The Development of Executive Functioning in South African Adolescents

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ABSTRACT

The purpose of this study is to investigate the specific developmental trajectory that executive functioning takes in South African adolescents. Such an investigation into this adolescent phenomenon has been considered somewhat redundant in past neuropsychological research due to the assumption that the executive system had reached maturity by late childhood – a claim that will attempt to be nullified in this research. A sample of 79 student participants between the ages 12 and 15 years, from several different Cape Town schools, was utilized in this study. An extensive neuropsychological test battery, including measures of general intellectual functioning, psychomotor ability, and executive functioning, was administered to all participants. It was hypothesized that the specifically developing and resource-poor nature of the South African context, and the subsequent wide variability in quality of education, would retard the development of childhood executive functioning relative to trajectories seen in resource-wealthy countries. Hence, more highly significant executive progression should take place within this post-pubescent age-interval. Furthermore, the specific adolescent developmental trajectories of each of the executive domains, as laid out by previous tentative research findings (e.g., a slightly flattened developmental trajectory for executive organizational abilities and a more pronounced age-related progression in adolescent attentional capacity) were tested in this sample. Results confirm significant age-related EF progressions across various capacities; as well as implicating SES as both a significant indicator that interacts with age to impact adolescent executive ability, and as an agent that can undermine executive development such that it is delayed beyond the age of normal maturational expectation. Such results are unexpected in light of previous neuropsychological research, highlighting the importance of generating normative data in the South African setting such that clinical misdiagnoses can be prevented.

Keywords: executive functioning; neuropsychological testing; developmental psychology; adolescents; cognition; socio-economic status.

The contextual relevance of this study as a valid research endeavour is evident when one considers the lack of normative neuropsychological data available for the South African population. Such a deficiency has vast practical implications and can result in gross clinical misdiagnosis when using assessment tools which have been standardized upon Western norms (S Anderson, 2001). Hence, the relevance of my study in mapping the adolescent developmental trajectory of executive functions might be pertinent to the future prevention of clinical misclassifications when diagnosing critical executive dysfunctions.

LITERATURE REVIEW

The study of executive functioning (EF) involves investigation into the multiple processes underlying goal-directed and outcome-driven thoughts and actions. It is a field of inquiry that has traditionally been fraught with difficulties due to fallacies in conceptual definition and debatable measurement tools (Senn, Espy, & Kaufmann, 2004; Zelazo & Mueller, 2002). Furthermore, an area within the executive functioning literature that has received especially poor attention is that of the demarcation of adolescent trajectories of EF development, largely because EF was until recently assumed to have reached developmental maturity by early pubescence (Anderson, Anderson, Northam, Jacobs, & Catroppa, 2001; Blakemore & Choudhury, 2006; Mantyla, Carelli, & Forman, 2007).

While this literature review will in part delineate the difficulties present both in the conceptualization and measurement of EF, its main focus will be to review the limited scope of research that has been undertaken in the domain of adolescent EF. The review will commence with an assessment of the difficulties present within conceptual understandings of EF, and the current disjunction that exists between conceptual and test-based measures of executive ability. Through such an exploration of definitional dilemmas and problematic measurement issues, an appropriate model of executive domains will then be delineated that has been used in the present study.

A review of the current absence of adolescent models of executive abilities will then follow, and this will examine recent neuropsychological studies into adolescent executive development that tentatively propose that this is a highly valuable area of study – thus setting the backdrop for the present research. This exploration will also allow the various developmental hypotheses that are tested within the current research to be delineated.

Difficulties in conceptualization

A problematic issue which is highly evident in contemporary EF research is the major dilemmas inherent in definitional systems of executive understanding (Zelazo et al., 2003). Zelazo et al. assert that a disjuncture exists between the operational test measures of EF which are in use today and the conceptualist and essentialist understandings of executive functioning. Many of these operationally defined test measures of EF were developed as early as 1917 in complete absence of neurological and cognitive understandings of the executive domain (Zelazo & Mueller, 2002). Conceptual theories of EF and a delineation of its possible components were only formalized far later in history, following the important discovery that the executive system was situated within the prefrontal cortex (Zelazo et al., 2003). One of the earliest of these theories was that of the Inhibitory model, which argued that EF could entirely be explained as the ability to control and inhibit responses (Luria, 1966, in Zelazo & Mueller, 2002). This was an explanation which the author found to be particularly useful in that many early studies into PFC lesions revealed that consequent EF dysfunctions took the outward appearance of perseveration when implementing plans. Later conceptual theories attempted to further develop such oversimplified models by incorporating the element of working memory into explanations of EF (Diamond, 1991, in Zelazo & Mueller).

Zelazo and Mueller (2002) argue that while such theories were valuable in initially exploring the categories that might be inherent to the executive system, their conception of this domain as a unitary and composite explanatory model were soon revealed to be largely deficient in place of more complex and integrated models of the multitude of executive functions. Such arguments emerged in tandem with findings as to the fact that there is no unitary or domain-general ‘dysexecutive syndrome’, but that differing patterns of cognitive and executive dysfunction are exhibited when prefrontal cortex lesions occur – such as impairments in one’s self-monitoring ability when right lateral PFC damage takes place (Alexander & Stuss, 2007). Thus, in remedying such problematic and overarching EF theories, Zelazo et al. (1997, in Zelazo & Mueller, 2002) propose a problem-solving approach to understandings of EF – which comprises a complex set of interrelated functions that underlie the production of goal-directed behaviours. The authors explain that such a model conceptualizes of executive processes as a series of stages, beginning at (a) the stage of conceptualization of the ‘problem-space’, (b) progression to the ‘planning’ stage, (c) the ‘action’ stage, and (d) an ‘evaluation’ stage in which possible errors made in the completed task are reviewed. The authors argue that this is a useful explanatory model in its ability to incorporate a variety of executive components into the stages of problem-solving; an example being that the working memory component plays significant importance in moving from the stage of problem conceptualization to being able to hold this 'problem-space' in one's mind and begin planning (Zelazo & Mueller, 2002). The authors argue that the value of such a model also lies in its ability to delineate the various stages in which the limitation of age or an executive deficit might cause perseveration.

An exploration of this domain-ambiguous conceptual framework reveals that while the descriptive value of this model can be established, the inability of this framework to be incorporated into practical study is evident when one considers the widely-accepted contemporary utilization of domain-specific EF tests when conducting research. These tests, such as those specializing in attentional capacity, do not coalesce with broader conceptual frameworks, but exist almost as an entirely separate basis of executive understanding (Zelazo et al., 2003).

Difficulties in measurement

As has thus been established, conceptualization difficulties have arisen due to the fact that EF test measures have traditionally served as operational definitions for this construct due to their practicality in research studies, despite the lack of theoretical knowledge underpinning their construction. Problematic measurement issues which have resulted from the use of such operational test definitions are evident in the attempts made by various research studies to identify broader EF domains by generating factor analyses of a variety of EF test measures, such as working memory or problem-solving tasks (Zelazo et al., 2003). Zelazo et al. argue that the construction of such factor labels which underlie the shared variation seen in individual tests is highly problematic as researchers cannot make assumptions as to what shared cognitive processes underlie these tests without the evidence of theoretical research. This argument is substantiated when one takes into account that various domains and test groupings have emerged when factor analyses are performed at different age intervals (Zelazo & Mueller, 2002). Thus, the unique emergence of the three Factors of inhibition, working memory and attentional control for a sample of 3 – 4 year olds suggests that the shared variation seen in the test scores underlying each factor is not due to overarching EF domains, but to the shared developmental trajectory that these specific test scores will follow only at this particular age (Hughes, 1998b in Zelazo & Mueller, 2002). In short, these tests are not being grouped according to some common cognitive factor, such as attentional span, but instead what emerge are specific age-related domains that are expressive of the score patterns of a particular timetable of executive development (Senn et al., 2004). This notion is articulated by the findings of a study concerning the interrelationship of executive abilities, which uses a path analysis to demonstrate that scores along the construct of problem-solving are more strongly related to inhibition test scores in younger children (Senn et al., 2004). Senn et al. explain that a different pattern of correlation is seen in older children, and that they exhibit significant associations between problem-solving and working memory performance because these variables exist at the same maturational level for this older age group.

Thus, one might argue that there is not as of yet evidence as to rigid domains of executive functioning that can be generalized across a variety of age intervals, and that the best model of EF domains that can be applied in any research setting is one that has been substantiated in past literature for the specific age interval within which one's sample lies. However, in contrast to such arguments is the tentative suggestion of P. Anderson (2002) as to a domain-specific EF model which is largely generalizable across the life-span. The author proposes a 4-factor model on the basis that that the results of past factor analyses have always revealed roughly 3 to 4 executive factors to be optimal. After reviewing past domain categorizations he proposes an executive model composed of the domains of cognitive flexibility, goal setting, attentional control and information processing, and argues that such domains are repeatedly seen in a variety of factor analyses and are substantiated by recent neurological evidence in the field of frontal lobe functioning (Alexander & Stuss, 2000 in P. Anderson, 2002). In this respect, attempts are made to unify test definitions of broader executive domains such that they do not exist within the variable and age-dependent framework of current practise – a fact which has rendered the findings of various EF studies difficult to integrate due to their use of differential executive categories.

Proposed Model

While such a model shows promise in its aspects of domain uniformity, the framework under which the present study has conceptualized executive domains is that of a more age-specific model (see Figure 1), so as to be directly comparable to V. Anderson et al.'s (2001) past seminal work in the field of adolescent EF. It has hence followed a framework under which the 3 factors of (a) Attentional Control, (b) Cognitive Flexibility and (c) Goal Setting are identified (V. Anderson et al., 2001).

ATTENTIONAL CONTROL	COGNITIVE FLEXIBILITY	GOAL SETTING
-sustained attention -attention capacity -processing speed	-word generation -self-monitoring -complex working memory -inhibition	-planning -problem-solving -organizational abilities

Figure 1. V. Anderson et al.'s (2001) Executive Framework

Attentional Control encompasses both the ability to sustain one's attention upon a particular task for an extended period of time, and the size of one's attentional capacity. This construct also measures speed of information-processing. An example of a test measure falling under this construct is that of the Digit-Forwards Test (Wechsler, 2003).

Cognitive Flexibility encompasses the capacity to flexibly move between multitudes of task regulations, and to adapt one's responses based on various rules without falling prey to perseverative errors. Self-monitoring is required in order to inhibit incorrect responses, as is the use of complex working memory abilities, as required in the Digit-Backwards test (Wechsler, 2003). An example of another construct falling under this category is that of 'generativity' and the capacity to generate words, as measured by the Verbal Fluency test (McCarthy, 1970).

Goal Setting encompasses both planning and organisational abilities. The organisational aspect of this domain refers to one's ability to construct appropriate organisational layouts and to configure a set of plans or rules in a rational and hierarchical fashion. The most renowned of these tests is the Rey-Osterrieth Complex Figure Test (*RCFT*; Osterrieth, 1944). One's problem-solving abilities are measured by the ability to conceptualize the problem area, plan a set of actions, implement one's strategy, and to most importantly be able to shift between alternate response sets on the basis of new information (P. Anderson, 2001)

This framework was selected in part so that the current study's results were made comparable to the most substantial past findings within this research area, and in part because this domain-specific model has been shown to be a valid grouping of test measures for the specifically 11.0 to 17.11 adolescent age interval. The test scores for separable executive measures were hence found to correlate to a moderate-to-high level within the particular executive domain that they were purported to probe (V. Anderson et al., 2001). Anderson et al. assert, however, that an exception to such confirmatory findings was the distinct nature of the organisational planning and problem-solving ability scores, which exhibited poor correlations with one another despite their grouping under the broader domain of Goal Setting.

Neurological Understandings of EF Development

While the major dilemmas inherent in definitional systems of executive understanding remain a problematic issue, further concerns are the absence of research in many critical areas of EF (Zelazo et al., 2003). The insufficiency of research into post-childhood executive development has in part been due to the absence of neural research with which to nullify the theories of early developmental psychologists, who proposed that the executive system had reached its maturational level by early pubescence (P. Anderson, 2002; V. Anderson et al., 2001). Competent neurological understandings of the brain processes underlying adolescent cognition have only emerged in recent years due to the advent of magnetic resonance imaging and the ability to view the structures and functions involved in performing particular cognitive tasks. The most significant findings that have contributed to the emergence of adolescent EF research are the discovery that the neural processes of myelination and synaptic pruning continue throughout adolescence in the frontal lobes – the brain regions most implicated in the formation of goal-directed executive behaviours (Blakemore & Choudhury, 2006). Blakemore and Choudhury (2006) argue that the functional MRI evidence of this assertion is clear in the adolescent activation of a far more specialized and localized pattern of brain regions than their child counterparts when completing EF tasks. They assert, however, that because of the scarcity of neuropsychological studies into this phenomenon, there is a lack of data showing that this neural observation has explicit implications for the performance results of adolescents when being administered cognitive test batteries.

The Limited Scope of Adolescent EF research

As has been discussed, the proliferation of EF research in the childhood years is asserted to be the result of popular views in developmental psychology as to the formalization of an adult level of thinking by the age of 12 years (P. Anderson, 2002; V. Anderson et al., 2001).

This perception has led to a plethora of studies into the specific developmental trajectories of EF during childhood and the generation of standardized EF tests based on child samples – which might not be particularly sensitive in detecting fluctuations of EF over adolescent age-intervals. While the generation of standardized norms for adolescents along the constructs of EF has hence never been firmly established, such an absence has perhaps traditionally been seen as insignificant due to the heavier requirement for child norms in the critical developmental years when the majority of inborn cognitive deficits, such as mental retardation, are first identified (De Luca et al., 2003). While such an argument has in part been the impetus for decreased interest in mapping adolescent cognitive trajectories, the recent discovery as to the continued growth of EF capacity in adolescents highlights the importance of developing specific norms for this age-interval – a necessity which might otherwise lead to misdiagnosis of critical EF dysfunctions (V. Anderson et al., 2001).

