Multilingualism and Executive Function: Evidence from Assessments of Working Memory, Cognitive Flexibility and Selective Attention.

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Abstract

Previous research has shown patterns of executive function to vary among individuals contingent on number of languages spoken. The current study aims to expand on research investigating the complex mechanisms of executive function which underlay language acquisition. Performance of monolingual, bilingual and multilingual speakers on a battery of executive function tasks was investigated. The study defined executive function as working memory, selective attention and cognitive flexibility. A quasi-experimental between-groups design was adopted. Participants who were divided into monolingual (*n*=13), bilingual (*n*=11) and multilingual speakers (*n*=10) were assessed individually in groups of two or three in the National College of Ireland over a four week-period. Outcomes of working memory, selective attention and cognitive flexibility were evaluated using pen-to-paper versions of The Rey Osterreith Complex Figure test, The Stroop Task and The Trail Making Test. Response latencies and accuracy levels predicted performance of all groups in all levels of executive function. A one-way between groups analysis of variance was conducted to explore between-groups differences on executive function. Results found a statistical difference in mean scores of selective attention for multilinguals and bilinguals, with multilinguals preforming faster on the Stroop Test [$F(2, 31) = 3.74$, $p < 0.05$]. However, after applying Bonferroni Correction, statistical difference was deemed insignificant. No significant statistical differences were found between groups on levels of working memory or cognitive flexibility. Implications are discussed in relation to multilingualism, as a potential contributor to the delay in the onset of neurodegenerative diseases.

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Introduction

Since the earliest years of humankind, multilingualism has always been inherent in many regions of the world. However, in recent times, scientific research has investigated multilingualism anew under the title of applied linguistics. Due to the overwhelming influence of globalization exacerbated by mass media, the complex phenomena of multilingualism and multiple language acquisition are gaining increasing interest in the realm of cognitive and linguistic psychology. Researchers posit that there are more people in the world who speak several non-native languages, in addition their own native tongue (i.e. Multilanguage acquisition) than individuals who speak only one language (i.e. Monolingualism) (Cenoz & Genesee, 1998).

Quantitative analysis reveals that speaking at least one other language (i.e. bilingualism) is typical of most human language users and monolingualism is now the exception, highlighting the preeminent importance of this topic to sociolinguistic research (Auer & Lier, 2007). Bilingual and multilingual speakers all differ from each other in a multitude of cognitive and behavioural aspects, not all of which are fundamental to the current study but will be addressed below, when relevant (Auer & Lier, 2007; Genesee, Paradis & Crago, 2004). Applied linguistics refers not only to the study of language in academia, but also the practical problems associated with everyday use of language. For example, it may be of importance to society that multiple language acquisition may potentially delay the effects of cognitive ageing (Kavé, Eyal, Shorek & Cohen-Mansfield, 2008).

Previously, behaviourist and Chomskyan theories of language acquisition (please see Skinner, 1957 and Chomsky, 1965) were developed in light of people who only speak one language. Nowadays, more studies have been conducted on second language acquisition and bilingualism, but in comparison, the process of acquiring three or more languages, and its effect on cognitive outcomes is still relatively understudied (Cenoz & Genesee, 1998). It has long been established by researchers that the way in which individuals process, comprehend and remember language is linked to the neural mechanisms which underlie day-to-day maintenance in the brain (i.e. Executive function) (Broca, 1861; Wernicke, 1885 Baddeley, Gathercole, & Papagno, 1998; Masoura & Gathercole, 1999).

Over the years, cognitive and neuropsychologists have defined working memory, cognitive flexibility and selective attention as functions of executive function through various standardized measures of cognitive function. These measures consist of a number of well-studied and straightforward tasks which tap into each target function and functional neuroimagery technology (Miyake, Friedman, Emerson, Witzki, Howerter & Wager, 2000). However, the issue of how several languages are represented in the brain; that is to say, to what degree multilingualism stimulates each of these facets of executive function is understudied.

Contribution of Working Memory in Acquisition of Language.

Working memory is a popular and prominent cognitive model which is strongly linked with executive function and was first proposed by Baddeley (1974). It refers to the temporary processing and storage of information. The wholly acknowledged and multi-component model of working memory was both an extension and augmentation to the unitary theory of short term memory or multistore model proposed by Atkinson and Shiffrin (1968).

The working memory model offers three components which are orientated in the maintenance of phonological, visual and spatial information, with particular emphasis on the support of speech production (Baddeley, 1974). The phonological loop and visuospatial sketchpad both act as “slave” systems in accordance with the central control structure, also known as the central executive (i.e. executive function) (Miyake et al., 2000; Baddeley, 1974). These are recognised as underlying processes which regulate and control other cognitive functions and are frequently associated with activation within the frontal lobes (Miyake et al., 2000). Furthermore, the nature of the relationship between working memory and executive function is described by an 'updating function' which requires incoming information to be encoded and restored by substituting irrelevant information with new, target information (Miyake et al., 2000).

Daneman and Carpenter (1980) proposed a theory which was supplementary to the works of Baddley (1993), which highlighted working memory as being critical to language comprehension. A meta-analysis review suggested that in order to ascertain predictive validity of working memory in language, researchers must not assess the singular capacity at which verbal material is stored, but the dual capacity at which verbal material is understood and stored (Daneman & Merikle, 1996). There is much evidence to support working memory as an attentional, cognitive control which underpins or at least exudes influence over the complex cognitive action of first language comprehension (Linck, Osthus, Koeth & Bunting, 2014).

The component of working memory which maintains temporary storage of information has been shown to be positively consequential for skilled comprehension of language (Daneman & Merikle, 1996). Linck and colleagues (2014) posit that working memory may in fact play a more significant role than that of short-term memory when acquiring a second language. Indeed, children aged 8-11 years who were deemed skilled or non-skilled readers did not differ in terms of short-term memory capacity; however, skilled readers performed better than their less skilled peers on a more complex measure of language comprehension (i.e. Discourse task) (Perfetti & Goldman, 1976).

These results highlight working memory as paramount to skilled language comprehension. In light of this, it should be of no surprise that working memory is heavily implicated in the process of learning a second language. Furthermore, patterns of activation in a bilingual brain during working memory tasks present increased complexity in juxtaposition to their monolingual controls (Ardila, 2003). However, the effect of bilingualism on individual working memory capacity presents mixed results to researchers (Engel de Abreu, 2011; Adesope, Lavin, Thompson & Ungerleider, 2010; Van den Noort, Bosch & Hugdahl, 2006). These discrepancies between researchers may be result of an evident lack in comparative empirical evidence investigating the working memory capacities of first, second and third language users.

Adesope and colleagues (2014) posit there are two major theories regarding the complex relationship between bilingualism and working memory; the first stating a greater demand placed on cognitive load will hamper the effects of effective processing (Van Merrienboer & Sweller, 2005). Paradoxically, evidence from tasks of cognitive control (i.e. Simon task) suggest that as a result of consistent control of inhibitory processing, a bilingual speaker becomes disciplined to rejecting one language whilst using the other (Bialystok, Craik, Klein & Viswanahan, 2004). This stimulus-response based task which tests the degree to which a dominant association with irrelevant spatial information affects individual's reaction to task target nonspatial information (Bialystok et al., 2004). This is a good example of the nature of the relationship between working memory and executive function.

In more recent studies, language proficiency, that is to say, how capable an individual is in expression of written and verbal language(s), has been identified as an appropriate means by which to measure working memory capacity among bilingual and multilingual samples (Van den Noort et al., 2006). Although, relatively few of these studies exist, researchers suggest bilingual and multilingual speakers present positive strong correlations with increased verbal working memory outcomes from simple (digit-span) and complex tasks (reading-span task and letter-number ordering) (Blom, Kuntay, Messer, Verhagen & Leseman, 2014; Van den Noort et al., 2006).

Capacity theory of comprehension aims to explain how individual working memory capacity influences language comprehension (Just & Carpenter, 1992). They suggest that the total amount of activation available in a working memory capacity is varied in individuals and both processing and storage are mediated under a single processing storage capability. These underlie the individual differences in working memory such as syntactic modulation and ambiguity. That is to say, greater working memory capacities enable interaction between syntactic and pragmatic stimuli and grant individuals with the ability to maintain multiple interactions during tasks of reading-span (Please see Dane & Carpenter, 1980) (Just & Carpenter, 1992). While this ‘umbrella’ like view of processing links may be useful to explain the general nature of the relationship between working memory and executive function in that it exudes general maintenance of over a higher cognitive process, it is too simplistic in concept to ascertain the complexity of how language is retained.

