animals. Keep going until I say stop.

3. **Animals Alphabet:** Before we start this part I need you to say the alphabet for me. Now I want you to tell me as many animals as you can but this time I want you to order them according to the alphabet. That is, the first one is to begin with A, the next one with B, then C and so on. Say only one animal for each letter and keep going until I say stop.

APPENDIX C

Controlled Oral Word Association Test (COWAT
Instructions)

Controlled Oral Word Association Test (COWAT)

I will say a letter of the alphabet. Then I want you to give me as many words that begin with that letter as quickly as you can. I do not want you to use words that are proper names or the same word with a different ending. Begin when I say the letter. The first letter is F. Go ahead.

The letters are F, A, and S

60 seconds is allowed for each letter

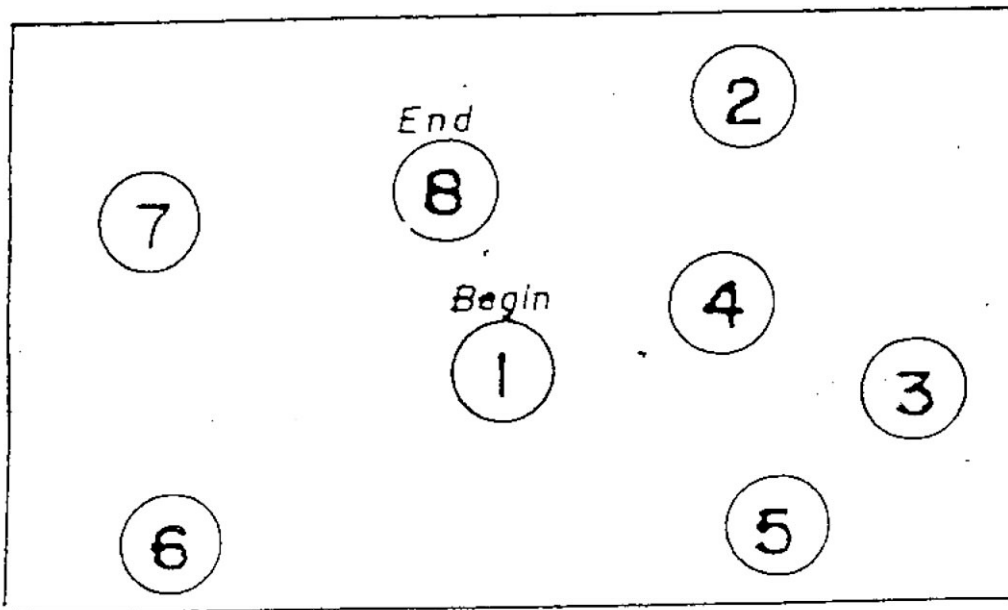
APPENDIX D

Trail Making Test (TMT) part A and part B

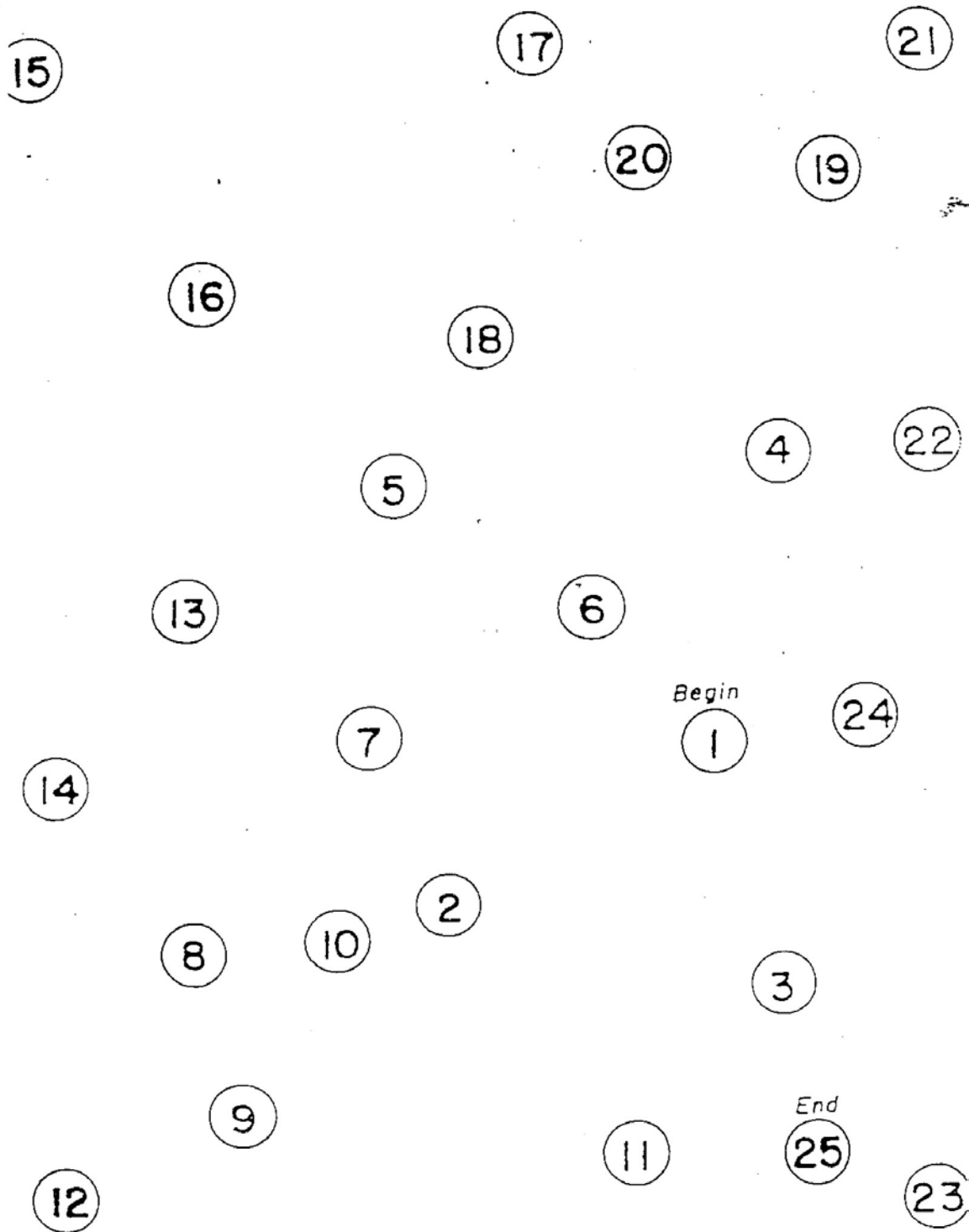
TRAIL MAKING

PART A

SAMPLE



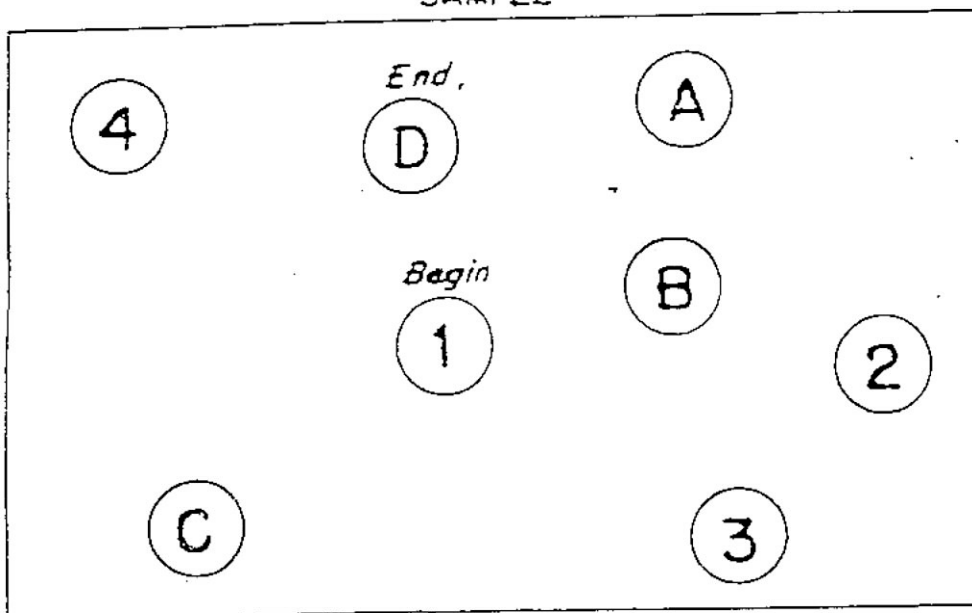
TRAIL MAKING PART
A



TRAIL MAKING

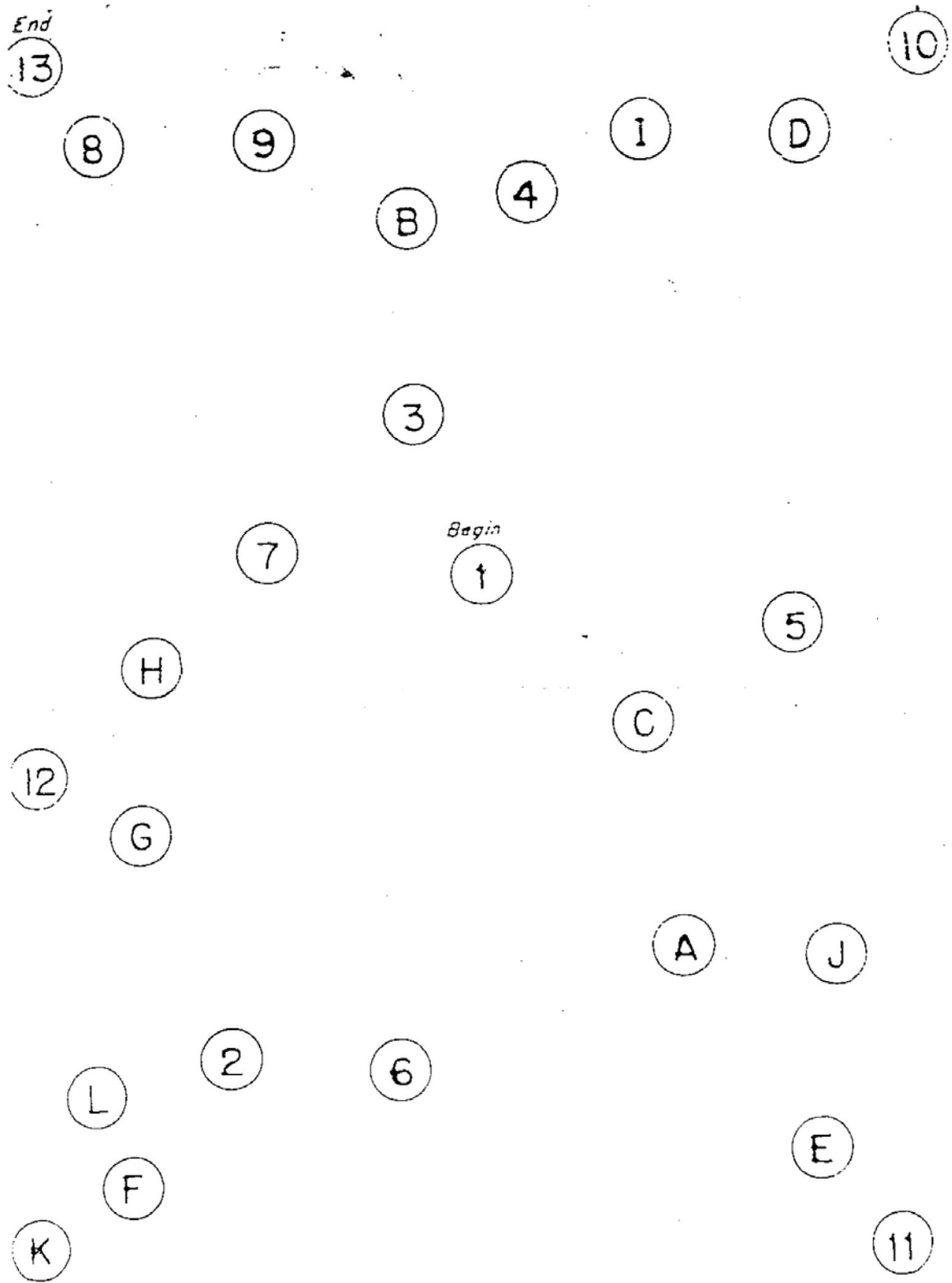
PART B

SAMPLE



TRAIL MAKING

PARTB



APPENDIX E