An essential study by De Luca et al. (2003) into measures of executive functioning across the full human life-span has further emphasised the deficient contemporary understandings of EF systems. By using a sample encompassing the age interval of 8 to 64 years of age, the results of the study revealed that certain executive abilities are only mature by adulthood. This is suggested in the finding that the significantly highest scores along such measures of EF as strategic planning were exhibited by participants falling within the age-interval of 20 – 29 years (De Luca et al., 2003). De Luca et al. thus make the tentative suggestion that while development within the frontal lobes, the area most implicated in the formation of executive abilities, continues throughout adolescence; the post-pubescent only acquires the practised ability to execute these EF abilities well into the second decade of their existence.

A potential flaw of this study lies in the unsophisticated groupings of participants into relatively large age intervals, producing the inability to sensitively map detailed trajectories within specific developmental periods. Such a drawback was remedied in the present study with the use of a narrower age-interval. However, while this design can be critiqued for its cumbersome age groupings, it has nonetheless facilitated the detection of overall significant executive differences between ‘older’ age categories – which might not have been detected within the examination of narrower intervals. These neuropsychological tendencies might previously have gone unnoticed due to the application of executive tests which are often insensitive to the minor executive progression taking place within older age groups, and are best suited to the drastic developmental fluctuations taking place over childhood (De Luca et al., 2003). It was hypothesized in the present research, however, that the developing nature of the South African context and the large variability in received quality of education would retard the development of executive abilities during childhood such that gross fluctuations would be seen within an adolescent age-interval.

Hypothesized Adolescent EF trajectories

A seminal study in the area of adolescent executive functioning is that of 138 Australian adolescents aged 11.0 to 17.11 years researched by V. Anderson et al. (2001). The results of this study are promising in that they suggest that certain domains of executive functioning take a prolonged developmental trajectory and mature only after the age of 12 years. The construct of attentional capacity, which falls under the earlier-mentioned domain of Attentional Control in V. Anderson et al.'s (2001) model, was found to undergo developmental growth at the age of 15years.

A second emerging hypothesis pertains to the executive domain of Goal Setting, for which problem-solving abilities were found by V. Anderson et al. (2001) to be relatively stable over the adolescent years. However, 11-year-old participants were found to perform significantly more poorly on planning-impulsivity than 15-year-olds. This finding is confirmed to some degree by De Luca at al.'s (2003) research, whose results indicate that developmental gains are made in planning-strategy ability across the age intervals of 11–14 and 15–19 years. The organisational planning element of goal setting, however, as measured by the Rey Complex Figure Test (*RCFT*; Meyers & Meyers, 1996) was found to reach a far earlier level of developmental maturity by the age of 12years.

Finally, in the executive domain of Cognitive Flexibility, a stable level of ability was found to be reached prior to the adolescent years along most components, which was a finding in part informed by unwavering scores along word-generation tasks between the ages of 11 and 17 years (Anderson et al., 2001). Conversely, De Luca et al. (2003) found working memory ability, falling within this domain, to be significantly higher at the ages of 15–19 years than any other tested age interval across the human lifespan. Such findings, however, remain only hesitant hypotheses that have yet to be confirmed due to the absence of replication studies in the field of adolescent EF – hence setting the conditions for my present research.

Conclusion

This literature review has established that a multitude of deficiencies exist within the framework of EF research, and has explored the poverty of hypotheses and developmental understandings of post-pubescent executive development – thus setting the backdrop for the present study. Furthermore, deficiencies in executive functioning conceptualization have been reviewed by evaluating the poor theoretical groundings of executive test measures and the inability of such applied tasks to be amalgamated with conceptual and essentialist theory. The limitations of such tests' measurement abilities has also been established in the context of their failure to be grouped into overarching and age-generalized EF domains – a problematic issue which has resulted in a multitude of incongruent executive categories being employed in different studies. Following such a discussion, an appropriate domain-specific model for the proposed study was hence selected such that current findings could be made comparable to past hypotheses.

AIMS AND HYPOTHESES

The objective of the present study was to determine whether a sample of South African adolescents would follow the same developmental trends in executive development as has been set out by past work in this field. As such, the tentative hypotheses established in past literature outlining the trajectory of executive development in specific domains were tested. It was hypothesized in the present research that the specifically developing and resource-poor nature of the South African context, and subsequent divides in economic status and received quality of education, would have the effect of impeding executive development in childhood. As such, it was hypothesized that a more pronounced trajectory of development would be exhibited over the adolescent age-interval of the current sample versus those documented in past literature. These findings were expected to be the result of slight developmental delays in the executive maturation of South African adolescents in contrast to the trajectories outlined by overseas samples of economically homogenous populations.

METHODOLOGY

Research Design and Setting

Data was collected from learners both on an individual recruitment basis and at schools of differing educational quality in Cape Town. The inclusion of a range of schools ensured that diverse levels of socioeconomic status were represented in the sample, ensuring its generalizability to the wider South African population. A synchronic cross-sequential design was used on the basis of non-randomized sampling criteria and the once-off administration of a testing battery.

Participants

A sample of 79 participants falling within the age interval of 12 to 15 years was recruited from various schools. A balanced sample of participants, with equal numbers of boys and girls and roughly equal numbers within age groups, was also recruited. As such, 27x 12-year-olds, 21x 13-year-olds, 18x 14-year-olds, and 13x 15-year-olds were recruited. Selection took place on the basis of teacher recommendation for use in the study; the criteria that teachers used to suggest potential participants were such that the recommended sample of students encompassed a wide berth of academic abilities and was representative of the general student population.

The final selection of students was based on a screening interview for psychological disorders: Students suffering from various forms of psychological and psychiatric pathology were excluded. The screening interview used was the M.I.N.I Kid (Sheehan & Lecrubier, 2001), and a variety of medical questions were also used to determine that the potential participant did not suffer from any medical condition affecting their mental or motor abilities.

Consent to collect data within various schools was obtained from the Western Cape Education Department. Approval for all study procedures was granted by the Research Ethics Committee of the University of Stellenbosch Medical School.

Materials

The test battery being used measured both levels of EF and general intelligence scores, such that IQ might be removed as a covariate because of its potential influence upon executive scores and its confounding of the effect of age upon executive ability.

General intellectual functioning was measured by using 4subtests from the Wechsler Abbreviated Scale of Intelligence (*WASI;* Psychological Corporation, 1999). This intelligence battery has been normed and standardized for use in persons from the age of 6 to 89years. It is the original Wechsler model of intelligence, which conceptualizes of intelligence as falling under the traditional verbal and performance index-split (Strauss, Sherman & Spreen, 2006).

Under the *Verbal IQ* index of the *WASI*, the *Similarities* and *Vocabulary* tests were administered; the first of which requires the participant to identify how two concepts are similar, and the second of which requires participants both to identify the name of an object, and describe the meaning of a word (Psychological Corporation, 1999). Under the *Performance IQ* index of the *WASI*, the *Block Design* and *Matrix Reasoning* subtests were administered (Psychological Corporation, 1999). The Block Design subtest requires participants to copy geometric patterns with red and white-coloured blocks, and the Matrix Reasoning subtest requires that one select the correct piece of a missing picture from a series of options. While the validity of these tests has never been established in a South African context, it is thought that the performance-oriented subtests would be more appropriate than verbal tasks due to their lesser reliance on culturally-specific, school-based, and previously learned information (Strauss, Sherman, & Spreen, 2006).

The EF test scores were obtained through the administration of 7 subtests, each of which was grouped together under the broader domains of Anderson et al.'s (2001) adolescent EF framework. In the domain of Attentional Control, the *Digit-Span Forwards* and *Coding* subtests were placed (Wechsler, 2003). The *DS- Forwards* requires testers to initially repeat a set of numbers in the same order as the test administrator, and then to repeat number sets in the reverse order (Wechsler, 2003). This test measures attentional capacity and the ability to recite a set of numbers from one's short-term memory, whereas the *Coding* test fulfils the processing-speed and sustained-attention aspect of this domain, and involves participants repeatedly copying the correct symbols that have been assigned to a set of numbers within a 2-minute time limit (Strauss, Sherman, & Spreen, 2006; Wechsler, 2003). Another subtest placed in this domain is that of the *Children's Colour Trails Test- Trial 1* (*CCTT*; D'Elia, Satz, Uchiyama, & White, 1996), in which participants must use their sustained-attention and processing-speed abilities to join a series of dots in numerically ascending order.

Within the Cognitive Flexibility domain of Anderson et al.'s (2001) framework, the *Stroop Colour and Word* test (Golden, Freshwater, & Golden, 2003), the second *Children's Colour Trails Test* (*CCTT*; Llorente, Williams, Satz, & D'Elia, 2003), the *Digit Backwards* test (Wechsler, 2003) and *Verbal Fluency* tests (McCarthy, 1970) were placed. The trial of the *Stroop* that probes executive ability is the task in which participants must call out the colour of the ink in which a word is printed and refrain from reading out the printed word; the gold standard measure for inhibition tasks. The *CCTT Trial 2* measures complex-monitoring ability by requiring participants both to connect a series of dots in numerically ascending order and to alternate the colours of the dots that are being connected. The *DS-Backwards test* taps into the working memory function of this domain as one is required to hold a list of numbers in one's mind and perform a manipulation upon them in order to recite the list in the reverse order. Finally, the Phonemic *Verbal Fluency* task requires participants to generate as many words as they can think of that begin with a prescribed letter, and the Semantic *Verbal Fluency* task requires participants to name as many items or 'things' which belong in a particular category, such as animals. These tasks measure word-generation ability (Strauss, Sherman, & Spreen, 2006).

In the Goal Setting domain of Anderson et al.'s (2001) adolescent EF model, the *Rey-Osterrieth Complex Figure test* (*RCFT*; Meyers & Meyers, 1996) and the *Tower of London* (*TOL;* Culbertson & Zillmer, 2001) tasks have been placed. The executive component of the *RCFT* is probed by assigning an organisational score to the participants' copied drawings of a complex design. The *TOL* probes planning and problem-solving abilities by requiring participants to move individual beads along a pegboard in order to try to replicate the tester's arrangement of beads. This must be done in as few moves as possible, and also as quickly as possible, so as to tap into problem-solving capacities (Strauss, Sherman, & Spreen, 2006).

Table 1 provides an overview of the test components and the cognitive domain tested by each, excluding those tests which were being administered for the purposes of the overarching parent study but are irrelevant to the present research.

Table 1.

Test Battery used in the Current Study

Measure	Domain tested	Reference
WASI	Intelligence scale for children and adults	Psychological Corporation, 1999
Block Design	Spatial analysis, visuomotor skills	
Similarities	Abstract reasoning	
Vocabulary	Word knowledge	
Matrix Reasoning	Pattern recognition	
Measure	**Domain tested**	**Reference**
EF Tests		Strauss et al. (2006)
Attentional Control		
Digit Span (Forwards)	Attentional span	Wechsler (2003)
Children's Colour Trails Trial 1	Sustained attention	Llorente et al. (2003)
Coding	Processing speed	Wechsler (2003)
Cognitive Flexibility		
Children's Colour Trails Trial 2	Complex-monitoring	Llorente et al. (2003)
Digit Span (Backwards)	Working memory	Wechsler (2003)
Stroop Colour and Word Test	Inhibition	Golden et al. (2003)
Verbal/Phonemic Fluency	Word generativity	McCarthy (1970)
Goal Setting		
RCFT	Organizational ability	Meyers & Meyers (1996)
Tower of London	Problem-solving and planning skills	Culbertson & Zillmer (2001)

Procedure

After recruiting potential participants, individual screening interviews with the M.I.N.I Kid (Sheehan et al., 1998) were conducted. If participants were revealed to be suitable for testing, the tester carefully read through the assent form (Appendix A) with them and assisted them in completing it, making sure that they understood they were guaranteed the right to withdraw from the study at any stage of the process, and were assured total confidentiality such that their name would never be attached to the study. If the parent of the participant was present at this stage, the same procedure took place such that the parental consent form (Appendix A) was completed. Alternatively, participants were asked to take the consent section of the form home with them for completion prior to their commitment to the study. After this, the administration of the 3-hour neuropsychological test battery took place. A 15-minute break was taken halfway through the testing to prevent fatigue.

Data Analysis

Analysis of the collected data took place using the Statistica8 software package (StatSoft, 2007), and commenced with detailed analyses of descriptive statistics characterizing the performance of adolescents along the measures of executive functioning. The Hierarchical Regression procedure was then used to factor general intelligence out of the analysis, such that it could be established that the effect of SES and age upon EF was not being confounded by the impact of intelligence. The surprising result that SES was a significant predictor of EF performance informed my decision to include it as a categorical predictor. The indicator of SES was constructed by combining a multitude of participant and parental scores and responses on such variables as annual household income, Hollingshead parental employment categories, and self-reported ratings of one's assets. The participant questionnaire capturing these variables is presented in Appendix B, and the parent questionnaire is attached in Appendix C. The main analysis consisted of a series of multiple Factorial ANOVA designs, which were used to examine the impact of the variables of Age and SES upon each of the executive component tests. Planned post-hoc tests (using Tukey's HSD) were conducted to determine the nature of the executive developmental trajectory across Age and SES intervals.

RESULTS

Demographic Characteristics

ANOVA found significant differences for FSIQ scores across the categorical predictor of SES, $F(1, 77) = 53.68$, $p < .0001$. With regard to their FSIQ performance, High SES participants ($n = 37$, $M = 108.9$, $SD = 13.60$) had significantly higher scores than their Low SES counterparts ($n = 42$, $M = 86.05$, $SD = 14.03$). Although the significance of SES as a predictor of intelligence is unsurprising in light of past research, later exploration reveals that, contrary to predictions made in past seminal work in the field (e.g., Anderson et al., 2001), it is similarly able to predict executive ability on various tasks.

Associations between EF Measures

The specific test components that fall within each executive domain are presented in Table 2.