In contestation to this, Walters & Caplan (1996) claim that working memory is not a unitary system mediated by the verbal process; indeed, it involves two mental systems. In their critique of the work of Just and Carpenter (1992) they argue that the capacity theory of comprehension lacks sufficient empirical evidence to validate their findings. The Separate-Sentence-Interpretation-Resource theory (Walters & Caplan,

1996) is more comprehensive and they were able to support their hypothesis with evidence, as seen by data from neuropsychological patients. Aphasic stroke patients with extremely restricted verbal memory spans were able to implement a multitude of syntactic structures (i.e. Phrasing structure) (please see Chomsky, 1956) when attempting to give meaning to phrases (Walters & Caplan, 1995).

These theories which were tested with participants who were individually measured on levels of storage and processing revealed inconsistent findings (Miyake, Carpenter & Just, 1995; Caplan & Waters, 1995). However, further evidence has found that the degree to which working memory aids in multiple language acquisition may be contingent on the task provided, in addition to language proficiency (Service, Simola, Metsänheimo & Maury, 2002; Turner & Engle, 1989).

Few studies have utilized tasks which assess both storage and processing elements of working memory (i.e. letter-number ordering) in second language learners. However, Service and colleagues (2002) asserted that working memory capacity is taxed when the individual is not utterly proficient in their second language, thus increasing working memory capabilities. Previous research has clearly stated that in order to effectively assess working memory in second and third language users, psychologists must use tasks which examine the dual-system by which working memory operates and underpins foreign language acquisition.

As previously stated, multiple language acquisition appears to be the norm in current society. Therefore, it is reasonable to suggest that taking into consideration this norm it is not imperative solely to researchers and academics, but also to clinicians. Patients suffering from language disorders, particularly those disorders which inhibit one’s ability to formulate and produce sentences and phrase coherent utterances (i.e. Aphasia) exhibit irregularities in frontal lobe regions- particularly in Broca's area (Stromswold, Caplan, Alpert & Rauch, 1996; Stowe, Wijers, Willemsen, Reuland, Paans & Vaalburg, 1994).

The prefrontal cortex which has been deemed home to functional working memory and as previously mentioned, the comprehension of language, is located in close proximity an area associated with expressive speech (Levy & Goldman-Rakic, 2000; Paulesu, Frith & Frackowiak, 1993). Interestingly, expressive writing has also been shown to increase working memory capacity (Klein & Boals, 2001). Golestani and colleagues (2006) observed activation of the left prefrontal cortex of bilingual speakers during expression of their second language in comparison to their first language. In light of this, studies which have examined bilingual aphasia have gleaned some interesting results. It is important to mention that assessing a bilingual or multilingual speaker in only one language would not make logical sense; patients should be tested comparatively in their various languages. According to Fabbro (2001), a high proportion of bilingual speakers (65%) exhibit congruous impairment in both languages whilst interestingly, a smaller proportion (20%) describe a larger impairment in their second language.

Furthermore, Celsis and colleagues (1991) report prevalent involvement of left frontal cortical regions in the regulation of verbal memory; findings which propose that the associated regions support the process of learning and remembering verbal material. However, meta-analysis reveals much contention regarding neural correlates of language specific to syntactic production (Indefrey & Levelt, 2000). Perhaps, this contention may be a result of methodological issues, as characterized by the validity of implementing various techniques of functional imagery when attempting to identify language specific areas (Billingsley-Marshall, Simos & Papanicolaou, 2004).

Activation of the working memory, like any higher cognitive function varies greatly among individuals based on a multitude of factors relating to regulation of healthy brain activity.

Those who consume alcohol and use marijuana in conjunction with each other on a frequent basis are associated with short-term lower levels of working memory capacity (Jager, Kahn, Van Den Brink, Van Ree, & Ramsey, 2006; Schweinsburg et al., 2005). Particularly, the left superior parietal cortex (an area posited integral for manipulation of stimuli of working memory) demonstrates alterations in neural activity. Currently, prevalent use of cannabis and alcohol appears to be inherent among young adult and student populations (O'Hara, Armeli & Tennen, 2016; Schweinsburg, Schweinsburg, Cheung, Brown, Brown, & Tapert, 2005). However, little evidence has been found to suggest long term deficits in working memory in consistent cannabis users prior to a week of abstinence (Jager, Kahn, Van Den Brink, Van Ree, & Ramsey, 2006). Even so, one must consider the implications of consistent significant mutations to neural structure.

Contribution of Cognitive Flexibility in Acquisition of Language.

The flexibility inherent in the application of language in humans cannot be overemphasised. In terms of linguistic processing, cognitive flexibility refers to the mental fluidity employed when shifting between language stimuli (Meskill, Mossop & Bates, 2000). Cognitive flexibility, or 'task-switching' is recognised as an important facet of executive function (Miyake et al., 2000). Evidence to support this assertion stems from neuropsychological patients suffering from brain damage to the frontal lobes whom exhibited failures in control capabilities (Rogers & Monsell, 1995; Goldstein, 1944).

Furthermore, tasks which tap into the ability to switch between stimuli consist of set-shifting and number-letter paradigms, such as the Trail Making Test (Reitan, 1958) and Wisconsin Card Sorting test (Grant & Berg, 1948). Tests such as these require the individual to exhibit flexibility despite conflicting stimuli. Activation of the prefrontal cortex is associated with performance on this task, along with performance on the Wisconsin Card Sorting test. These findings highlight the role of cognitive flexibility in executive function (Moll, Oliveira-Souza, Moll, Bramati & Andreiuolo, 2002).

In the case of second language learners, expressive speech emphasises the demand placed on abilities to shift between the target and non-target language (Meskill et al., 2000). Bilingual speakers are understood to switch between two systems of communication which in turn requires the speaker to engage in a higher level of mental flexibility. Empirical investigations into the relationship between cognitive flexibility and dual language acquisition seem imperative to understanding the potential mediating effects of executive function and multiple language acquisition (Adi-Japha, Berberich- Artzi & Libnawi, 2010).

Research has revealed that bilingual children perform better than their monolingual peers in tasks of problem-solving which measure cognitive flexibility (Bialystok & Martin, 2004). Interestingly, at the time, these significant differences were not observed in the primary executive control (working memory), which has been shown to facilitate language acquisition in later life (Bialystok & Viswanathan, 2009). In contrast to general findings, Werker (1986) found a that broad experience of language did not mediate cognitive flexibility inherent in phonetic discrimination.

However, he takes into account the fact that when the content as opposed to the structure of the task is unknown to the individual, problem-solving capacities are diminished.

Contribution of Selective Attention in Acquisition of Language.

The process of selective attention or 'inhibition' refers to an individual's capacity to intentionally exhibit necessary control over governing responses (Miyake et al., 2000). In order to successfully attend to a desired outcome, an individual must consistently assess their immediate environment and choose appropriately from a multitude of conflicting stimuli (Wilcutt, 2005). The role of selective attention in executive function refers to integrating appropriate knowledge from cognitive inputs into a context which is successful for typical behavioural outcomes (Miyake et al., 2000). The vital role of selective attention in executive function is often described by clinical manifestations of attention deficits disorders (Wilcutt, 2005). Researchers posit that prefrontal abnormalities generate deficits in executive functioning thus resulting in impulsivity amongst other erratic behaviours (Fuster, 2001).

Selective attention is typically referred to in the context of a visual capacity however, in the case of language, in order to successfully comprehend and process language, one must effectively eliminate a multitude of competing semantic stimuli. For example, if one hears the word "for", they must actively choose from a range of options, such as, "former, forgo, format", etc. As the semantic structure of the sentence develops, it becomes clearer to the individual which word is appropriate to use. In that time, words irrelevant to the context are ignored and correct words are targeted; thus exhibiting correct selective response (Marian, Blumenfeld, Mizrahi, Kania & Cordes, 2013).

The majority of studies which have investigated the influence of inhibitory control in multiple language acquisition have primarily focused on the outcomes from second language speakers (Blumenfeld & Marian, 2011; Colzato et al., 2008; Costa, Hernández & Sebastián, 2008). Generally, results have found that as a result of consistent inhibitory control in the bilingual brain, language switching capabilities are reinforced.

Research regarding multilingual performance on selective attention studies are scarce, however, it has been suggested that changes in cognitive controls are present as a result of increased experience in maintaining multiple conflicting stimuli (Linck, Schwieter & Sunderman, 2012). Performance of trilingual speakers on the classic Stroop test strengthens these findings (Marian et al., 2013). The processes involved in performance on the Stroop effectively mirror the processes involved in selective attention. One must implement cognitive processes to recognise and reject stimuli which is contradictory in nature. For the task, names of colours are written in incongruent colours of ink. These are presented to the individual and they are asked to read aloud the colour in which the word is written, as opposed to the name of the word which is presented. This interference taxes individual selective attention capabilities.