Research Ethics Approval by Victoria University Human
Research Ethics Committee


**VICTORIA
UNIVERSITY**
**A NEW
SCHOOL OF
THOUGHT**

MEMO

TO Dr. Alan Tucker
School of Social Science & Psychology
St Albans Campus

DATE 25/09/2008

FROM Prof. Carolyn Noble
Chair
Arts, Education & Human Development Human Research
Ethics Subcommittee

SUBJECT Ethics Application – HRETH 08/182

Dear Dr. Tucker,

Thank you for resubmitting this application for ethical approval of the project:

HRETH08/182 Executive Functions in Early Adulthood: A Comparative Study

The proposed research project has been accepted and deemed to meet the requirements of the National Health and Medical Research Council (NHMRC) 'National Statement on Ethical Conduct in Human Research (2007)', by the Chair, Faculty of Arts, Education & Human Development Human Research Ethics Committee. Approval has been granted from 25/09/2008 to 25/09/2010.

Continued approval of this research project by the Victoria University Human Research Ethics Committee (VUHREC) is conditional upon the provision of a report within 12 months of the above approval date (by 25/09/2008) or upon the completion of the project (if earlier). A report proforma may be downloaded from the VUHREC web site at: <http://research.vu.edu.au/hrec.php>

Please note that the Human Research Ethics Committee must be informed of the following: any changes to the approved research protocol, project timelines, any serious events or adverse and/or unforeseen events that may affect continued ethical acceptability of the project. In these unlikely events, researchers must immediately cease all data collection until the Committee has approved the changes. Researchers are also reminded of the need to notify the approving HREC of changes to personnel in research projects via a request for a minor amendment.

On behalf of the Committee, I wish you all the best for the conduct of the project.

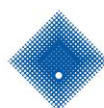
If you have any further queries please do not hesitate to contact me on 9919 2917.

Prof. Carolyn Noble
Chair
Faculty of Arts, Education & Human Development Human Research Ethics Subcommittee

APPENDIX F

Information to Participants Form

INFORMATION

**VICTORIA
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THOUGHT**

TO PARTICIPANTS INVOLVED IN RESEARCH

You are invited to participate

You are invited to participate in a research project titled Executive Functions in Early Adulthood: A Comparative Study.

This project is being conducted by postgraduate student researcher Jacqueline Evans-Barker, as part of a Doctor of Psychology (Clinical Neuropsychology) degree at Victoria University, under the supervision of Dr Alan Tucker from the School of Psychology, Faculty of Arts, Education, and Human Development.

Project explanation

The purpose of this study is to explore and examine aspects of cognitive functioning (information processing) and executive functioning in individuals who are in the early adulthood age range, between 18 and 40 years of age. Executive functions are a collection of cognitive functions that include sequencing, planning, organising, and monitoring in order to achieve a goal.

What will I be asked to do?

You will be asked to complete a variety of commonly used, fairly simple, non-invasive tasks each of which measures different aspects of cognitive function (information processing abilities) and executive function..

What will I gain from participating?

Participation in this study will result in a free assessment and report on important aspects of cognitive functioning (information processing abilities).