Table 2

Measures of Executive Functioning Used in the Current Study

Domain/Test Name	Outcome Measure
Attentional Control	
CCTT – Trial 1	Time to completion
Coding	Number of correct items
DS - Forward	Number of correct items
Cognitive Flexibility	
CCTT – Trial 2	Time to completion
Stroop - Trial 3	Number of correct items
Verbal Fluency – Phonemic	Number of words generated
Verbal Fluency – Semantic	Number of words generated
DS - Backwards	Number of correct items
Goal Setting	
TOL	Total correct move score / total moves / execution time
RCFT	RCF-OSS (organisational scoring)

Note. CCTT = Children's Color Trails Test; DS – Forward = Digit Span Forward; DS – Backward = Digit Span Backward; TOL = Tower of London; RCFT = Rey Complex Figure Test; RCF-OSS = Rey Complex Figure Organizational Scoring System.

As has been previously discussed, there is much disagreement in current literature concerning the explanatory domains of executive ability, with no standard EF model in use. In assessing the degree to which Anderson et al.'s (2001) executive model contains domain-specific categories, the factor analysis presented in Table 3 was generated.

Table 3.

Factor Analysis of executive domains

	Factor 1	Factor 2	Factor 3
RCF-OSS	0.11	0.02	0.78
TOL: Total Correct	0.26	-0.39	0.01
TOL: Total Moves	-0.15	0.62	0.14
TOL: Execution Time	-0.20	0.91	-0.08
TOL: Time Violations	-0.05	0.87	-0.12
CCTT Trial 1	-0.46	0.00	-0.42
Coding	0.82	-0.09	0.15
DS – Forwards	0.06	-0.21	0.54
DS – Backwards	0.10	0.05	0.52
Stroop Inhibition	0.45	0.12	0.15
Verbal Fluency- Phonemic	0.77	-0.15	0.06
Verbal Fluency- Semantic	0.67	-0.11	0.36
CCTT Trial 2	-0.74	0.06	-0.07
Expl.Var	2.95	2.25	2.07
Prp.Totl	0.20	0.15	0.14

Note. Factor Loadings were Biquartimax normalized with Principal components extraction.

The results of the factor analysis should be interpreted with caution due to the relatively small sample of 79 participants, and because the selected 3-factor model only accounts for 49% of the variability in the data. The factor analysis revealed that executive test measures comprise largely of overlapping abilities that cannot necessarily be organized into highly distinct categories. Hence, while *TOL* measures contain much shared variation, they do not load upon the same factor as that of the *RCF-OSS* test, despite their common grouping under the Goal Setting domain of Anderson et al.'s (2001) model. However, evidence as to the shared variability of such Cognitive Flexibility tasks as the *Stroop*, *Verbal Fluency* tests, and *CCTT trial 2* is seen in Factor 1. Further support for the model can be seen in the common loading of the *Coding* and *CCTT trial 1* tasks of sustained attention and processing speed. The *DS-Forwards* task, however, loads separately – despite being purported to fall within the same attentional domain. Hence, mixed and largely supportive evidence is provided for this explanatory framework.

Numerous authors have explored the relationship between EF and intelligence, based on the idea that IQ is (at least) an important covariate to account for when discussing individual or group differences in executive functioning. Although space constraints limit a full discussion of this issue here, Appendix D presents some preliminary data on the relationship between EF and intelligence in the current sample.

EF adolescent Trajectories: Age and SES Effects

Each of the EF test components investigated in the sample were presented in Table 1; the descriptive results for which are presented in Table 5 across the categories of age groups and SES. In using factorial ANOVA to investigate the significance of these effects, the assumptions of homogeneity of variances and normality were satisfied for all EF dependent variables, bar that of the Verbal Fluency (Phonemic) test. These scores exhibited significant heterogeneity of variances according to Levene's test, and as such a successful log transformation was applied in order to remedy this violation.

Attentional Control

Under the sustained attention and processing speed domain of the present research, it would appear from a review of average *CCTT Trial 1* time-to-completion scores that developmental progression is made across both High SES and Low SES age groups (see Figure 2). For instance, Low SES 15-year-olds complete the task more quickly than do their 12-year-old Low SES counterparts, and a similar and slightly more pronounced progression is seen in High SES participants. These age-related progressions occur regardless of SES; hence, the factor of age is the only significant predictor of performance on this task, with statistically significant differences between the performance of all 12-year-olds (M=27.26seconds, SD=6.90) versus those of all 15-year-olds (M=18.08seconds, SD=4.79), $F(3,71) = 4.55$, p=.0006, $d = 0.61$. Similarly significant results were also seen between the 13(M=25.57seconds, SD=6.85) versus 15-year-old categories (p=.009), with an effect size of 0.53.

Table 5. EF test performance across Age Groups and SES

	Low SES (n = 42)								**High SES** (n = 37)							
Test	12 Years (n = 9)		13 Years (n = 6)		14 Years (n = 16)		15 Years (n = 11)		12 Years (n = 18)		13 Years (n = 15)		14 Years (n = 2)		15 Years (n = 2)	
	M	*SD*	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
Attentional Control																
CCTT – Trial 1	26.8	(6.3)	28.0	(8.9)	24.6	(6.1)	18.4	(5.1)	27.5	(7.3)	24.6	(5.9)	20.0	(7.1)	16.5	(3.5)
Coding	42.1	(9.9)	44.0	(8.6)	48.0	(9.9)	57.0	(8.0)	55.7	(9.2)	54.3	(8.9)	80.0	(17.0)	48.5	(3.5)
DS- Forwards	8.6	(2.1)	9.5	(2.9)	7.9	(1.8)	8.5	(1.8)	9.4	(2.1)	10.7	(1.7)	12.0	(2.8)	14.0	(0.0)
Cognitive Flexibility																
CCTT Trial 2	45.6	(9.1)	40.0	(12.2)	45.6	(11.2)	40.5	(21.4)	40.4	(9.1)	37.1	(6.4)	31.0	(7.1)	25.5	(2.1)
Stroop- Trial 3	30.6	(5.4)	25.8	(10.3)	33.3	(8.2)	36.2	(5.1)	36.6	(10.7)	37.4	(7.6)	49.5	(4.9)	48.5	(6.4)
Verbal Fluency (Phonemic)	27.7	(10.0)	26.8	(7.0)	28.1	(7.4)	34.4	(7.2)	30.3	(8.0)	31.3	(8.6)	33.5	(17.7)	70.0	(28.3)
Verbal Fluency (Semantic)	14.0	(3.7)	13.7	(3.9)	16.4	(3.6)	18.6	(5.4)	17.4	(4.2)	20.1	(4.9)	23.5	(4.9)	36.5	(12.0)
DS- Backwards	4.4	(2.0)	5.0	(1.7)	4.4	(1.5)	4.9	(1.9)	5.7	(2.1)	6.3	(2.1)	6.0	(2.8)	8.5	(0.7)
Goal Setting																
RCFT: RCF-OSS	4.7	(0.8)	4.8	(0.8)	3.3	(1.0)	5.0	(0.0)	4.7	(0.8)	5.4	(1.1)	6.5	(0.7)	5.0	(0.0)
TOL:																
Total Correct	2.6	(1.2)	3.3	(0.8)	3.0	(1.1)	3.5	(1.6)	3.8	(1.8)	3.3	(1.0)	5.0	(2.8)	6.5	(2.1)
Total Moves	28.1	(7.7)	26.0	(6.1)	29.4	(11.2)	22.4	(10.0)	26.6	(14.5)	27.6	(11.0)	28.0	(28.3)	9.5	(5.0)
Execution Time	206.8	(95.5)	156.7	(32.7)	184.0	(56.6)	183.1	(102.9)	191.9	(74.6)	155.8	(49.2)	197.5	(91.2)	143.0	(31.1)

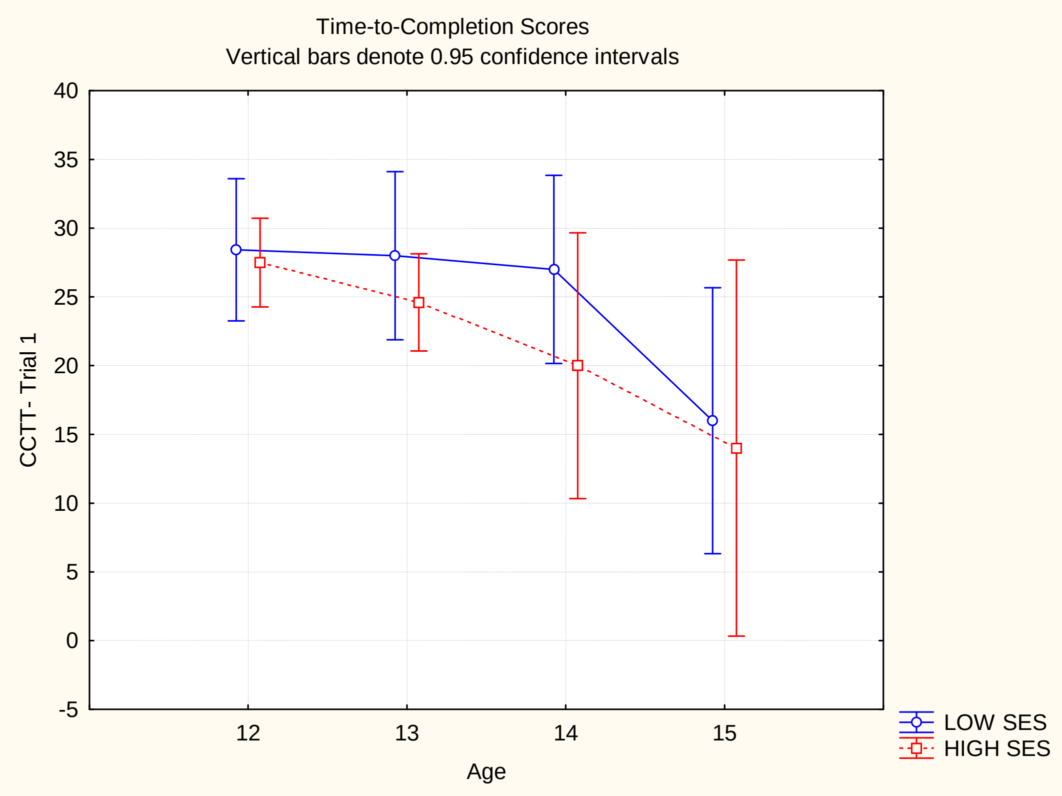

Figure 2. CCTT trial 1 time-to-completion scores across age and SES

Evidence for this attentional developmental progression is slightly less clear in the *DS-Forward* test. Although average scores appeared to increase quite steadily with age in High SES participants, with 12-versus 15-year-olds showing substantial performance increase, a far more inconsistent developmental trajectory was apparent in Low SES participants (see Figure 3). A 2X4 Factorial ANOVA showed, however, that the main effect of Age was statistically significant, $F(3,71)=2.66$, $p=.05$, and that the interaction of Age and SES was also statistically significant, $F(1,71)=21.90$, $p=.000013$. The nature of these interactions were such that High SES 15-year-olds performed significantly better than Low SES 15-year-olds ($p= .01$).

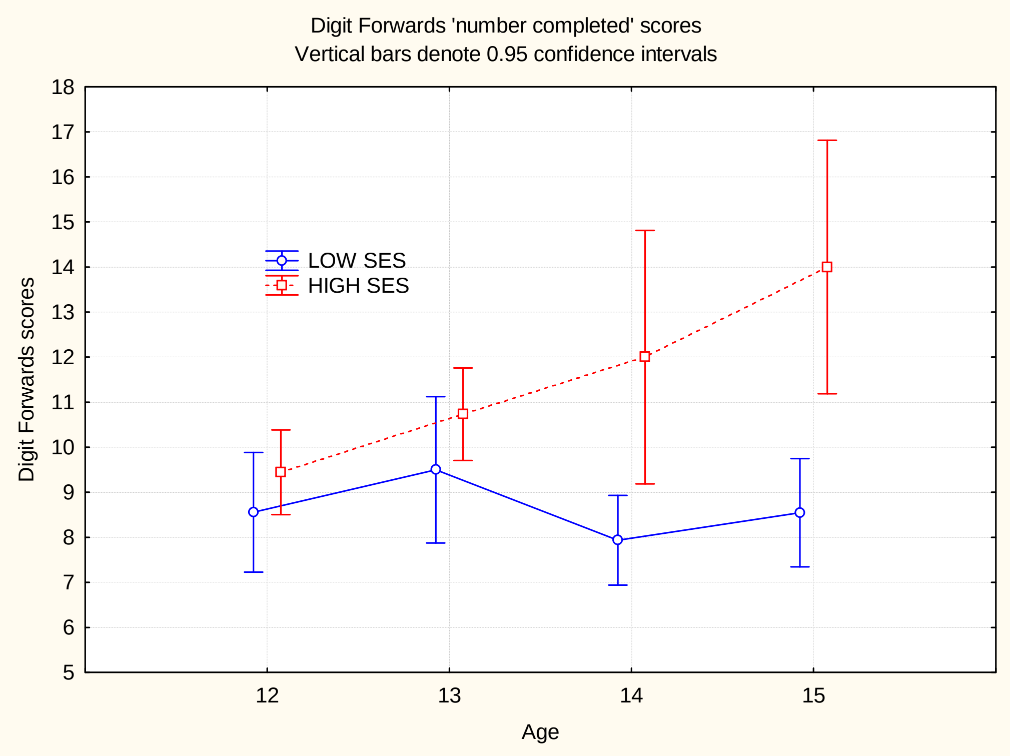

Figure 3. DS- Forwards scores across age and SES

While differences in *DS-Forwards* scores between the category of High SES 13 and 14 year olds are significant (p = .01) according to Tukey's HSD, it is surprising that the differences between the performance of High SES 12-year-olds and High SES 15-year-olds were not statistically significant by the same test (p =.06). An explanation for this discrepancy lies in the fact that the High SES 15-year-old group is weakened by its small sample (n =2), with the bulk of tested 15-year-olds (n =11) falling in the Low SES category.