Results from Marien and colleagues (2013) found trilingual performance in terms of response latencies and levels of accuracy were enhanced by language proficiency and support the contention that multiple language acquisition augments alterations in cognition. Furthermore, Bench and colleagues (1993) identified activation in the right hemisphere of the prefrontal cortex, an area previously associated with executive function and language production.

Tasks of executive function are routinely used in assessing cognitive capabilities of elderly individuals who are subject to typical cognitive decline (Tucker & Stern, 2011; Buckner, 2004; Scarmeas et al., 2003). A frailty within the frontal processing systems, specifically working memory has been linked to a decline in cognitive reserve capacity (Nyberg et al., 2003). Cognitive reserve refers to the active use of cognitive paradigms which are less inclined to negatively interrupt the daily process undergone in task management (Stern, 2012). Therefore, it would make logical sense to propose that age-related onset of dementia and AD exacerbates the typical age induced decline of executive function.

Environmental outcomes have been shown to positively affect a delay in the onset of AD, and a prime example of this is education (Kavé et al., 2008). It is a key factor associated with one's environment. Supplementary to this, and perhaps more importantly, multilingualism has been suggested to contribute to an individual's cognitive reserve (Chertkow et al., 2010; Kavé et al., 2008). Interestingly, it appears that an increased number of languages spoken has a complementary effect on cognitive reserve. That is to say that multilinguals will have an increased cognitive reserve in comparison to their bilingual peers (Perquin et al., 2013; Chertkow et al., 2010).

However, Goral (2004) ascertains that as we age, it is more difficult to retrieve words, thus positing that bilingualism, and indeed multiple language acquisition may engender further difficulties as we age. This theory that has been contested by Bialystok and colleagues (2004) argue that governance of two languages throughout our lives ensures continuous practice exercising of inhibitory control. They posit that this constant usage actually hampers the effect of age-onset deficiency in executive controls.

Current Study

Research investigating the cognitive outcomes of speaking several languages has received little attention in recent years. Albeit scarce, current research suggests that there is reason to believe that the number of languages one speaks will positively impact one's cognition. Evidence stems from studies which investigate the impact of multiple language acquisition on ageing cognition (Chertkow et al., 2010; Kavé et al., 2008; Bialystok et al., 2004). A recent study found multilingualism, as opposed to bilingualism to hamper the effects of ageing on cognition (Kavé et al., 2008).

Moreover, second and third language acquisition research has expanded from studies which ascertain where exactly different languages are represented in the brain (Vingerhoets et al., 2003) to comparative studies which measure cognitive capabilities of individuals who speak varying numbers of languages (Engel de Abreu, 2011; Blom et al., 2004). However, due to an evident absence in empirical evidence, there is much room for speculation regarding to what degree multiple language acquisition stimulates various aspects of our cognition responsible for memorizing, comprehending and processing language. Thus, more evidence is needed to provide a better understanding of why speaking one language, as opposed to speaking three affects our cognitive outcomes.

Furthermore, future research should now take into account the societal norm of the multilingual speaker; the implications of the unique and complex underlying mechanisms of multiple language acquisition which influence how we acquire and process language today (Cenoz & Genesee, 1998). The evident influence of the flexibility of human cognition upon acquiring multiple languages should be taken into account; and the monolingual bias be scrutinized in conceptualising future theories of second and third language acquisition (Herdina & Jessner, 2002). Previous research has shown bilingual speakers to somewhat exceed the capabilities of monolingual speakers in levels of executive function (Van den Noort et al., 2006). That is to say, bilingual speakers occasionally exhibit superior cognitive capabilities; contingent on task dependency and levels of proficiency. Furthermore, neuroimaging studies have discovered increased activation of the frontal cortex, specifically Broca's area, in multilinguals in comparison to bilinguals (Vingerhoets et al., 2003).

The primary aim of the current study is to compare different patterns of executive function across individuals who speak varying numbers of languages. The current study posits differences in levels of executive function will be observed among each group; however, significant differences are anticipated of multilingual speakers in comparison to monolingual and bilingual speakers.

Participants of the current study were allocated to groups contingent on how many languages they spoke. It was expected that monolingual (Group One), bilingual (Group Two) and multilingual speakers (Group Three) would significantly vary in exhibited levels of executive function, as described by working memory, cognitive flexibility and selective attention.

Hypotheses:

Hypothesis One: Significant difference in working memory capacities are expected, as described by response latencies and levels of accuracy on the Rey Osterrieth Complex Figure drawing test, in Group 3 versus Group 1 or 2, although variance within groups is to be expected.

Hypothesis Two: Significant difference in cognitive flexibility capacities are expected, as described by response latencies and levels of accuracy on the Trail Making Test, in Group 3 versus Group 1 or 2, although variance within groups is to be expected.

Hypothesis Three: Significant difference in selective attention capacities are expected, as described by response latencies and levels of accuracy on the Stroop Task, in Group 3 versus Group 1 or 2, although variance within groups is to be expected.

Method

Participants

The participants consisted of thirty-six males (*n*=16) and females (*n*=18) from varying backgrounds all of whom are currently living in Ireland. Two participants were excluded from the data due to participant drop out. They spoke English, as well as native/second/third learned languages frequently, in their social circles or in a professional environment. It was difficult to approximate the number of participants approached due to the recruitment strategies implemented. Participants were obtained through methods of convenience. The three groups and means of sampling are described below:

Monolingual Group (Group One): These participants (*n*=15) largely consisted of students from the National College of Ireland (NCI) (*n*=7), Trinity College Dublin (*n*=2) and University College Dublin (*n*=1) obtained by means of convenience and working professionals obtained through snowball sampling means (*n*=5) (mean age: 21.6, *SD* = , range = 18.00 – 24.00). Two participants were excluded from the data due to participant drop out. The native language of the monolingual cohort was English. Majority of participants acquired a second language during second level education, however, upon leaving school participants no longer retaining this language. Some of the participants continued to practice second language acquisition into their third level education but did not describe themselves as fluent and therefore could not be included in the respective groups.

Bilingual Group (Group Two): These participants (*n*=11) consisted of students from NCI (*n*= 7), some of whom were contacted by an international peer mentor from NCI, work colleagues (*n*=2) obtained through means of convenience and a working professional was obtained through random sampling via the social media platform Facebook (*n*=2) (mean age: 28.2, *SD* = , range = 21.00 – 38.00). Bilingual speakers all spoke English plus one of Irish, French, German, Mandarin, Croatian, Spanish, Portuguese, Swedish.

Multilingual Group (Group Three): These participants (*n*=10) consisted of students from NCI and working professionals, again who were contacted via an international peer mentor from NCI (*n*= 4), and the researcher by means of convenience (n=3) and snowball sampling techniques (*n*=3) (mean age: 27, range = 19.00 – 39.00). Multilingual speakers spoke, in addition to English, over two languages (mean number of language spoken = 3.3, range = 3.00-4.00) which were either Arabic, French, Ukrainian, Russian, Dutch, Romanian, Polish, Croatian, German, Hindi, Bengali, Tamil, Telugu. This cohort was largely comprised of those who spoke languages which are not based on the Latin alphabet, i.e. scripts such as Hindi, Arabic and Cyrillic.

All participants were educated in and spoke English with fluency. The original sample was comprised of those whose languages were derived from the Latin alphabet, however, due to small sample size and timing constraints, the sample was expanded to those whose language derived from any alphabet or script.

An equal number of participants per group were allocated to each group so as to avoid Type 1 error.

A brief conversation was had with each participant prior to declaration of consent to confirm advanced proficiency/fluency in their spoken language(s).

Design and Statistical Analysis

The current study incorporated a quasi-experimental between groups design to measure response latencies and levels of accuracy on a battery of cognitive assessment tasks. All participants completed three short assessments; a test to measure working memory, followed by a test to measure cognitive flexibility and finally a test to measure selective attention. The independent variable consisted of number of languages spoken. Individuals were categorized into monolingual, bilingual, and multilingual speakers. The dependant variable consisted of executive function. Executive function was categorized into working memory, cognitive flexibility and selective attention. Patterns of EF across individuals who spoke varying numbers of languages was examined.

The statistical analysis consisted of three one-way between groups analysis of variance tests. The current study aimed to compare the variability in scores of executive function with the variability in number of languages spoken. Monolingual, bilingual and multilingual speakers were compared on levels of working memory, cognitive flexibility and selective attention, respectively.

Tests of the three hypotheses were conducted using Bonferroni adjusted alpha levels of .0166 per test (.05/3). Results were only deemed significant if p was less than .02.