How will the information I give be used?

The information obtained will remain confidential and will only be viewed by myself, Jacqueline Evans-Barker (Provisional Psychologist) and my supervisor Dr Alan Tucker (Registered Psychologist and experienced Clinical Neuropsychologist). No information that could in anyway identify you or any other participant will appear on the final report or other research reports; only group data will be reported.

What are the potential risks of participating in this project?

There are no appreciable risks associated with this study. Occasionally a person may become a little anxious in the course of the doing the cognitive tests. If this happens a short break may be taken or the person may withdraw from the study.

How will this project be conducted?

If you would like to participate in this study I would like to spend one session of approximately one hour with you in a quiet room the Victoria University Psychology Clinic (on St Albans campus), or at another mutually convenient suitable testing location. During this session you will be assessed with a variety of fairly simple, non-invasive, established information processing tests, each of which measures different aspects of cognitive function. You will also be asked to answer a short questionnaire on aspects of your medical history, age, and language spoken at home, work, and school background

Who is conducting the study?

Dr Alan Tucker (Principal Researcher)
Co-Director, Victoria University Psychology Clinic
Convenor, M Psych & D Psych - Clinical Neuropsychology
School of Psychology
Victoria University
PO Box 14428, Melbourne, VIC 8001
Ph. 9919 2266

Jacqueline Evans-Barker (Student Researcher)
Psychologist and D.Psych (Clinical Neuropsychology) Candidate
School of Psychology
Victoria University
PO Box 14428, Melbourne, VIC 8001
Ph. 0422 650 193

Any queries about your participation in this project may be directed to the Principal Researcher listed above.
If you have any queries or complaints about the way you have been treated, you may contact the Secretary,
Victoria University Human Research Ethics Committee, Victoria University, PO Box 14428, Melbourne, VIC, 8001
phone (03) 9919 4781.

APPENDIX G

Consent Form for Participants



**VICTORIA
UNIVERSITY**

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THOUGHT**

CONSENT FORM FOR PARTICIPANTS INVOLVED IN RESEARCH

INFORMATION TO PARTICIPANTS:

We would like to invite you to be a part of a study investigating aspects of cognitive functioning (information processing) and executive functioning in individuals who are in the early adulthood age range, between 18 and 40 years of age. Executive functions are a collection of cognitive functions that include sequencing, planning, organising, and monitoring in order to achieve a goal.

CERTIFICATION BY SUBJECT

I,

of

certify that I am at least 18 years old* and that I am voluntarily giving my consent to participate in the study: **“Executive Functions in Early Adulthood: A Comparative Study”**, being conducted at Victoria University by: Dr Alan Tucker & Ms Jacqueline Evans-Barker

I certify that the objectives of the study, together with any risks and safeguards associated with the procedures listed hereunder to be carried out in the research, have been fully explained to me by:

Jacqueline Evans-Barker

and that I freely consent to participation involving the below mentioned procedures:

- Wechsler Abbreviated Scale of Intelligence (WASI)
- Digit Span subtests from the Wechsler Adult Intelligence Scale – Third Edition (WAIS-III)
- Controlled Animal Fluency Test (CAFT)
- Controlled Oral Word Association Test (COWAT)
- Trail Making Test (TMT)

I certify that I have had the opportunity to have any questions answered and that I understand that I can withdraw from this study at any time and that this withdrawal will not jeopardise me in any way.

I have been informed that the information I provide will be kept confidential.

Signed:

Date:

Any queries about your participation in this project may be directed to the principal researcher
Dr Alan Tucker 9919 2266.

If you have any queries or complaints about the way you have been treated, you may contact the Secretary,
Victoria University Human Research Ethics Committee, Victoria University, PO Box 14428, Melbourne, VIC, 8001
phone (03) 9919 4781

*[*please note: Where the participant/s are aged under 18, separate parental consent is required; where the participant/s are unable to answer for themselves due to mental illness or disability, parental or guardian consent may be required.]*