A similar explanation may hold for the pattern of performance observed on the *Coding* subtest: the highly significant age-related progression seen between 14-year-old High SES participants and all younger counterparts is followed by a sudden plummet in the scores of 15-year-olds (see Figure 4). Thus, despite the fact that this test exhibits both a significant overall age effect, $F(3,71)=6.22$, p= .0008, and a significant Age X SES interaction effect, $F(3,71)=3.45$, p= .02, the small sample size of High SES 15-year-olds distorts the age-related progression that might otherwise be seen.

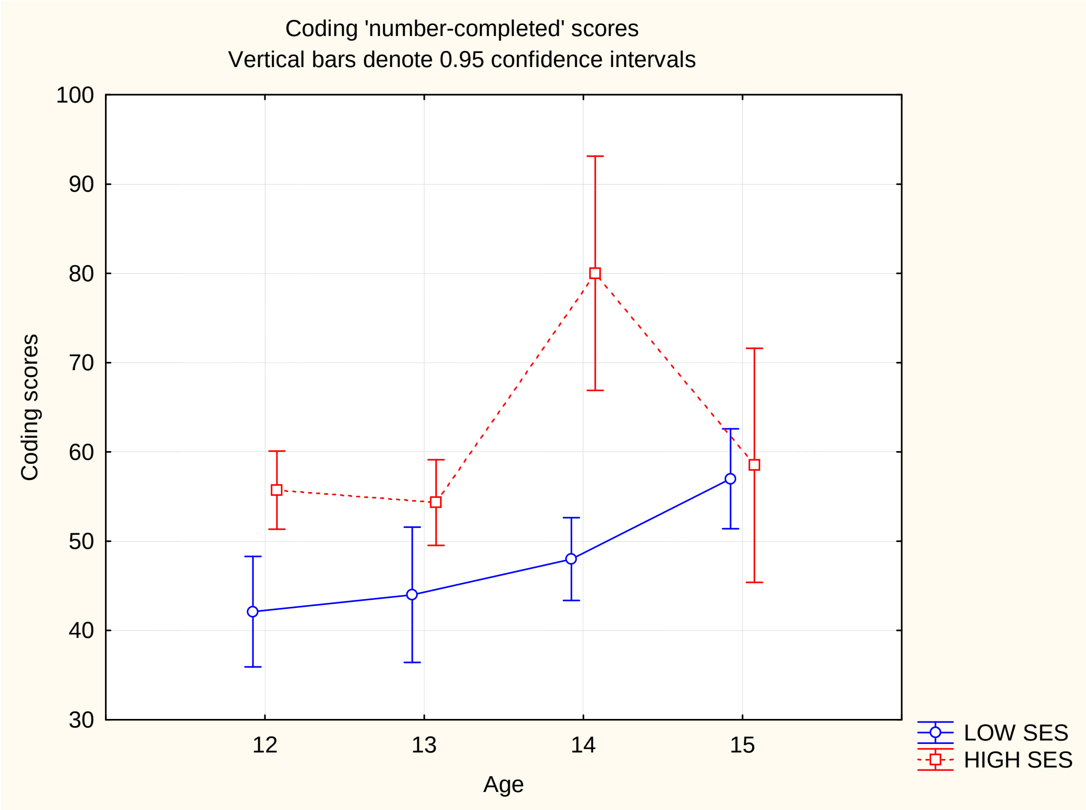

Figure 4. Coding scores across age and SES

To rectify the imbalance caused by the small sample in the High SES group, I grouped the 12- and 13-year-olds together and compared their performance on *DS–Forward* and *Coding* to those of a combined 14-and 15-year-old group (see Figures 5 and 6). Results of the *DS–Forward* across clustered age groups now revealed significant progression across the performance of the High SES 12-13-year-old group (*M*=10.03, *SD*=2.01) versus that of the High SES 14-15-year-old group (*M*=13.00, *SD*=2.00), *F*(1,75)=8.82, *p*= .004, *d*=0.59. The Low SES bracket, alternatively, exhibits non-significant age-related inconsistencies in performance across this attentional capacity task, *F*(1,75)=8.82, *p*=.66.

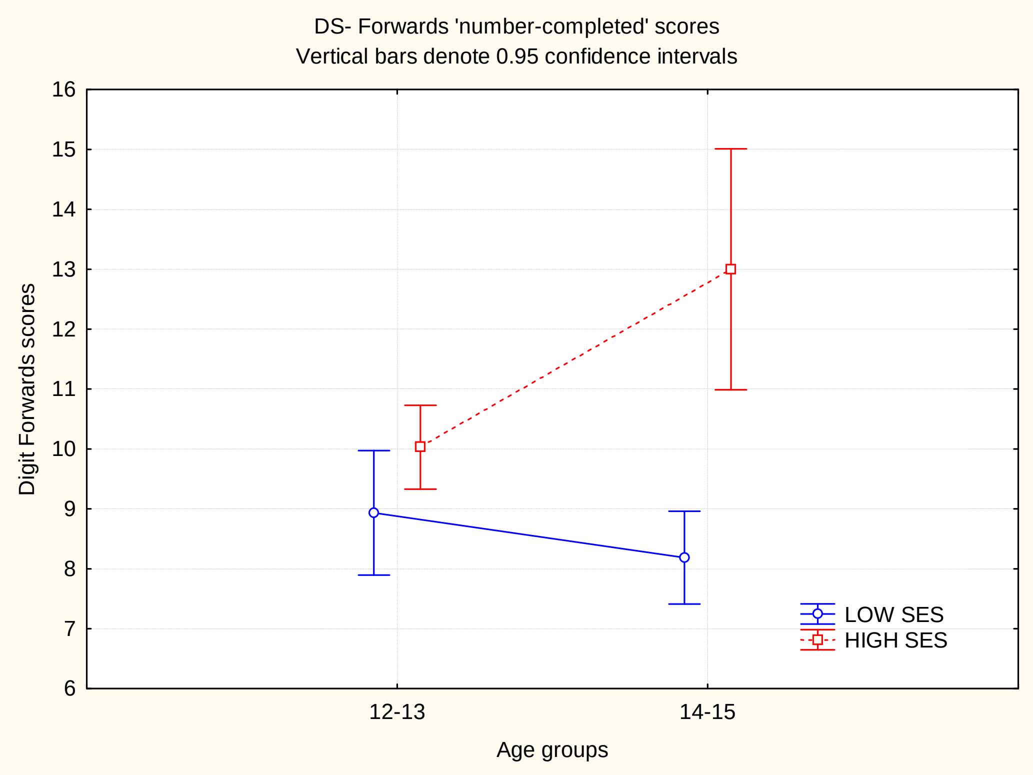

Figure 5. DS- Forward scores across clustered age and SES

With regard to the *Coding* subtest, results are now seen to be more aligned with performance on the *CCTT Trial 1*, and significant age-related improvement is seen regardless of SES over the 12-13 (M=51.27, SD=10.62) to 14-15 (M=53.94, SD=12.22) age-categories, $F(1,75)=14.38$, $p=.0003$. The effect-size, however, is a disappointing 0.17, and substantially increases to the range of 0.45 if one considers these age-related increases across High versus Low SES categories separately.

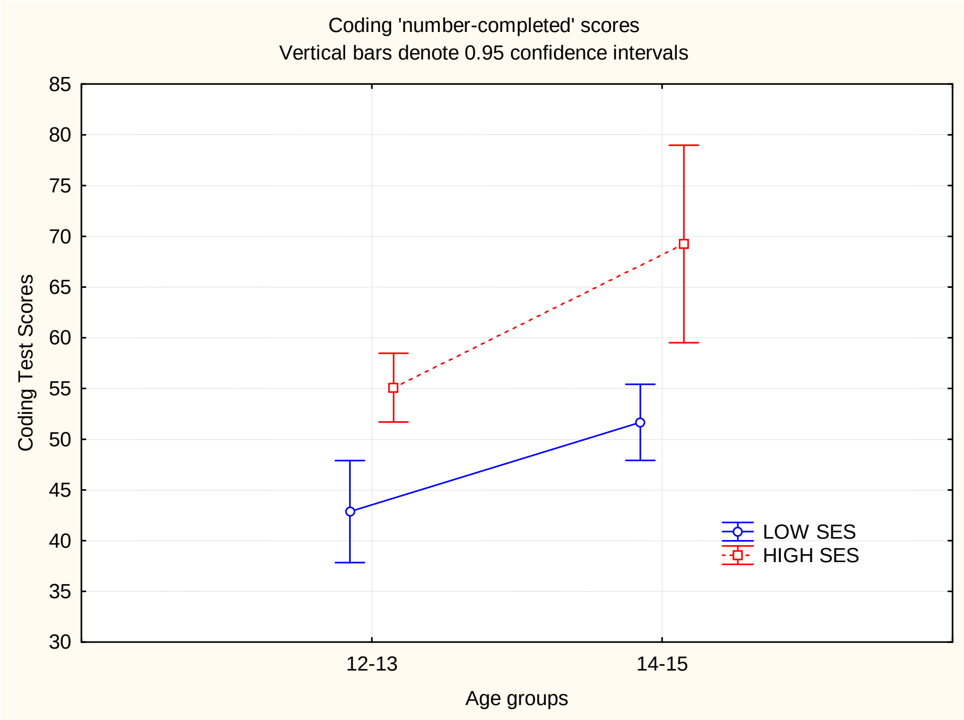

Figure 6. Coding scores across clustered age and SES

As might be clear from the preceding analyses, SES is a highly statistically significant predictor of performance in this domain of executive functioning. Specifically, in performance on the *DS-Forwards* test, High SES participants (M=8.45, SD=2.04) significantly out-performed their Low SES equivalents (M=10.35, SD=2.19), $F(1,75)=22.31$, p=.00001, d=0.90. Similarly, on the *Coding* subtest, High SES participants (M=56.62, SD=10.62) attained significantly higher scores than Low SES adolescents (M=48.52, SD=10.55), $F(1,75)=14.38$, p=.0003, d=0.77. This result is surprising in that it stands in contrast to predictions made by previous studies in this field (e.g., Anderson et al., 2001).

Cognitive Flexibility

In the Cognitive Flexibility executive domain, the *Stroop* colour-word trial probed inhibition. Age-related progressions appeared to occur in the High SES group upon this task, with average scores exhibiting relatively stable increases from the 12-year-old to 15-year-old performer (see Figure 7). Such patterns are exclusive, however, to the High SES group, with the Low SES category exhibiting minor fluctuations in inhibition scores not illustrative of age-associated developmental gains. ANOVA results indicate that age is implicated as a general significant predictor of success in the *Stroop*, ($F(3,71)=4.37$, p= .007), and as such this suggests that the inhibition component of Cognitive Flexibility continues to mature over adolescence. Conversely, while *CCTT Trial 2* scores reveal quicker average completion-times having been achieved by each consecutive High SES age group, this Age-SES interaction effect is non-significant, (*F*(3,71)=0.721, *p*=.54), providing evidence that the complex-monitoring component of Cognitive Flexibility might be developmentally mature by late childhood.

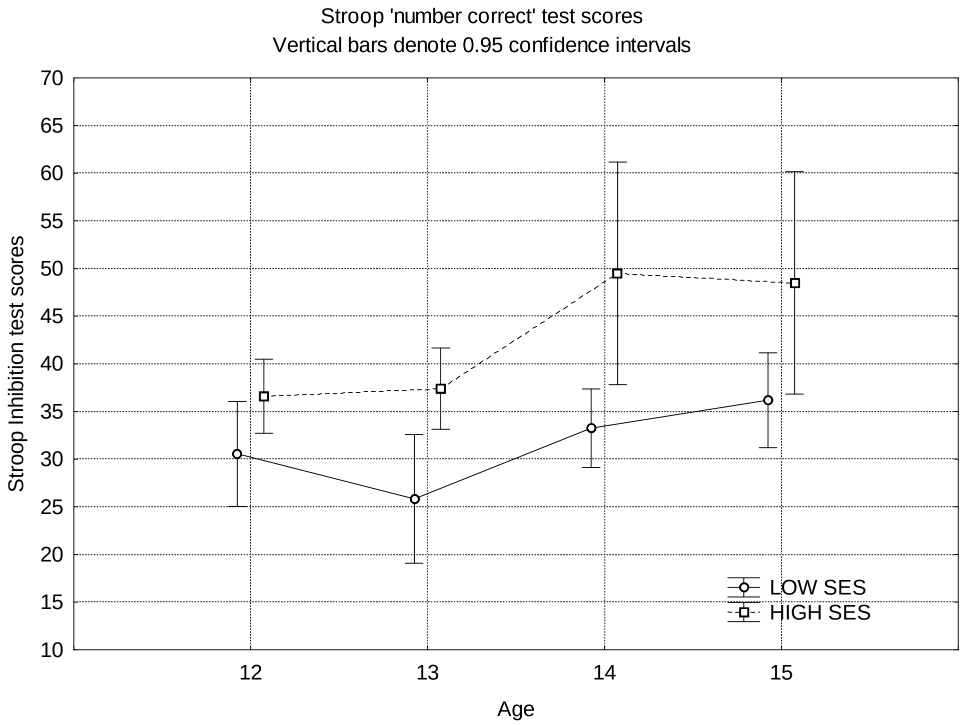

Figure 7. *Stroop* test scores across age and SES

Contrastingly, while results across the inhibition and complex monitoring measures do not concur with respect to age-associated effects, the working memory component of the Cognitive Flexibility domain, as tapped by the *DS-Backwards* test (see Figure 9), confirmed the *CCT Trial 2'*s findings as to a non-significant age-related executive development, *F*(3,71)=1.43, *p* = .24. Furthermore, all three measures of cognitive flexibility identified SES as a significant predictor of performance. As such, High SES participants (*M*=37.76, *SD*=8.46) attained significantly quicker completion times in the *CCTT Trial 2* complex-monitoring task than Low SES adolescents (*M*=43.45, *SD*=14.11), *F*(1,71)= 6.52, *p*=.013. Similarly, performance in the *Stroop* demonstrated that High SES participants (*M*=38.27, *SD*=9.64) achieved significantly more correct colour-word inhibition items than Low SES adolescents (*M*=32.38, *SD*=7.81), *F*(1,71)=20.04, *p*=.00003. Finally, Low SES groups (M=4.62, SD=1.70) performed significantly more poorly in the *DS-Backwards* working memory task than High SES adolescents (M=6.12, SD=2.11), $F(1,71)=10.67$, $p= .002$. Effect size correlations were 0.24, 0.32 and 0.36 respectively.