Materials

Measure of working memory

Working memory was measured using the Rey Osterrieth Complex Figure drawing test (Osterrieth, 1994). The stimuli used in the Rey Osterrieth Complex Figure drawing test consisted of the original figure; a complicated line drawing printed in black ink on a a4 sheet of paper. The test consists of three conditions which assesses their immediate recall capabilities and short-term memory. The figure is comprised of 18 specific design elements. It is scored according to how many design elements the individual includes in their drawing. Individuals are not typically timed, however, they are asked to complete immediately recall the drawing as rapidly as possible. Furthermore, notes on how the figure is reproduced are usually taken. Chronbach's alpha for Part A and B is .95 and .94, respectively. It is .96 for total scores (Cornell, Roberts & Oram, 1997).

Measure of cognitive flexibility

Cognitive Flexibility was measured using the Trail Making Task (Reitan, 1958). It is one of the most commonly used neuropsychological assessment of cognitive processing and executive function. It consists of two parts; Part A and Part B. Total time to complete the test is recorded and indicates an individual's level of cognitive processing. Part A consists of encircled numbers ranging from 1-25. Participants are required to connect all encircled numbers with a pencil. Typically, Part A takes 29 seconds to complete. Part B consists of numbers ranging from 1-12 and letters ranging from A-L. Participants are required to connect alternating encircled numbers and letters with a pencil. Typically, Part B takes 75 seconds to complete. Chronbach's alpha for the assessment is .84 (Salthouse, 2011).

Measure of selective attention

Selective attention was measured using a modified version of the Stroop colour-word task (Stroop, 1935). The stimuli used in the Stroop task consisted of two printed A4 sheets of paper with 21 different colour names written on each sheet (42 words in total) in English using coloured ink. Written colours consisted of the following 10 colours: green, blue, pink, purple, red, black, white, orange, yellow and grey. Colours were chosen contingent on the theory of universal colour categorisation (Berlin & Kay, 1969) The written words signified colour terms which were either congruent (same as) or incongruent (different) to the ink of the colour. In condition A, the colours were congruent to ink colour. In condition B, the colours were incongruent to the ink colour. This test is standardized in collecting a measurement of selective attention.

<u>Procedure</u>

Prior to data collection an information letter and consent form was created. A pilot study was administered previous to data collection. Participants of the pilot study comprised of five students from a third year undergraduate psychology class. Participants were categorized into monolingual (n = 3), bilingual (n = 1), multilingual (n = 1) speakers.

Following a brief conversation with each participant, a number of methodological errors regarding the testing procedure were highlighted; participants felt they were seated too close in proximity to each other, which negatively affected their level of comfort in asking the researcher any questions they may have had. This issue was addressed by decreasing the number of participants per group to 3 and spacing them a greater distance apart during testing. Furthermore, due to an administrative error, the researcher failed to include Condition B of the ROCF during the assessment procedure. Results from this sample were deemed invalid as a result. In light of this, a new sample was obtained. Condition B of the ROCF was included in the proceeding assessments.

On completion of the pilot study, scores on all levels of executive function were calculated. Furthermore, a brief analysis revealed that the multilingual group gleaned the highest scores on the measure of selective attention and second highest score on the measure of cognitive flexibility. These results however insignificant due to incredibly small sample size suggested that perhaps a similar trend might potentially occur in the main study. The aforementioned adjustments were implemented prior to conducting the main study.

The information letter was distributed via email to all international students in the National College of Ireland, college peers, work colleagues and acquaintances. Data collection for the main study took place from the 17^{th} of January to the 7^{th} of February.

Participants were invited into a classroom where they were seated at individual desks which were spaced apart. The researcher gave a brief speech regarding what the following forty minutes were going to entail. On each desk was an information letter and consent form (please see Appendix A); attached to these were three blank A4 sheets of paper, a booklet containing Part A and B of the TMT, and a page which contained a list of words (Condition B of the Stroop). Both the information letter and consent form was read by the participant and any questions following this were answered prior to declaration and signature of consent. Demographic information, such as age, gender and number of languages the individual spoke were obtained previous to testing.

Following this, the participants were assessed on each task, individually. Participants were tested consecutively for each task. Testing commenced by assessing each participant on their working memory. The stimulus (ROCF) (Please see Appendix B) was placed in front of the participant and they were asked to reproduce (copy) the stimulus on to a blank sheet whilst looking at it. This was Condition A (Copy

Condition). Then, immediately after the participant had completed the drawing, both the drawing and the stimulus were taken away from sight and the participant was asked to recall and re draw the image from memory on a new piece of paper. This was Condition B (Immediate Recall). This drawing was also removed from sight. The test was not timed. Participants were not informed that there was going to be a third condition to follow in approximately thirty minutes.

Following this, participants were assessed on their levels of cognitive flexibility. They were asked to complete Part A of the TMT (Please see Appendix C). Part A required the participant to use a pen to draw lines to connect encircled distributed numbers from 1-25 in ascending order without lifting their pen from the page. They were timed whilst doing this and were informed of this. Part B (please see Appendix D) was completed immediately after this. Part B required participants to use a pen to draw lines to connect encircled distributed numbers (1-12) and letters (A-L).

The letters and numbers were connected in ascending order but with the added task of alternating between the numbers and letters. For example, 1-A-2-B-3-C, etc. Participants were timed again. If the participant made an error, i.e. missed a number/letter they were asked to trace their pen back to the correct number and continue with the rest of the test. In doing this, errors made transferred to additional time it took to complete the task. Times taken to complete Parts A and B were recorded on the participants the testing sheet.

Following this, participants were assessed on their levels of selective attention. Participants first completed condition A (congruent condition) (please see Appendix E) of the test. They were asked to read aloud a list of 21 words. These words were the names of 10 various colours (green, blue, pink, purple, red, black, white, orange, yellow, grey) which were presented on a page printed in ink colour which was congruent to the name of the word. For example, BLUE. Participants were timed on how long it took them to complete the list of colours.

Following this, participants were asked to complete Condition B (please see Appendix F) of the test. This condition required the participants to read aloud the exact same words, in the same order; however, the words were printed in an ink colour which was incongruent the name of the colour. For example, BLUE. Response latency and number of errors made was recorded on the back of the page. An error was made of the participant read aloud the name of the word instead of the colour of the ink.

From the end of Condition B of the ROCF, approximately thirty minutes had elapsed. Participants were asked to reproduce the stimulus from their memory. This was Condition C (Delayed Recall). Condition B and C were scored according to the accurate reproduction and specific placement of 18 elements of the stimulus. Participants were not timed.

Participants were provided with cookies once they had completed the test.

Results

Descriptive Statistics

The descriptive statistics for demographic information of participants (age, gender and number of languages spoken) is presented in Table 1. The descriptive statistics for group differences in mean on all levels of executive function (working memory, cognitive flexibility and selective attention) is presented in Table 2.

Table 1

Frequencies for the current sample on each demographic variable (N = 36)

Variable	Frequency	Valid Percentage
Gender		
Male	16	47.1
Female	18	52.9
Age		
18-24	24	64.7
25-29	5	14.7
30+	7	20.6
Groups		
Monolingual	13	38.2
Bilingual	11	32.4
Multilingual	10	29.4

Table 2

Descriptive statistics including means, standard deviations and range in scores between groups on levels of executive function.

Variable	*Group*	*N*	*M*	*SD*	*Range*
Working Memory	Monolingual	13	45.85	12.59	0-46.00
	Bilingual	11	51.05	10.47	0-34.00
	Multilingual	10	48.80	13.14	0-43.00
Cognitive Flexibility	Monolingual	13	70.17	13.33	0-44.81
	Bilingual	11	67.86	15.56	0-46.40
	Multilingual	10	61.03	17.64	0-51.85
Selective Attention	Monolingual	13	33.46	6.25	0-22.21
	Bilingual	11	36.77	9.01	0-32.48
	Multilingual	10	28.52	4.65	0-15.10

Histograms and normal Q-Q plots were examined for each dependant variable in order to assess normality. The mean scores for working memory for each group; monolingual (M = 45.85, SD = 12.59), bilingual (M = 51.05, SD = 10.47), and multilingual (M = 48.80, SD = 13.14) indicated that all groups performed similarly on the Rey Osterrieth Complex Figure drawing test. The mean scores for cognitive flexibility for each group; monolingual (M = 70.17, SD = 13.33), bilingual (M = 67.86, SD = 15.56), and multilingual (M = 61.03, SD = 17.64) indicated that all groups performed similarly on the Trail Making Test Parts A and B. The mean scores for selective attention for each group; monolingual (M = 33.46, SD = 6.25), bilingual (M = 36.77, SD = 9.01), and multilingual (M = 28.52, SD = 4.65) indicated that the multilingual cohort performed faster than the bilingual cohort on the Stroop Task. However, mean scores between groups on levels of cognitive flexibility were more varied then mean scores between groups on levels of working memory; with the multilingual cohort performing faster than both monolingual and bilingual speakers.