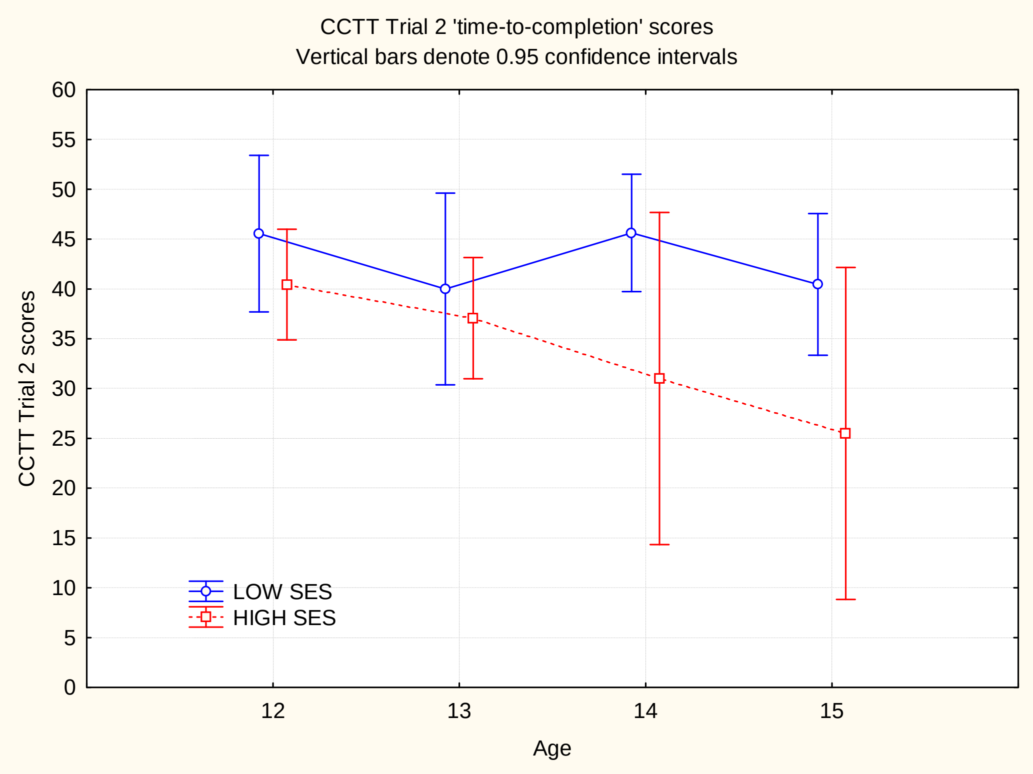

Figure 8. *CCTT Trial-2* test scores across age and SES

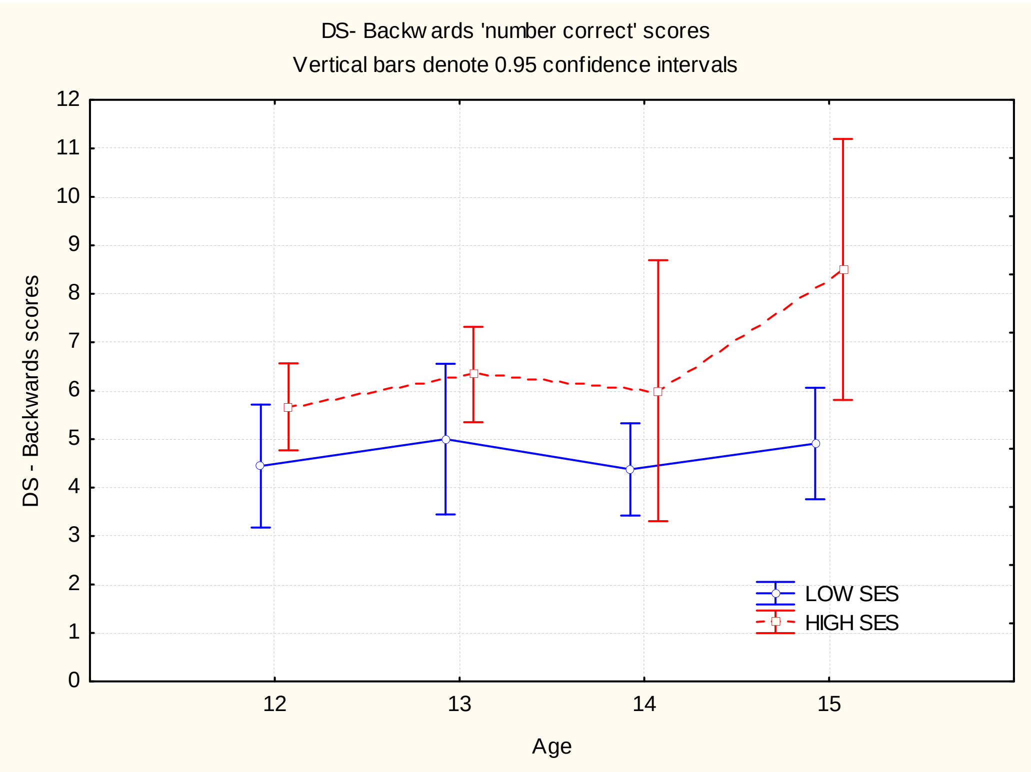

Figure 9. *DS- Backwards* scores across age and SES

In the word-generation component of this domain, participant performance on both Phonemic and Semantic *Verbal Fluency* word-generation tasks (see Figures 10 and 11) suggested that significant age-related progression was present only in the High SES group. ANOVA found a significant main age effect in both the Phonemic, ($F(3,71)=6.06$, $p=.0009$), and Semantic, ($F(3,71)=12.58$, $p= .000001$), tasks. These results are misleading, however, as they aggregate the extremely high scores of High SES-15-year-old participants on verbal fluency tasks with the average test performance of Low SES 15-year-olds, to produce a diluted overall age effect. Interestingly, these Age-SES effects between the High SES 15-year-old strong performers versus Low SES 15-year-old weak performers were significantly different for the semantic task, $F(3,71)=4.39$, $p = .0001$; whereas differences along the phonemic task fall short of significance, $F(3,71)=1.65$, $p=.08$.

Due to these disparities in the 15-year-old groups, a more accurate picture of executive development within this capacity requires SES to be factored out of the equation. As such, significant results were found only for the High SES group such that High SES 15-year-olds were able to generate significantly more words in both the phonemic, ($F(3,71)=1.65$, $p =.01$), and semantic, ($F(3,71)=4.39$, $p=.0001$), tests than High SES 12-year-olds – with effect sizes of 0.76 and 0.73 respectively. High SES 15year-olds were also found to exhibit significantly higher scores than 13-year-olds again in both the phonemic, ($F(3,71)=1.65$, $p=.02$), and semantic, ($F(3,71)=4.39$,p =.0004), tasks – hinting at a developmental spurt that might occur in this capacity at the age of 15years.

Finally, the trend of SES-significance in Cognitive Flexibility components was persistent in word-generation tests, such that High SES participants ($M=33.05$, $SD=13.02$) attained significantly more words in the Phonemic task than Low SES adolescents ($M=29.45$, $SD=8.2$), $F(1,71)= 8.33$, $p =.005$, $d=0.33$. Similarly, performance in the Semantic task demonstrated that High SES participants ($M=19.86$, $SD=6.47$) achieved significantly more word-items than Low SES adolescents ($M=16.07$, $SD=4.49$), $F(1,71)= 37.13$, $p<.000001$, $d= 0.68$.

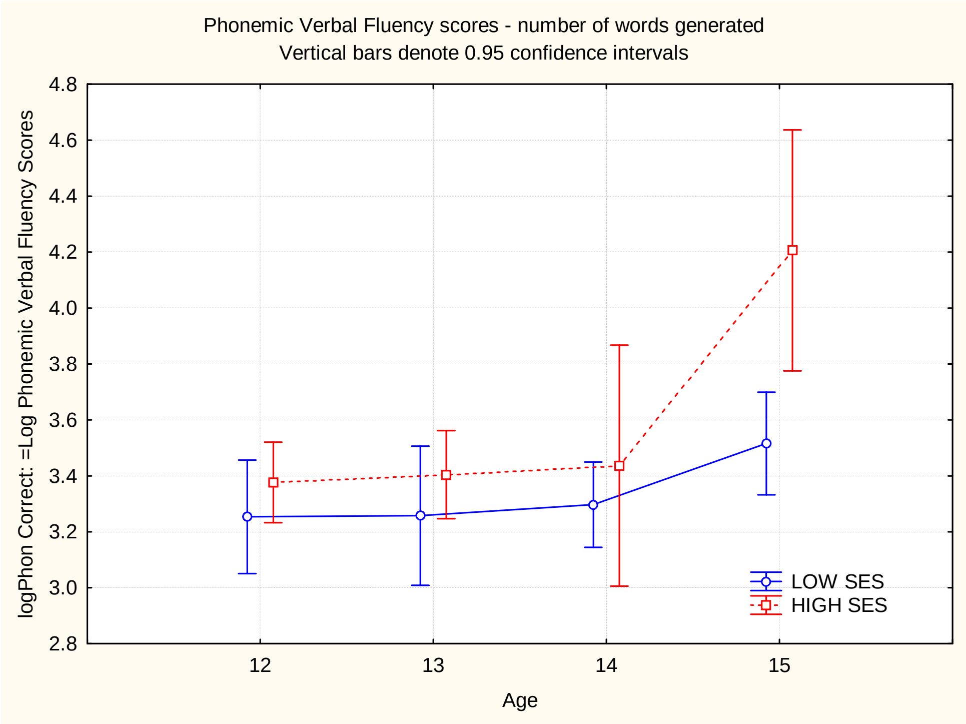

Figure 10. Phonemic *Verbal Fluency* scores across age and SES

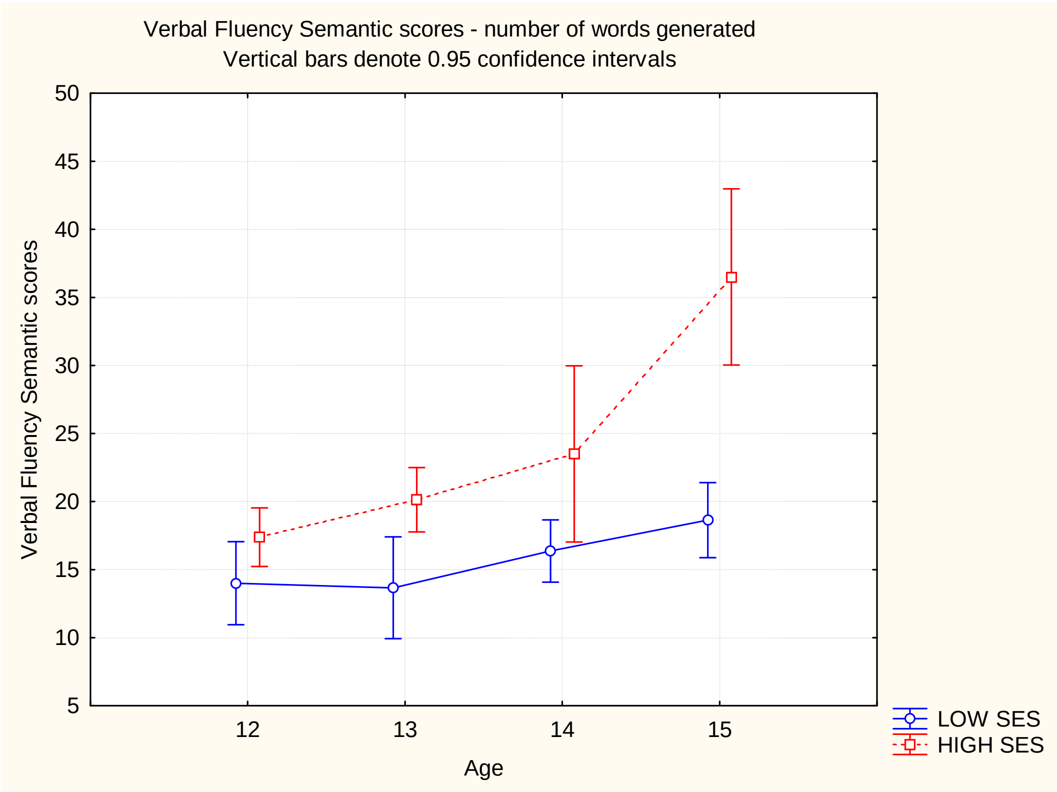

Figure 11. Semantic *Verbal Fluency* scores across age and SES

Goal Setting

In the organizational ability component of the goal-setting domain, I grouped the 12- and 13-year-olds together and compared their performance along the *RCF-OSS* to that of a combined 14- and 15-year-old group (see Figure 12). I performed this clustering in order to remedy the problem of several missing RCF-OSS data values, and as such I augmented the sample size of each group. Examination of organization scores revealed age-related significant progression across the 12-13 (*M*=6.00, *SD*=1.00) to 14-15-year-old *(M* =5.03, *SD*=0.98) High SES groups, *F*(1,50)=6.30, *p*=.02, *d* =0.98.

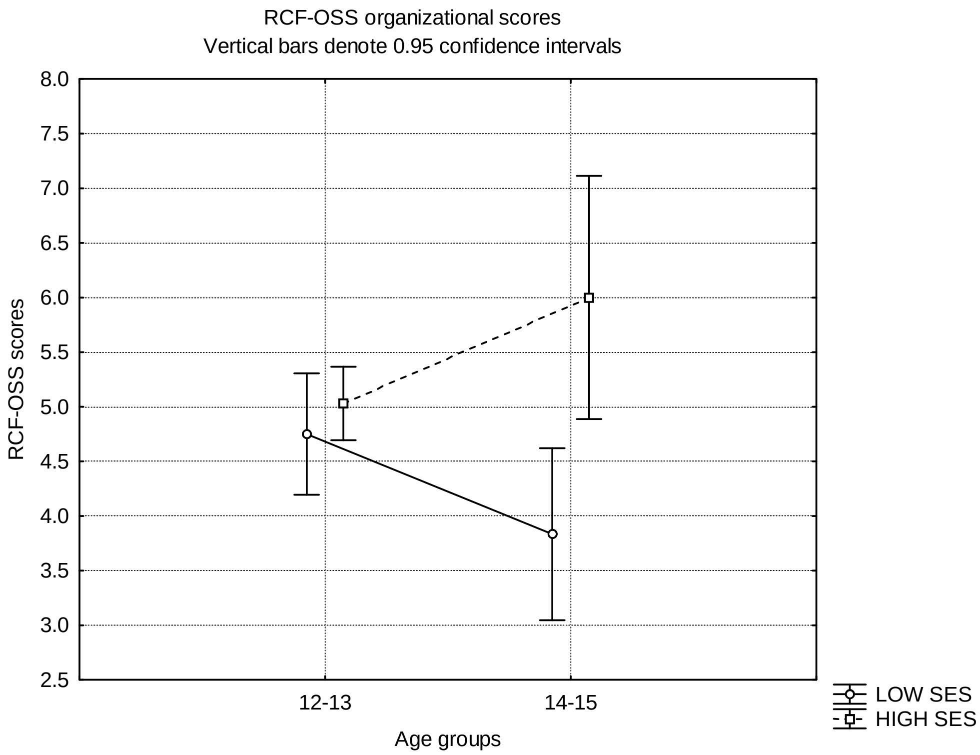

Figure 12. *RCF-OSS* scores across age groups and SES

Assessment of the scores for Low SES participants on this task revealed a non-significant pattern of age-related decrease in organizational ability across the 12-13 (*M*=4.75, *SD*=0.75) to 14-15-year-old (*M*=3.83, *SD*=1.17) categories, *F*(1,50)=6.30, *p*=.23. Hence, this non-significant decline is most likely due to chance fluctuations in the sample. Furthermore, SES was found to be a significant predictor of organizational ability along this task, with High SES participants attaining significantly higher *RCF-OSS* scores (*M*=5.11, *SD*=1.00) than Low SES adolescents (*M*=4.44, *SD*=0.98), (*F*(1,50)=10.59, *p*=.002), with an effect size of 0.68.

In the planning and problem-solving component of the goal-setting domain, the *TOL* generates several executive mastery and strategy scores. The trajectory of Total Move Scores (see Figure 13) indicated that High SES and Low SES adolescents followed a similarly flat trajectory until the age of 14years. This was followed by slight developmental gains at the age of 15years, at which time they appeared to waste less unnecessary 'moves'; although this appeared to take place only in the High SES group. However, such an age-related progression was found to be non-significant, ($F(3,71)=1.94$, $p=.13$).

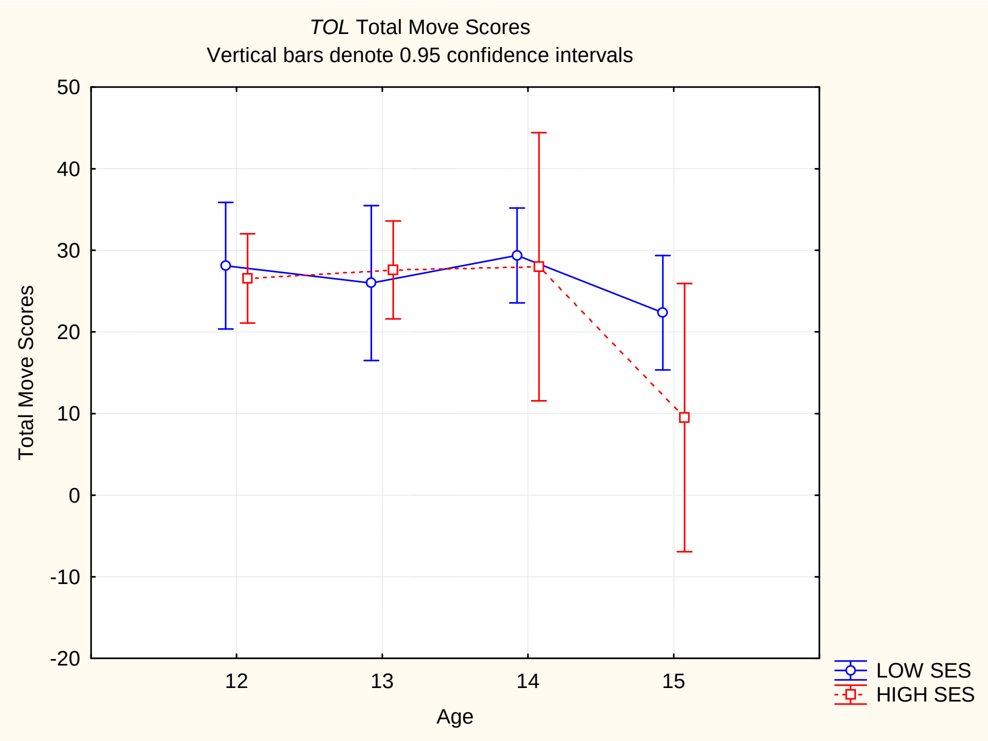

Figure 13. *TOL* Total Move Scores across age and SES

An examination of the 'Total Correct' scores on the *TOL* task (see Figure 14) revealed similar age-related progressions in the correct strategy-execution of High SES group as those seen in the Total Moves scores, although age is now implicated as a significant overall predictor of success, $F(3,71) = 3.43, p = .02$. ANOVA further found SES to be an overall significant predictor of success in *TOL* Total Correct scores, with High SES participants ($M=3.78$, $SD=1.70$) out-performing Low SES adolescents, ($M=3.10$, $SD=1.27$), $F(1,71)=11.95$, $p=.0009$, $d = 0.45$.

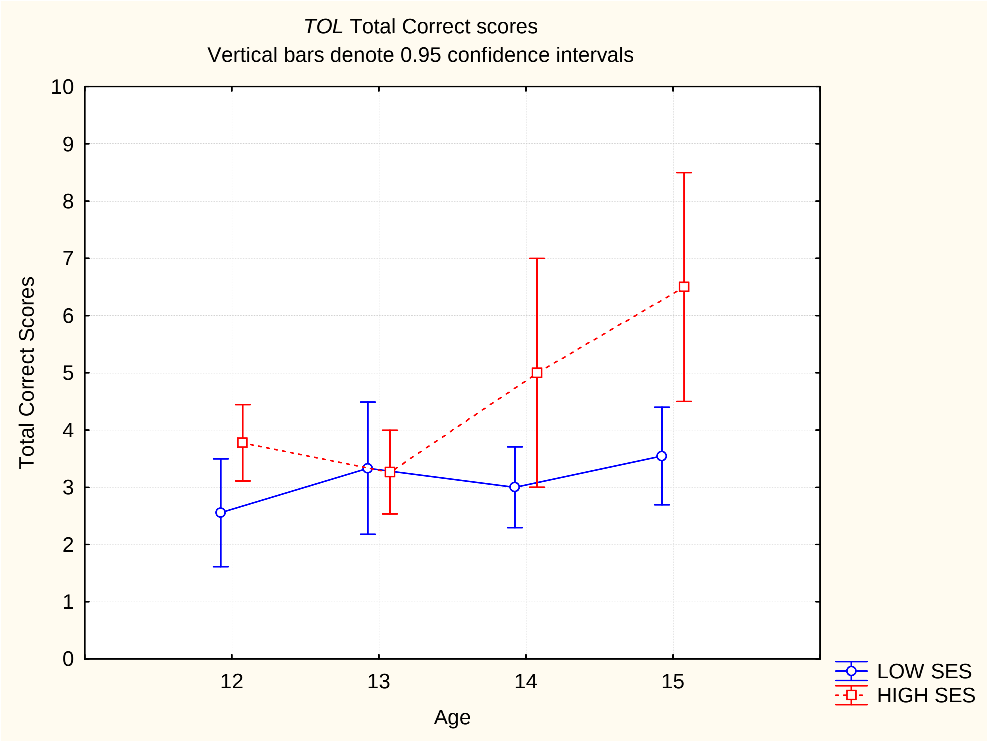

Figure 14. *TOL* Total Correct Scores across age and SES

In the *TOL* test component of Execution time (see Figure 15) neither significant age, (*F*(3,71)=1.37, *p*=.26), nor SES effects, (*F*(1,71)=0.22, *p*=.64) were present across participant scores. As such this capacity appears to have reached developmental maturity by adolescence, as was seen in the *TOL* Total Move scores test component.

Interesting effects were further found in the *TOL* executive strategy measure of initiation time (see Figure 16), which measures planning-impulsivity. Executive trajectories on this task revealed a significant Age X SES interaction effect such that 15-year-olds (*M*=94.00seconds, *SD*=5.66) in the High SES group took longer to deliberate a move than both High SES 12-year-olds (*M*=29.06seconds, *SD*=19.25) and High SES 13-year-olds (*M*=18.27, *SD*=7.34), (*F*(3,71)=14.10, p= .0001), with effect size correlations of 0.91 and 0.98 respectively.

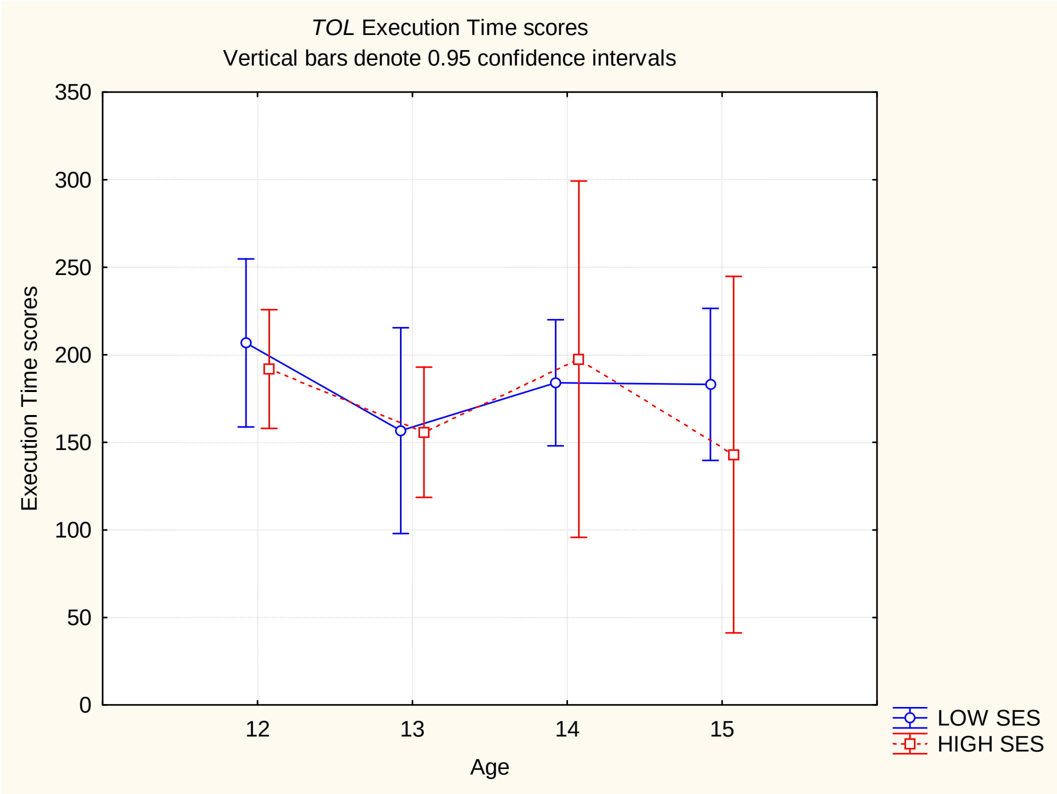

Figure 15. *TOL* Execution Time scores across age and SES

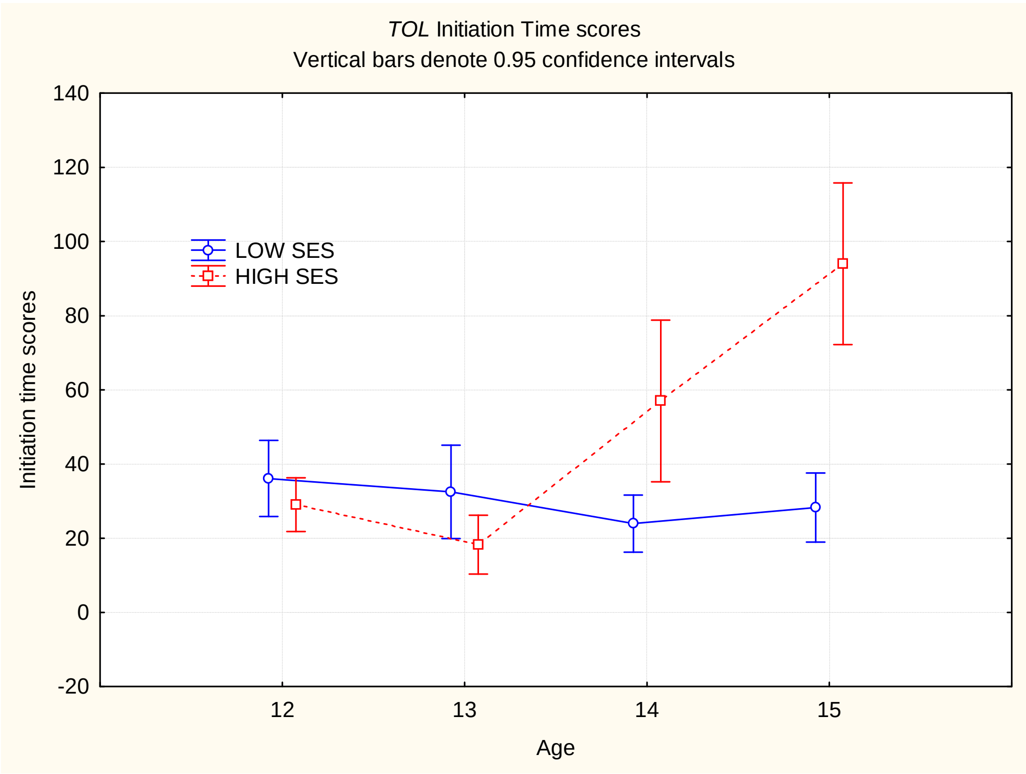

Figure 16. *TOL* Initiation Time scores across age and SES

DISCUSSION

Development within Executive Domains

Attentional Control

Anderson et al. (2001), in their influential work on adolescent EF, hypothesized that overall attentional control (which includes attentional capacity, sustained attention, and processing speed components) would exhibit a developmental spurt in 15-year-olds. Furthermore, they argued that this spurt would be most prominent on tests of attentional capacity, such as DS–Forward. Hence, 15-year-olds were predicted to show significant performance-related progression over individuals falling at the lower end of the adolescent age interval. De Luca et al. (2003), who studied executive ability across the human lifespan, confirmed this prediction.