The Kolmogorov-Smirnov test of normally presented all three Sig. values greater than .05 which suggests there was no violation of the assumption of normality in the cases of all three groups for working memory. Upon inspection of all three histograms, a somewhat normally distributed bell curve was observed, and the Q-Q plots presented a reasonably straight line which suggests a somewhat normal distribution is present. The Kolmogorov-Smirnov test of normally presented all three Sig. values greater than .05 which suggests there was no violation of the assumption of normality in the cases of all three groups for cognitive flexibility. For cognitive flexibility in the bilingual cohort, the histogram presented a negatively skewed bell curve, and the Q-Q plots did not present an utterly straight line which suggests there was not a normal distribution. In the case of the other two cohorts, a somewhat normally distributed bell curve was observed, and the Q-Q plots presented a reasonably straight line which suggests a somewhat normal distribution is present. The Kolmogorov-Smirnov test of normally presented all three Sig. values greater than .05 which suggests there was no violation of the assumption of normality in the cases of all three groups for selective attention. Upon inspection of all three histograms, a somewhat normally distributed bell curve was observed, and the Q-Q plots presented a reasonably straight line which suggests a somewhat normal distribution is present.

Inferential Statistics

One-Way Analysis of Variance (ANOVA)

Outcome One: Working Memory

A one way between-groups analysis of variance was conducted to examine the relationship between working memory and number of languages an individual speaks. Participants were divided into three groups according to how many languages they spoke (monolingual speakers; bilingual speakers; and multilingual speakers).

There was no statistical difference was observed between working memory scores and number of languages an individual speaks [$F (2, 31) = .56, p > .05$]. After applying Bonferroni Correction, results were only deemed significant if *p* = < .02. No post-hoc tests were conducted due to non-significant differences in mean scores. The effect size calculated using eta squared, was .03. Results from this test are presented in Table 3.

Table 3

Means, standard deviations, F value and effect size of outcome from measure of working memory

Variable	*Group*	*N*	*M*	*SD*	*F*	η^2
Working Memory	Monolingual	13	45.85	12.59	.56	.03
	Bilingual	11	51.05	10.47		
	Multilingual	10	48.80	13.14		

Note. $\eta 2$ = eta squared; Statistical significance: *$p < .05$; Bonferroni correction: * $p < .01$

Outcome Two: Cognitive Flexibility

A one way between-groups analysis of variance was conducted to examine the relationship between cognitive flexibility and number of languages an individual speaks. Participants were divided into three groups according to how many languages they spoke (monolingual speakers; bilingual speakers; and multilingual speakers).

No statistical difference was observed between cognitive flexibility scores and monolingual, bilingual and multilingual speakers [F (2, 31) = 1.04, p > .05]. After applying Bonferroni Correction, results were only deemed significant if *p* = < .02. No post-hoc tests were conducted due to non-significant differences in mean scores. The effect size calculated using eta squared, was 1.04. Results from this test are presented in Table 4.

Table 4

Means, standard deviations, F value and effect size of outcome from measure of cognitive flexibility.

Variable	*Group*	*N*	*M*	*SD*	*F*	η^2
Cognitive Flexibility	Monolingual	13	70.17	13.33	1.04	.06
	Bilingual	11	67.58	15.56		
	Multilingual	10	61.03	17.64		

Note. η2 = eta squared; Statistical significance: **p* < .05; Bonferroni correction: * *p* < .02

Outcome Three: Selective Attention

A one way between-groups analysis of variance was conducted to examine the relationship between selective attention and number of languages an individual speaks. Participants were divided into three groups according to how many languages they spoke (monolingual speakers; bilingual speakers; and multilingual speakers).

A significant statistical difference was observed between selective attention scores and bilingual and multilingual speakers, with multilingual speakers exhibiting faster latency responses [F (2, 31) = 3.74, $p < 0.05$]. However, after applying Bonferroni Correction, results were only deemed significant if $p = < .02$, deeming result insignificant. No post-hoc tests were conducted due to non-significant differences in mean scores. The effect size, calculated using eta squared, was .19. Results from this test are presented in Table 5. Difference in mean scores from this test are presented in Figure 1.

Table 5

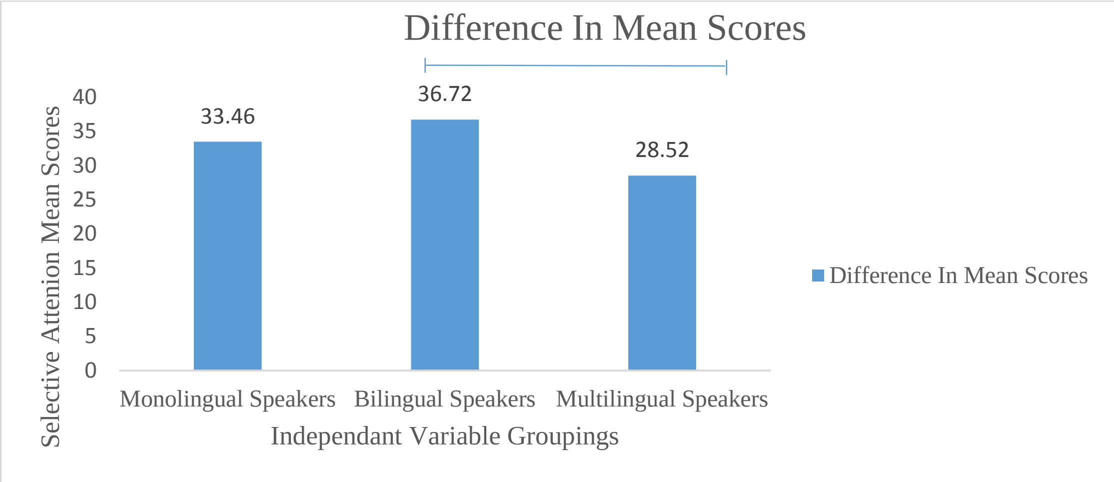
Means, standard deviations, F value and effect size of outcome from measure of cognitive flexibility.

Variable	*Group*	*N*	*M*	*SD*	*F*	η^2
Selective Attention	Monolingual	13	33.46	6.25	3.74	.19
	Bilingual	11	36.72	9.02		
	Multilingual	10	28.52	4.65		

Note. η2 = eta squared; Statistical significance: *$p < .05$; Bonferroni correction: * $p < .02$

Figure 1

Difference in mean scores of selective attention between groups.



Note. Horizontal line indicates significant difference.

Discussion

The primary aim of the present study was to compare different patterns of executive function across individuals who speak varying numbers of languages. This aim was derived from previous research which has suggested executive function to be a key contributor in language acquisition (Broca, 1861; Wernicke, 1885; Baddeley, Gathercole & Papagano, 1998; Masoura & Gathercole).

The present study described executive function as working memory, cognitive flexibility and selective attention. These are understood to be dependant and functional aspects of executive function (Miyake et al., 2000). In order to explore the above aim, three hypotheses were presented. Generally, it was postulated that differences in levels of executive function would be observed across monolingual, bilingual and multilingual speakers. However, significant differences are anticipated of multilingual speakers in comparison to monolingual and bilingual speakers.

Differences in working memory capacities of monolingual, bilingual and multilingual speakers

The hypotheses stated that differences in working memory capacities were expected, as described by a measure of working memory; however, significant differences were expected in multilingual speakers in comparison to monolingual and bilingual speakers. As previously stated, working memory refers to a higher cognitive component which facilitates the temporary storage and processing of information with a propensity for speech comprehension and production (Baddeley, 1974). Through the use of a one-way between ANOVA, variance in levels of working memory between the groups was analysed. Results found no significant differences between monolingual, bilingual and multilingual speakers in levels of working memory. Furthermore, the magnitude of the effect was found to be quite small.

These findings were not consistent with that of Linck and colleagues (2014) who support bilingualism as a consistent indicator of successful performance on measures of working memory. The present study used a complex and nonverbal based task which also assessed visuospatial capacities. Typically, researchers do not use such a measure to assess linguistic capabilities. As described by Linck and colleagues (2014), word, letter and listening span tasks are most frequently implemented when assessing for such capabilities. The nature of the measure utilized in the present study may have measured outcomes which were superfluous to the current study.

A qualitative observation was made with relation to the sample which may have contributed to inconsistent findings in working memory outcomes. The monolingual cohort was comprised of students whom were tested during the morning. Multilingual speakers were typically assed during the evening due to prior obligations. Fatigue among the sample of non-students may have negatively affected their ability successfully attend to the task.

As previously mentioned, young adults and students are recognised to engage in behaviours which may negatively affect working memory capacities in the short-term (O'Hara, et al, 2016; Schweinsburg, et al, 2005). The current sample is largely comprised of young adults and students whom according to research may engage in such behaviours; thus potentially negatively impacting on working memory capacities.