The present data also strongly confirmed this prediction, showing that, on tasks of sustained attention and processing speed, participants in both the older age groups, but particularly 15-year-olds, showed strong improvements in performance over those younger than them. Also consistent with previous research (Anderson et al., 2001), SES had no effect on the developmental progression of these executive abilities. These attentional components are singled out in the present results as being the only one in which executive development; namely sustained attention-processing speed progression, occurred irrelevant of the relative SES of participants.

The effects of SES were, however, significant on the attentional capacity component of this domain: high SES participants out-performed low SES participants, most notably in the 15-year-old age group. This result might be a consequence of the fact that low SES adolescents had not undergone attentional capacity progression over the early adolescent years, and so were relatively developmentally immature in this faculty in later adolescent years. In contrast, high SES adolescents reach what appears to be their maturational capacity by the ages of 14-15 years, showing significant progressions in performance compared to their 12-13-year-old counterparts.

Cognitive Flexibility

Anderson et al. (2001) predicted a flat and stable developmental trajectory within this domain: Their results suggested that both complex monitoring, inhibition and word generation abilities generate steady score patterns across adolescence, probably because maturational level has already been reached by late childhood. De Luca et al. (2003), however, predicted that the working memory component of this domain would show pronounced performance progressions across adolescence, most notably at the age of 15 years.

Data from the current study provide some support for Anderson et al.'s (2001) predictions: Age-related performance progressions were not detected in complex-monitoring capacities. However, the present research's findings did not confirm the hypothesis of a flattened developmental trajectory for Cognitive Flexibility along the Inhibition and word generation abilities (Verbal Fluency tests). Age was thus found to be a general predictor of Inhibition performance, and significant age-related progression was also made in word-generation abilities – although this trajectory was only significant in the High SES group.

Furthermore, data from the current study do not confirm the prediction made by De Luca et al. (2003): On the working memory component of this domain, I detected no age-related performance progressions. A possible explanation for the failure to confirm this hypothesis (beyond the fact that the hypothesis might simply be wrong) is that the working memory task used here, DS – Backwards, does not tap strongly enough into that construct (Lehto, 1996); hence, a direction for future research might be to administer a multitude of working memory tasks to adolescents, as was the case in Lehto's research.

The current findings within this cognitive flexibility domain offer strong support for the present study's overarching hypothesis that the resource-poor nature of the South African population should impede EF progression in late childhood, such that significant age-related progressions are made in adolescents to a much greater degree than in resource-wealthy countries. For instance, evidence for a prolonged developmental course is seen in the Verbal Fluency scores of high SES adolescents, with 15-year-olds strongly outperforming both their 12- and 13-year-old counterparts.

The most striking finding in this domain, however, is that SES is a predictor of adolescent performance on all tasks of Cognitive Flexibility, with low SES participants performing more poorly than high SES participants. Furthermore, low SES adolescents did not exhibit age-related performance progressions on tasks of inhibition and generativity; in fact, they simply continued to function at unchanged levels on these tasks throughout adolescence. It thus appears that the economic poverty of low SES adolescents causes greater delays in the maturation of Cognitive Flexibility abilities to the extent that development is postponed beyond even the 12 – 15year-old age interval.

Goal Setting

Anderson et al. (2001) predicted that performance on organisational strategy and problem-solving tasks (the two components of this EF domain) would remain, for the most part, relatively stable over the adolescent years, with developmental maturity having been reached by the age of 12 years. Those authors did, however, find a steeper developmental trajectory on aspects of the TOL assessing impulsivity-planning, which is purported to peak only at around 15 years. De Luca et al. (2003), however, predicted that the TOL component of the total number of correct scores, which probes successful planning and problem-solving strategy, reaches maturation only at the age of 15 – 19 years.

Data from the current study provide some support for Anderson et al.'s (2001) predictions: Age-related performance progressions were not detected on the *TOL* Execution Time and Total Moves test components, which measure problem-solving ability. This construct of goal-setting was thus found to have reached developmental maturity by the age of 12years such that no further advances were made during adolescence. Support for Anderson et al.'s impulsivity-planning hypothesis was also seen in the present research, in which 15year olds took longer to deliberate before executing a strategy and were far less impulsive than younger adolescents – although this trajectory was only confirmed for high SES participants. Furthermore, evidence that this premeditated and non-impulsive strategy was a highly effective problem-solving method was shown by the fact that a greater number of total correct strategies were executed by the high SES group over the adolescent age-interval – as predicted by De Luca et al. (2003). As such, it appears that even when planning and problem solving trajectories were found to concur with those set out by overseas samples, they did so only in high SES South African adolescents, while low SES adolescents exhibited large developmental delays in planning.

The present findings were unsupportive of Anderson et al.'s (2001) hypothesis that a stable level of organisational ability (*RCF-OSS* scores) has been reached by 12-year-olds. As such, significant age-related progressions in organisational ability were made across the high SES 12-13-year-old participants to the high SES 14-15-year-old participants. Conversely, the low SES participants made no maturational progress in this executive ability, and exhibited an incomplete maturational level of development at 15years of age.

As was seen in the cognitive flexibility domain, SES was also found to be a predictor of performance in all organisational and planning tasks; bar those problem-solving components of the TOL as Execution Time and Move Score, in which no significant effects were found.

Domain-Specificity of Executive Model

The results of the present study also provide evidence consistent with data from Anderson et al. (2001) in terms of the correlations between, and shared trajectories of, measures grouped under the Attentional Control and Cognitive Flexibility domains of the adolescent EF model. However, many correlations were found to be both slightly weak in strength and share the variability of other domains. With regard to the third domain of the model, Goal Setting, the present results are also consistent with Anderson et al.'s findings that organizational and problem-solving abilities follow different time-related discourses. Specifically, the current data showed (a) using factorial ANOVA, that these two components of the Goal Setting domain presented differing developmental trends, and (b) using factor analysis, that the tests measuring these components load on different factors.

Because one of the central problems in the field of EF research is to generate supposedly 'airtight' categories of EF that are rigidly domain-specific, findings such as these are contentious. As a result of these sorts of disjunctures in domain-models, the findings of various past research endeavours have been rendered ambiguous and difficult to integrate due to the use of differing executive explanatory categories.

In summary, the overlapping variations of several test measures from different domains confirms that executive capacities are somewhat domain-general and ambiguous, and are an inter-related set of functions that stand mainly to gain explanatory and conceptual clarity in cross-referenced research endeavours if placed in a domain-specific model.

Limitations and Directions for Future Research

Limitations of the present research are such that while a sample balanced across both age and SES was collected, there is an unequal balance of high versus low SES participants within the 14- and 15-year-old age brackets, which are heavily weighted toward the Low SES group. Directions for future research in this field thus lie in replications of this study that use both a larger sample from the population, and contain balanced proportions of high and low SES members within each adolescent age group. This is a necessity for EF research in South Africa that has never been stipulated in overseas studies (e.g., Australia and the United States) due to both the greater economic homogeneity of these populations and because SES has not been established in past literature as a concrete predictor of EF, as evidenced in the findings of Anderson et al.'s (2001) research.

Furthermore, the current study's interval of examined adolescent ages, (i.e. 12 – 15 years) has not been broad enough to determine the age at which progression in low SES adolescents takes place such that developmental delays in executive maturation are overcome. Future research will thus need to encompass participants of an age range stretching beyond the 15-year-old group in order to determine whether low SES South African adolescents reach a higher level of executive maturity in later years.

Finally, due to limitations of space and constraints on time, the effects of gender and received quality of education upon EF could not be examined in the present research, and future research thus needs to be directed towards examining the interaction of these potential predictors of executive ability in concert with age and SES effects in order to generate a richer image of adolescent executive progression in South Africa.

Summary and Conclusions

This study has confirmed that the development of different executive functions proceeds at a different pace in adolescence, and that these developments are present even after factoring out the effect of IQ scores. Such developmental trajectories are largely consistent with several of the main patterns laid out by Anderson et al. (2001). Those abilities which most notably continue to develop in the present research and reach a more complete maturational capacity at (and perhaps beyond) 15 years of age are sustained attention and processing speed, as well as planning-impulsivity, word generation, organisational ability and inhibition. Problem-solving and complex-monitoring abilities, however, appear to have reached developmental maturity by 12-years of age.

The overarching hypothesis of this study was that the specifically developing nature of the South African context, and the subsequent vast divides in economic resources and quality of education, would retard the development of executive functioning relative to trajectories seen in resource-wealthy countries. This hypothesis was, by and large, confirmed. As such, one of the most significant findings of this study is that greater executive progression is seen in South African adolescents, and over a wider variety of test measures, compared to those documented in Anderson et al.'s (2001) research, which was conducted in Australia, with a far more economically homogenous sample. However, this pronounced trajectory was seen only in high SES adolescents, who appear to have suffered certain slight developmental delays in executive ability that lead maturation to continue between the ages of 12 to 15 years. For low SES adolescents, however, these developmental delays are far more pronounced such that they appear to extend beyond the age of 15years.

As such, maturation consistent with adolescents in other countries (e.g., Australia and the United States) is often exclusive to high SES South African adolescents, with their low SES counterparts either exhibiting a much slower course of development, or making no gains in executive capacity. The clinical relevance of such research findings is that they shed light on the fact that critical EF disorders might possibly be misdiagnosed in a South African context wherein adolescents follow a path of executive maturation that is not only so different from resource-wealthy populations, but also contains so many within-group differences across the great social and economic divides of the South African populace. This study's findings thus suggest that in constructing samples of normative data for the executive trajectory of South African adolescents, different norms must be constructed for resource-wealthy versus resource-poor segments of the population.

Thus, what is perhaps the most important finding of this study is that SES impacts the developmental trajectories of a multitude of executive capabilities, and that differential patterns of EF maturation take place in resource-wealthy versus resource-poor South African adolescents. This evidence for a differential pattern of executive unfolding and maturational trajectory in high versus low SES adolescents is extremely surprising in light of past research. For instance, Anderson et al. (2001) found neither significant executive-related performance differences across SES nor significant differences in the economic statuses of the sample. Hence, the social and economic homogeneity of overseas samples may be responsible for largely concordant executive maturation across all adolescents, whereas the disparity between these same demographic variables in the South African populace undermines cognitive progression and produces a checkerboard of differing maturational courses.

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APPENDIX A

Consent and Assent Form

PATIENT INFORMATION AND CONSENT LEAFLET

Effects of Heavy Alcohol Abuse on Adolescent Brain Structure and Function

Investigators: Dr. P. Carey, Mrs H Ferrett, N Maskwikiti, T Petousis, Dr Kevin Thomas

Principal Investigator: Prof. D.J. Stein

Dear Volunteer

DESCRIPTION AND PURPOSE OF THE STUDY

You/your child are/is being invited to take part in a study carried out by the Anxiety and Stress Disorders Research Unit in the Department of Psychiatry at the University of Stellenbosch, and the Department of Psychology at the University of Cape Town. Please take some time to read the information presented here, which will explain the details of this project. Please ask the study staff or doctor any questions about any part of this project that you do not fully understand. It is very important that you are fully satisfied that you clearly understand what this research entails and how your child could be involved. Also, your child's participation is **entirely voluntary** and you are free to decline to participate. If you say no, this will not affect you or your child negatively in any way whatsoever. You are also free to withdraw him/her from the study at any point, even if you do initially agree to let him/her take part. The study has been approved by the Committee for Human Research of the University of Stellenbosch and the ethics and research committee of the Department of Psychology at Cape Town University. . It will be conducted according to Medical Research Council guidelines on good clinical practice (2003) as well as the Declaration of Helsinki Guidelines (Edinburgh, 2000), which provide detailed guidelines that relate to the ethical conduct of studies involving human subjects.

Why are we doing this research?

The broader context for this work is the examination of the effects of heavy use of alcohol on the brain and whether these effects may be damaging. We are at present unsure as to how serious these effects may be in young people. This study will try and answer some of these questions by studying the effects of heavy alcohol use in young people (adolescents) during this time of important brain growth and development. It may be that you have been requested to participate as a suitable candidate, or as someone who matches other young people for age and education, but who does not use or uses only a very limited amount of alcohol – i.e. a normal control.

We will be asking young people between the ages of 12 and 18 years who are heavy users of alcohol and a similar control group who do not use/use only limited amounts of alcohol, to participate. We plan to enroll a total of 300 people in this study which will be conducted at the MRC Unit on Anxiety Disorders of the University of Stellenbosch and the Department of Psychology at Cape Town University. Much of the testing however for the normal control group will be completed in the schools from which the young people are drawn.