Furthermore, an interesting observation was noted, as participants who performed better at the drawing task tended to begin with more prominent features of the figure, rather than the finer details.

The mean age of the bilingual and multilingual cohort was between twenty-seven and twenty-eight, as opposed to the monolingual cohort who's mean age was twenty-one. Initially, the researcher expected this contrast in age groups to impact on results. However, results found no such incongruences within the data. This is consistent with the theory that suggests levels of executive function do not change significantly until later life (Tucker & Stern, 2011; Buckner, 2004).

The current findings do however augment that of Bialystok & Viswanathan (2009) who did not find working memory to contribute to significant differences between monolingual and bilingual children. The task which researchers used to identify elements of executive function did not conform to typical measures of executive control. They implemented a "faces task" which also tapped into visuospatial components of executive function. In light of this, it can be postulated that researchers should use measures which conform to typical testing practice when assessing individuals working memory capacities.

Differences in cognitive flexibility capacities of monolingual, bilingual and multilingual speakers

The hypotheses stated that differences in cognitive flexibility capacities were expected, as described by a number-letter measure of cognitive flexibility; however, significant differences were expected in multilingual speakers in comparison to monolingual and bilingual speakers. As previously stated, cognitive flexibility or task-switching refers to the ability to fluidly shift between mental tasks (Miyake et al., 2000).

Through the use of a one-way between ANOVA, variance in levels of cognitive flexibility between the groups was analysed. Results found no significant differences between monolingual, bilingual and multilingual speakers in levels of cognitive flexibility in a task-dependant experimental setting. Despite having obtained a non-meaningful result, the strength of association (i.e. effect size) between the number of languages spoken by participants combined with the strength of the difference between the groups was moderate (Cohen, 1988). Stevans (1996) suggests that a small sample size, which is that of below (n = 100), and has obtained an insignificant result, is not indicative of insufficient power. That is to say, if the study was to be replicated with a larger sample, data may elicit statistically significant results. Bearing this moderate influence in mind, it may be suggested that cognitive flexibility may be somewhat influenced by the number of languages an individual speaks.

These present findings mirror that of researchers who have successfully identified cognitive flexibility as a component of executive function which is enhanced as a result of bilingualism (Bialystok & Viswanathan, 2009; Bialystok & Viswanathan, 2009).

Levels of proficiency have been highlighted as critical in ensuring successful outcomes from measures of working memory in first, second and third language learners (Van den Noort et al., 2006; Werker, 1986). Werker (1986) suggests that a broad experience of language may not facilitate increased inhibitory levels. The current study controlled for this by ensuring all participants were fully proficient in the number of languages that they spoke.

Differences in selective attention capacities of monolingual, bilingual and multilingual speakers

The hypotheses stated that differences in selective attention capacities were expected, as described by a word interference measure of selective attention; however, significant differences were expected in multilingual speakers in comparison to monolingual and bilingual speakers. As previously stated, selective attention refers to the ability to consciously exhibit necessary control over automatic responses (Miyake et al., 2000).

Through the use of a one-way between ANOVA, variance in levels of selective attention between the groups was analysed in a task-dependant experimental setting. Results found a significant difference between bilingual and multilingual speakers in levels of levels of selective attention. However, in order to control for potential influence of running multiple comparisons on the present data set (i.e. Type 1 and Type 2 error) a Bonferroni Correction was applied to negate this potential effect. This correction elicited a non-meaningful result. However, a large effect size was observed which, as previously mentioned, suggests the influence of number of languages spoken may be underestimated due to small sample size. In light of this, the finding suggests that if the study is replicated with a larger sample the number of languages an individual speaks, may have a positive effect on propensity for selective attention.

These findings are somewhat consistent with previous hypotheses which state that consistent and increased levels of selective attention augments alterations in the brain of those who speak more than one language (Marien et al., 2013; Blumenfeld & Marian, 2012).

Furthermore, previous research which has found correlations between multilingualism and successful performance on the Stroop somewhat mirror that of the current findings; however, as previously stated results were distorted as a result of small sample size. If the present study was to be replicated, results may be consistent with that of Marian and colleagues (2013).

Limitations

Limitations of the current study are discussed in light of methodological flaws. Many studies which are grounded in experimental research are partial to such flaws. Firstly, due to timing constraints, the number of participants that were obtained were not sufficient enough to provide meaningful statistical results. As previously mentioned, if the sample size gathered were larger, number of languages spoken may have significantly positively influenced both cognitive flexibility and selective attention.

Originally, the researcher had intended to gather a sample which did not include those who spoke languages which did not conform to the Latin alphabet. However, due to timing constraints and a limited access to those who speak such languages, individuals who spoke Indian, Russian and Mandarin were included. It was noted that these participants took longer to complete the number-letter measure of cognitive flexibility. Furthermore, these individuals did not become proficient in English until late adolescence. Age of foreign language acquisition was not noted by the researcher. This may have negatively impacted on performance in measures which used the English alphabet to ascertain levels cognitive flexibility and selective attention.

Furthermore, participants noted that some of the colours on the Stroop test were somewhat incongruent to the correct response, which affected their ability to respond as rapidly as they would have wished.

Implications

Implications of the current study are discussed in light of previous research which has highlighted multilingualism as a contributor to increased cognitive reserve capacitates (Chertkow et al., 2010; Kavé et al., 2008).

The number of languages an individual can speak has been shown to be a significant predictor of cognitive state in old age (Kavé et al., 2008). Furthermore, multilingualism in comparison to demographic variables has been highlighted as a significant determinant of cognitive state in later life (Kavé et al., 2008).

Theories of cognitive reserve are grounded in empirical evidence which suggest that a multitude of environmental factors and life factors are involved in negating the effects of cognitive ageing which in turn, contribute to deferment of neurodegenerative diseases such as AD and dementia (Chertkow, Whitehead, Phillips, Wolfson, Atherton & Bergman, 2010; Jankowsy et al., 2005, Stern, 2002).

Currently in Ireland, there are approximately 55,000 people suffering from dementia (Census, 2011). In addition to this, it is estimated that for each person who suffers from this neurodegenerative disease, a further three family members are directly affected (Census, 2011). In light of this, it is apparent that the implications of the current research area are applicable to a large proportion of the population.

Research regarding the contributions of multilingualism to cognitive reserve capacities in later life have gleaned promising results regarding AD and potentially negating the onset symptomology (Kavé et al., 2008). In comparative studies, it has been shown that multilingual speakers present larger cognitive reserve capacities, in comparison to bilingual speakers (Chertkow et al., 2010). Therefore, it is reasonable to assume that cognitive reserve capacities will be positively affected by multiple language acquisition, combined with a high level of proficiency. These factors may potentially negate the effects of age-related neurodegenerative diseases (Chertkow et al., 2010; Kavé et al., 2008).

Conclusion

Overall, this study has expanded on existing research which has investigated the cognitive capabilities of those who can speak more than one language. It is very important that an in-depth understanding of the role of working memory in multiple language acquisition is ascertained. Currently, researchers are still somewhat ambiguous in defining the strength of the relationship between working memory and multiple language acquisition. The present research has validated this ambiguity; therefore, a further investigation using highly proficient speakers of multiple languages is suggested. It is apparent from the research that cognitive flexibility and selective attention are secondary to working memory in acquiring further languages. However, both elements aid in successful language comprehension and production.

Unfortunately, it appears that the results of the current study may have been undermined by a small sample size. However, this study has contributed to pre-existing knowledge which posits multiple language acquisition as potential mediator of increased capabilities of executive function. The findings also contribute to the theoretical constructs of executive function and the elements involved in successful higher cognitive function.

Future research in the area multilingualism and cognition is needed to glean a better understanding of why these different patterns of executive function contribute to trends in cognitive reserve capacities.

References

Adesope, O. O., Lavin, T., Thompson, T., & Ungerleider, C. (2010). A systematic review and meta-analysis of the cognitive correlates of bilingualism. *Review of Educational Research, 80*(2), 207-245.

Adi-Japha, E., Berberich-Artzi, J., & Libnawi, A. (2010). Cognitive flexibility in drawings of bilingual children. *Child development*, *81*(5), 1356-1366.

Andreasen, N. C., O'Leary, D. S., Hurtig, R., Watkins, D. L., Ponto, B., Argenyi, E., & Hichwa, R. D. (1993). Effects of language and directed attention on regional cerebral blood flow assessed by PET using *[15O] H2O. Journal of Cerebral Blood Flow and Metabolism, 13,* (Suppl. 1), S516.

Ardila, A. (2003). Language representation and working memory with bilinguals. *Journal of communication disorders, 36*(3), 233-240.

Aronin, L., & Singleton, D. (2008). Multilingualism as a new linguistic dispensation. *International journal of multilingualism*, *5*(1), 1-16.