If you decide to take part in this study and you are using/abusing alcohol, you will be asked not to drink alcohol before each of the study sessions.

STUDY PROCEDURES

Your involvement in the study will require you to visit the study doctor/team on two occasions. At a screening visit with the study doctor or psychologist we will interview you, much like a normal visit to your family doctor to assess whether you are eligible for our study. This visit will include questions on your emotional and physical health as well as your school and home environment. If, following this initial examination you appear to be suitable for the study, we will invite you to go through this information and consent form to ensure that you understand all of what the study will involve. Once we have addressed any questions you may have and you and your parent/guardian provide written consent (permission) to your participation, we will proceed with the study.

At the second visit you will undergo a series of tests called a neuropsychological evaluation. This study visit with the psychologist will take the form of a number of pencil and paper tests which will involved some writing and drawing as we test your memory, concentration and mental flexibility. Many of these are like a normal IQ test that you may have done at school before. All of these tests are important and will help us determine if alcohol has any effects on these aspects of your brain's functioning. This will take about 2 ½-3 hours.

DISCOMFORT ASSOCIATED WITH THE STUDY

There are only low or minimal risks associated with your participation in this study. If you feel tired at any point in any of the visits, you should please ask your study doctor/psychologist for a rest. If for some reason you are unable to complete a visit on a particular day we may reschedule to complete the assessments at another time.

POTENTIAL BENEFITS

There may be no direct benefits to you for participating in this study. However, you will be making an important contribution to this research that may benefit others in the future. We expect that the results of this study will help us understand the effects of heavy alcohol use on brain development in young people.

COMPENSATION FOR STUDY PARTICIPATION

While you will not be paid to take part in this study, all evaluations will be provided at no cost to you or your medical aid. We will however offer you a voucher to the value of R150 in appreciation of your involvement in this work.

CONFIDENTIALITY

Your participation is regarded as strictly confidential. The results of the study will be published in the professional literature and made available to of the Committee for Human Research of Subcommittee C at the University of Stellenbosch, but your identity will not be revealed at any time to people outside of the study team.

THE RIGHT TO ASK QUESTIONS/WITHDRAW FROM THE STUDY

You have the right to ask questions at any time about any aspect of the study. If you have any queries, you can contact Dr. Carey at 021-9389623, or Mrs Helen Ferrett 021-9389189 during office hours. You will also be given 24 hour contact details should you need to contact us in the event off an emergency.

Your participation in the study is entirely voluntary. You have the right to withdraw at any time. If you decide to withdraw from the study, it will not jeopardize you or any future treatment you may require in any way.

You are entitled to a signed copy of this document.

If you agree to take part, please complete the following section.

Assent of minor

I (*Name of Child/Minor*)……………………………………………. have been invited to take part in the above research project entitled Effects of Heavy Alcohol Abuse on Adolescent Brain Structure and Function.

- The study doctor/psychologist and my parents have explained the details of the study to me and I understand what they have said to me.
- They have also explained that this study will involve 2 assessments which include interviews, filling questionnaires, and a neuropsychological evaluation
- I also know that I am free to withdraw from the study at any time if I am unhappy.
- By writing my name below, I voluntary agree to take part in this research project. I confirm that I have not been forced either by my parents or doctor to take part.

...

Name of child

(To be written by the child if possible)

Declaration by parent/legal guardian

By signing below, I *(name of parent/legal guardian)* …………………………………..……. agree to allow my child (name of child) ……………………………….….. who is ………. years old, to take part in a research study entitled: **Effects of Heavy Alcohol Abuse on Adolescent Brain Structure and Function**

I declare that:

- I have read or had read to me this information and consent form and that it is written in a language with which I am fluent and comfortable.
- If my child is older then 7 years, he/she must agree to take part in the study and his/her ASSENT must be recorded on this form.
- I have had a chance to ask questions and all my questions have been adequately answered.
- I understand that taking part in this study is **voluntary** and I have not been pressurised to let my child take part.

- I may choose to withdraw my child from the study at any time and my child will not be penalised or prejudiced in any way.
- My child may be asked to leave the study before it has finished if the study doctor or researcher feels it is in my child's best interests, or if my child do not follow the study plan as agreed to.

Signed at (*place*) ....…........…………….. on (*date*) …………...……….. 2005.

..

Signature of parent/legal guardian

Declaration by investigator

I *(name)* ……………………………………………..……… declare that:

- I explained the information in this document to …………………………………..
- I encouraged him/her to ask questions and took adequate time to answer them.
- I am satisfied that he/she adequately understand all aspects of the research, as discussed above
- I did/did not use a interpreter

Signed at (*place*) ....…........…………….. on (*date*) …………...……….. 2005.

..

Signature of investigator

APPENDIX B

Participant Questionnaire informing SES evaluation

1

DEM – DEMOGRAPHIC QUESTIONNAIRE (participant)
(CLINICIAN ADMINISTERED or SELF-REPORT)

Name of interviewer:			
Interview / self-report date:	Year:	Month:	Day:

GENERAL INFORMATION

Full name:					
Date of birth:	Year:	Month:	Day:	Age:	years
Gender:	1. Male		2. Female		
How would you describe your race?	1. Black	2. Coloured			3. White
	4. Asian	5. Other(specify):			6. Refuse to answer
Contact numbers:	Person	Home	Work	Cel	
	Self				
	Mother				
	Father				
	(Guardian)				
Residential Address:					

EDUCATION

Details of Primary School/s attended:	School	Area	Grades
Name and area of Current School:	School: Suburb /area:		
School Telephone Number:			
Contact Person at Current School:			
Current Grade:			

DEm 2

RESIDENTIAL INFORMATION

Have you ever lived away from home for more than 3 months?		1. Yes 2. No
If you have lived away from home for more than 3 months, where did you live, and how old were you at the time?	**Place**	**Age**
	1. Foster home(s)	
	2. Group home(s)	
	3. Shelter	
	4. Residential setting	
	5. Hospital	
	6. Home of a relative	
	7. Home of a friend	
	8. Detention centre	
	9. Other (specify):	

How long have you lived at your current address?	
How would you describe your dwelling?	1. Shack 2. Wendy house or backyard dwelling 3. Tent or traditional dwelling 4. Flat / apartment 5. Town house / semi-detached house 6. Freestanding brick house 7. Other (specify):
How many rooms does your dwelling have?	1. one 2. two 3. three 4. four 5. five 6. more than five
Which of these items do you have in your home? (mark as many as necessary)	A. Tap water B. Flush toilet inside home C. Electricity D. Telephone (landline) E. Television F. Computer F. Car
Which ONE of the following best describes how things are in your home?	1. We don't have enough money for food 2. We have enough money for food, but not for other basic items such as clothes 3. We have enough money for food and clothes but are short of many other things 4. We have the most important things, but few luxury goods 5. We have money for luxury goods 6. We have money for luxury goods and extra things 7. Not applicable
Who lives with you? (mark all)	1. Mother 2. Father 3. Stepmother 4. Stepfather 5. Grandmother 6. Grandfather 7. Foster parent(s) 8. Sibling(s) No.__ 9. Half-sibling(s) No.__ 10. Step-sibling(s) No. __ 11. Other family member(s) No.__ 12. Boyfriend / girlfriend 13. Other No. ___
Who takes care of you at home?	
How many people sleep in the same room with you at night when you are at home?	1. one 2. two 3. three 4. four 5. five 6. more than five 7. none
Are you satisfied with these arrangements?	1. Completely satisfied 2. Fairly satisfied 3. A little dissatisfied 4. Very dissatisfied 5. Desperately unhappy

APPENDIX C

Parent Questionnaire informing SES evaluation

1

PAR – PARENT INTERVIEW
(CLINICIAN ADMINISTERED or SELF-REPORT)

Name of interviewer:			
Interview / self-report date:	Year:	Month:	Day:

GENERAL INFORMATION

Full name:			
Relationship to child:	1. Mother 2. Father 3. Grandmother 4. Grandfather 5. Guardian 6. Other (specify):		
How would you describe your race?	1. Black	2. Coloured	3. White
	4. Asian	5. Other(specify):	6. Refuse to answer
Contact numbers:	Home:	Work:	Cel:
Residential Address:			
Marital status:	1. married 2. co-habiting 3. widowed 4. divorced & living apart 5. divorced & living together 6. separated 7. remarried 8. other (specify):		
Combined annual household income (gross):	1. Less than R10 000 2. R10 000 – 20 000 3. R20 000 – 40 000 4. R40 000 – 60 000 5. R60 000 – R100 000 6. More than R100 000		
Do you live with anyone that has a current alcohol problem or uses other drugs?	Y ES NO If yes, specify what substance(s):		

SIBLINGS (of participant): (including half-siblings, step-siblings) Names of siblings	Gender	Age	History of drug or alcohol use
1.			
2.			
3.			
4.			
5.			
6.			

PAR

PARENTAL EMPLOYMENT:

Hollingstead categories:	Biological mother	Biological father	Guardian
1. Higher executives, major professionals, owners of large businesses)	1.	1.	1.
2. Business managers of medium sized businesses, lesser professions (e.g. nurses, opticians, pharmacists, social workers, teachers)	2.	2.	2.
3. Administrative personnel, managers, minor professionals, owners / proprietors of small businesses (e.g. bakery, car dealership, engraving business, plumbing business, florist, decorator, actor, reporter, travel agent)	3.	3.	3.
4. Clerical and sales, technicians, small businesses (e.g. bank teller, bookkeeper, clerk, draftsperson, timekeeper, secretary)	4.	4.	4.
5. Skilled manual – usually having had training (e.g. baker, barber, chef, electrician, fireman, machinist, mechanic, painter, welder, police, plumber, electrician)	5.	5.	5.
6. Semi-skilled (e.g. hospital aide, painter, bartender, bus driver, cook, garage guard, checker, waiter, machine operator)	6.	6.	6.
7. Unskilled (e.g. attendant, janitor, construction helper, unspedified labour, porter, unemployed)	7.	7.	7.
8. Homemaker	8.	8.	8.
9. Student, disabled, no occupation	9.	9.	9.

PARENTAL EDUCATION:

	Biological mother	Biological father	Guardian
Highest level of education reached? Mark one response for each person as follows:			
1. 0 years (No Grades / Standards) = No formal education (never went to school)	1.	1.	1.
2. 1-6 years (Grades 1-6 / Sub A-Std 4) = Less than primary education (didn't complete primary school)	2.	2.	2.
3. 7 years (Grade 7 / Std 5) = Primary education (completed primary school)	3.	3.	3.
4. 8-11 years (Grades 8-11 / Stds 6-9) = Some secondary education (didn't complete high school)	4.	4.	4.
5. 12 years (Grade 12 / Std 10) = Secondary education (completed senior school)	5.	5.	5.
6. 13+ years = Tertiary education (completed university / technikon / college)	6.	6.	6.
7. Don't know	7.	7.	7.

PAR 3

RESIDENTIAL INFORMATION

Has your child ever lived away from home for more than 3 months?		1. Yes 2. No
If your child lived away from home for more than 3 months, where did he or she live, and how old was she or he at the time?	Place	Age
	1. Foster home(s)	
	2. Group home(s)	
	3. Shelter	
	4. Residential setting	
	5. Hospital	
	6. Home of a relative	
	7. Home of a friend	
	8. Detention centre	
	9. Other (specify):	

How long have you lived at your current address?	
How would you describe your dwelling?	1. Shack 2. Wendy house or backyard dwelling 3. Tent or traditional dwelling 4. Flat / apartment 5. Town house / semi-detached house 6. Freestanding brick house 7. Other (specify):
How many rooms does your dwelling have?	1. one 2. two 3. three 4. four 5. five 6. more than five
Which of these items do you have in your home? (mark as many as necessary)	A. Tap water B. Flush toilet inside home C. Electricity D. Telephone (landline) E. Television F. Computer F. Car
Which ONE of the following best describes how things are in your home?	1. We don't have enough money for food 2. We have enough money for food, but not for other basic items such as clothes 3. We have enough money for food and clothes but are short of many other things 4. We have the most important things, but few luxury goods 5. We have money for luxury goods 6. We have money for luxury goods and extra things 7. Not applicable

APPENDIX D

Relationship between EF and Intelligence

Table 4. Correlations between IQ and EF measures

Correlations.

Marked correlations are significant at p < .05000

	FSIQ
RCF-OSS	0.33
TOL: Total Correct	0.49
TOL: Total Moves	-0.30
TOL: Execution Time	-0.30
CCT Trial 1	-0.14
Coding	0.48
Digit Forwards	0.58
CCT Trial 2	-0.45
Stroop Inhibition	0.42
VFLU Phonemic	0.38
VFLU Semantic	0.62
Digit Backwards	0.53

In examining the correlations between executive test measures and FSIQ scores, seen in Table 4, an abundance of significant correlations are found. This provides evidence that IQ is a significant covariate that must be factored out of executive scores in order to remove this possible confounding effect – and hence examine only the ‘pure’ effect of Age and SES upon executive ability. Correlations are found to range roughly between 0.3 and 0.4, which is notably higher than the 0.1 to 0.2 correlations found in Anderson et al.’s (2001) past seminal work in the field. Hence, in this prior research, the economically and socially homogeneous Australian sample did not yield enough variability in intelligence scores for IQ to be used as a covariate.

In the present research, instead of performing ANCOVA to remove IQ effects, a hierarchical regression was performed as it had fewer assumptions to satisfy. This advantage of fewer assumptions is especially pertinent when one considers that degrees of freedom are to be forfeited in such an analysis, which might present a problem due to the small number of High SES 14-15year old adolescents in the collected sample. In performing this hierarchical regression upon each executive test measure, it was found that after factoring out the effect of

Intelligence, SES and Age were still significant predictors of executive performance in tests that had formerly exhibited significant SES or Age effects. In several cases, however, the significance of Age and SES was lowered slightly after removing the influence of intelligence. However, such slight differences were not deemed influential enough to affect later analysis.