Atkinson, R. C., & Shiffrin, R. M. (1968). Human memory: A proposed system and its control processes. *Psychology of learning and motivation*, *2,* 89-195.

Auer, P., & Wei, L. (Eds.). (2007). *Handbook of multilingualism and multilingual communication* (Vol. 5).

Baddeley, A. D. (1993). *Working memory or working attention?* Clarendon Press/Oxford University Press.

Baddeley, A., Gathercole, S., & Papagno, C. (1998). The phonological loop as a language learning

Baddeley, A. D., & Hitch, G. (1974). Working memory. *Psychology of learning and motivation*, *8*, 47 89.

Bench, C. D., Frith, C. D., Grasby, P. M., Friston, K. J., Paulesu, E., Frackowiak, R. S. J. & Dolan, R. J. (1991). Investigations of the functional anatomy of attention using the Stroop task.

Bialystok, E., Craik, F. I., Klein, R., & Viswanathan, M. (2004). Bilingualism, aging, and cognitive control: evidence from the Simon task. *Psychology and aging*, *19*(2), 290.

Bialystok, E., & Martin, M. M. (2004). Attention and inhibition in bilingual children: Evidence from the dimensional change card sort task. *Developmental science*, *7*(3), 325-339.

Blom, E., Küntay, A. C., Messer, M., Verhagen, J., & Leseman, P. (2014). The benefits of being bilingual: Working memory in bilingual Turkish–Dutch children. *Journal of experimental child psychology*, *128*, 105-119.

Blumenfeld, H. K., & Marian, V. (2011). Bilingualism influences inhibitory control in auditory comprehension. *Cognition*, *118*(2), 245-257.

Broca, P. (1861). Sur le principe des localisations cérébrales. *Bulletin de la Société d" Anthropologie*, *2*, 190-204.

Buckner, R. L. (2004). Memory and executive function in aging and AD: multiple factors that cause decline and reserve factors that compensate. *Neuron*, *44*(1), 195-208.

Caplan, D., & Waters, G. S. (1995). Aphasic disorders of syntactic comprehension and working memory capacity. *Cognitive neuropsychology*, *12*(6), 637-649.

Carpenter, P. A., Miyake, A., & Just, M. A. (1995). Language comprehension: Sentence and discourse processing. *Annual review of psychology*, *46*(1), 91 120.

Cenoz, J., & Genesee, F. (1998). Psycholinguistic perspectives on multilingualismand multilingual education. *MULTILINGUAL MATTERS*, 16-34.

Chomsky, N. (1956). Three models for the description of language. *Transactions on information theory*, *2*(3), 113-124.

Chomsky, N. (1965). Aspects of the Theory of Syntax. MIT Press, Cambridge, Mass, 1965.

Colzato, L. S., Bajo, M. T., van den Wildenberg, W., Paolieri, D., Nieuwenhuis, S., La Heij, W., & Hommel, B. (2008). How does bilingualism improve executive control? A comparison of active and reactive inhibition mechanisms. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *34*(2), 302.

Cook, V. J. (1992). Evidence for multicompetence. *Language learning*, *42*(4), 557 591.

Costa, A., Hernández, M., & Sebastián-Gallés, N. (2008). Bilingualism aids conflict resolution: Evidence from the ANT task. *Cognition*, *106*(1), 59-86.

Daneman, M., & Merikle, P. M. (1996). Working memory and language comprehension: A meta-analysis.

Engel de Abreu, P. M. (2011). Working memory in multilingual children: Is there a bilingual effect? *Memory*, *19*(5), 529-537.

Franceschini, R. (2009). The genesis and development of research in multilingualism. *Aronin/B.*

Hufeisen (red.), The Exploration of Multilingualism: Development of research on L, *3*, 27-60.

Fuster, J. M. (2001). The prefrontal cortex—an update: time is of the essence. *Neuron*, *30*(2), 319-333.

Genesee, F, Paradis, J., & Crago, M. B. (2004). *Dual language development & disorders: A handbook on bilingualism & second language learning, Vol. 11*. Paul H Brookes Publishing.

Goldstein, K. (1944). The mental changes due to frontal lobe damage. *The Journal of Psychology*, *17*(2), 187-208.

Golestani, N., Alario, F. X., Meriaux, S., Le Bihan, D., Dehaene, S., & Pallier, C. (2006). Syntax production in bilinguals. *Neuropsychologia*, *44*(7), 1029-1040.

Grant, D. A., & Berg, E. (1948). A behavioral analysis of degree of reinforcement and ease of shifting to new responses in a Weigl-type card-sorting problem. *Journal of experimental psychology*, *38*(4), 404.

Herdina, P., & Jessner, U. (2002). *A dynamic model of multilingualism: Perspectives of change in psycholinguistics* (Vol. 121). Multilingual Matters.

Jager, G., Kahn, R. S., Van Den Brink, W., Van Ree, J. M., & Ramsey, N. F. (2006). Long-term effects of frequent cannabis use on working memory and attention: an fMRI study. *Psychopharmacology*, *185*(3), 358-368.

Jankowsky, J. L., Melnikova, T., Fadale, D. J., Xu, G. M., Slunt, H. H., Gonzales, V., ... & Savonenko, A. V. (2005). Environmental enrichment mitigates cognitive deficits in a mouse model of Alzheimer's disease. *Journal of Neuroscience, 25*(21), 5217-5224.

Just, M. A., & Carpenter, P. A. (1992). A capacity theory of comprehension: individual differences in working memory. *Psychological review*, *99*(1), 122.

Just, M. A., Carpenter, P. A., Keller, T. A., Eddy, W. F., & Thulborn, K. R. (1996). Brain activation modulated by sentence comprehension. *Science*, *274*(5284), 114.

Kavé, G., Eyal, N., Shorek, A., & Cohen-Mansfield, J. (2008). Multilingualism and cognitive state in the oldest old. *Psychology and aging*, *23*(1), 70.

Kempel P, Lampe K, Parnefjord R, Hennig J, Kunert HJ. Auditory-evoked potentials and selective attention: different ways of information processing in cannabis users and controls.

Levy, R., & Goldman-Rakic, P. S. (2000). Segregation of working memory functions within the dorsolateral prefrontal cortex. In *Executive control and the frontal lobe: Current issues* (pp. 23-32).

Linck, J. A., Schwieter, J. W., & Sunderman, G. (2012). Inhibitory control predicts language switching performance in trilingual speech production. *Bilingualism: Language and Cognition*, *15*(03), 651-662.

MacDonald, M. C., Just, M. A., & Carpenter, P. A. (1992). Working memory constraints on the processing of syntactic ambiguity. *Cognitive psychology*, *24*(1), 56-98.

Masoura, E. V., & Gathercole, S. E. (1999). Phonological short-term memory and foreign language learning.

Milner, B. (1963). Effects of different brain lesions on card sorting: The role of the frontal lobes. *Archives of neurology*, *9*(1), 90-100.

Miyake, A., Carpenter, P. A., & Just, M. A. (1995). Reduced resources and specific impairments in normal and aphasic sentence comprehension. *Cognitive neuropsychology*, *12*(6), 651-679.

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex “frontal lobe” tasks: A latent variable analysis. *Cognitive psychology*, *41*(1), 49-100.

Moll, J., Oliveira-Souza, R. D., Moll, F. T., Bramati, I. E., & Andreiuolo, P. A. (2002). The cerebral correlates of set-shifting: an fMRI study of the trail making test. *Arquivos de neuro-psiquiatria*, *60*(4), 900-905.

Nyberg, L., Sandblom, J., Jones, S., Neely, A. S., Petersson, K. M., Ingvar, M., & Bäckman, L. (2003). Neural correlates of training-related memory improvement in adulthood and aging. *Proceedings of the National Academy of Sciences*, *100*(23), 13728-13733.

Paulesu, E., Frith, C. D., & Frackowiak, R. S. (1993). The neural correlates of the verbal component of working memory. *Nature*, *362*(6418), 342.

Perfetti, C. A., & Goldman, S. R. (1976). Discourse memory and reading comprehension skill. *Journal of Verbal Learning and Verbal Behavior*, *15*(1), 33-42.

Perquin, M., Vaillant, M., Schuller, A. M., Pastore, J., Dartigues, J. F., Lair, M. L., ... & MemoVie Group. (2013). Lifelong exposure to multilingualism: new evidence to support cognitive reserve hypothesis. *PloS one*, *8*(4), e62030.

Scarmeas, N., Zarahn, E., Anderson, K. E., Hilton, J., Flynn, J., Van Heertum, R. L., ... & Stern, Y. (2003). Cognitive reserve modulates functional brain responses during memory tasks: a PET study in healthy young and elderly subjects. *Neuroimage*, *19*(3), 1215-1227.

Service, E., Simola, M., Metsänheimo, O., & Maury, S. (2002). Bilingual working memory span is affected by language skill. *European Journal of Cognitive Psychology*, *14*(3), 383-408.

Stern, Y. (2012). Cognitive reserve in ageing and Alzheimer's disease. *The Lancet Neurology*, *11*(11), 1006-1012.

Stern, Y. (2002). What is cognitive reserve? Theory and research application of the reserve concept. *Journal of the International Neuropsychological Society*, *8*(03), 448-460.

Stowe, L. A., Wijers, A. A., Willemsen, A., Reuland, E., Paans, A. M., & Vaalburg, W. (1994). PET studies of language: An assessment of the reliability of the technique. *Journal of Psycholinguistic Research*, *23*(6), 499-527.

Stromswold, K., Caplan, D., Alpert, N., & Rauch, S. (1996). Localization of syntactic comprehension by positron emission tomography. *Brain and language*, *52*(3), 452-473.

Stroop, J. R. (1935). Studies of interference in serial verbal reactions. *Journal of experimental psychology*, *18*(6), 643.

Tucker, A.M., & Stern, Y. (2011). Cognitive reserve in aging. *Current Alzheimer Research*, *8*(4), 354-360.

Turner, M. L., & Engle, R. W. (1989). Is working memory capacity task dependent? *Journal of memory and language*, *28*(2), 127-154.

Van Merrienboer, J. J., & Sweller, J. (2005). Cognitive load theory and complex learning: Recent developments and future directions. *Educational psychology review*, *17*(2), 147-177.

Vingerhoets, G., Van Borsel, J., Tesink, C., van den Noort, M., Deblaere, K., Seurinck, R., ... & Achten, E. (2003). Multilingualism: an fMRI study. *NeuroImage*, *20*(4), 2181-2196.

Waters, G. S., & Caplan, D. (1996). The capacity theory of sentence comprehension: Critique of Just and Carpenter (1992).

Werker, J. F. (1986). The effect of multilingualism on phonetic perceptual flexibility. *Applied Psycholinguistics*, *7*(02), 141-155.

Willcutt, E. G., Doyle, A. E., Nigg, J. T., Faraone, S. V., & Pennington, B. F. (2005). Validity of the executive function theory of attention-deficit/hyperactivity disorder: a meta-analytic review. *Biological psychiatry*, *57*(11), 1336-1346.

Appendices:

Appendix A

Consent Form and Information Letter

Title: Multilingualism and Executive Function: Evidence from Assessments of Working Memory, Selective Attention and Cognitive Flexibility.

INVITATION

You are being asked to take part in a study which is researching the executive functions of those who are monolingual, bilingual, and multilingual speakers. These functions give us the ability to plan, focus our attention, remember instructions and complete various tasks at the same time. The study will be assessing working memory capacity and selective attention. This is a part of your short term memory which aids in maintaining concentration.

My name is Molly Forde-Bates and I am an undergraduate student in my final year of studying Psychology in the National College of Ireland. I am interested in the cognitive capabilities (brain functions) of people who are multilingual (people who can speak several languages). I want to better understand if being able to speak several languages will have an effect on and possibly increase a person's day-to-day mental flexibility.

The aim of the proposed study is to assess and compare the cognitive capabilities of people can speak one, two or over two languages. This study will in no way be indicative of levels of intelligence. The tests will simply assess your ability to pay attention to a task for a specific amount of time and an aspect of your short term memory.

If you wish to participate one must be fluent/proficient in the spoken language(s) or have attained a B2 in the Common European Framework of Reference for Languages (CEFR). One must also be able to read English fluently.

This research will be supervised by the National College of Ireland. This project has been approved by the Psychology Ethics Committee in the National College of Ireland.

WHAT WILL HAPPEN

On the day, you will be asked to complete a series of cognitive assessments. You will be required to visit the National College of Ireland. You will receive a personal identification number and enter a class room and complete three pen to paper tests. There will be other individuals in the class room completing this task at the same time as you. The first test requires you to copy a complex figure and redraw it from memory. The second test requires you to draw lines to connect encircled numbers and letters. The third test requires you read aloud words from a page. The researcher will apply each assessment individually at an assigned desk, person to person.

There will be snacks provided. Return your completed assessments to the researcher. On completion of your participation your name will be entered into a draw to win a meal for two people .

TIME COMMITMENT

The study typically takes approximately 35 minutes.

PARTICIPANTS' RIGHTS

You may decide to stop being a part of the research study at any time without explanation. You have the right to ask that any data you have supplied to that point be withdrawn/destroyed.

You have the right to omit or refuse to answer or respond to any question that is asked of you.

You have the right to have your questions about the procedures answered (unless answering these questions would interfere with the study's outcome). If you have any questions as a result of reading this information sheet, you should ask the researcher before the study begins.

BENEFITS AND RISKS

Participation in this study involves completion of some standardised tests which are routinely used as preliminary screens for clinical conditions involving cognitive impairment, i.e. brain damage of which you may not be aware. Scores from these tests **would not be sufficient basis for clinical decisions or diagnosis** and **are not used for diagnostic purposes in this study**.

As you will not receive any individual results or scores there are no known risks or benefits to participation in this study.

CONFIDENTIALITY/ANONYMITY

The data we collect do not contain any personal information about you except your age, gender and how many languages you can speak. No one will link the data you provided to the identifying information you supplied. The researchers will maintain responsibility for obtaining the data and the disposal of the data. Your data will not be viewed by any third parties.

FOR FURTHER INFORMATION

I can answer any questions about this study if you email Molly at x14571483@student.ncirl.ie. Alternatively my supervisor Dr. Joanna Power will be glad to answer your questions about this study at any time. You may contact her at joanna.power@nci.irl

If you want to find out about the final results of this study, you should visit

www.nationalcollegeofireland.ie or email x14571483@student.ncirl.ie

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INFORMED CONSENT FORM

Title: Multilingualism and Executive Function: Evidence from Assessments of Working Memory, Selective Attention and Cognitive Flexibility.

This study will assess the cognitive capabilities of monolingual, bilingual and multilingual speakers. The series of cognitive assessments will examine executive functions, specifically working memory capacity and selective attention and overall cognitive flexibility. These results will hope to add to current research attempting to explain the complex relationship between multilingualism and higher cognitive function.

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

N/A

____

Participant's Name (Printed)*

INITIALS

____

____

Participant's signature* Date

Molly Forde-Bates

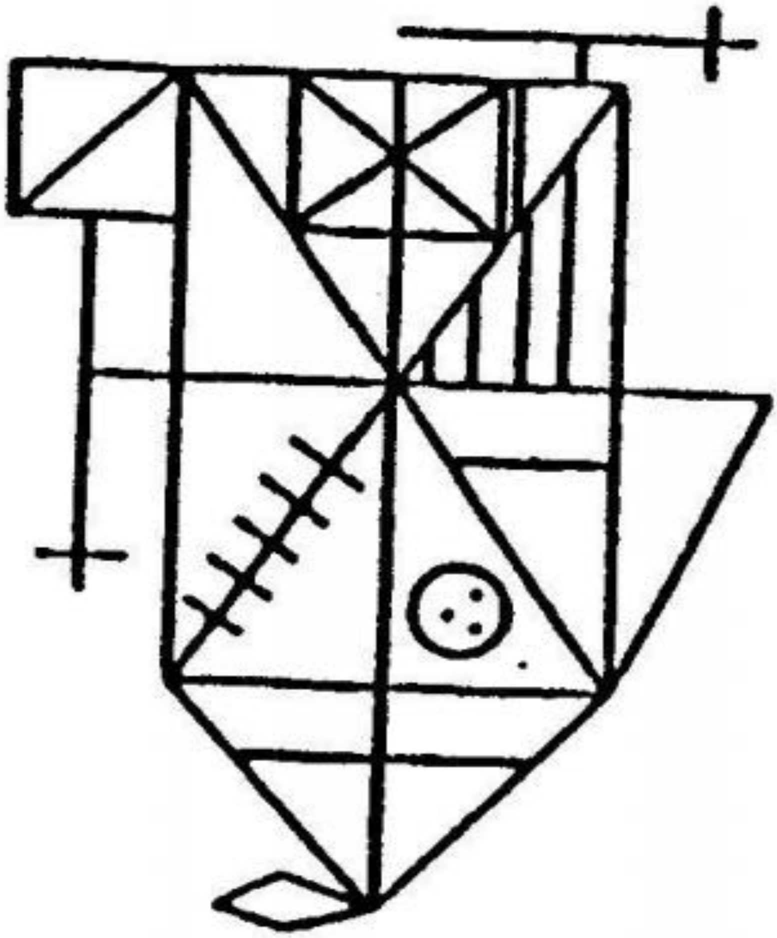
____

____

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

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

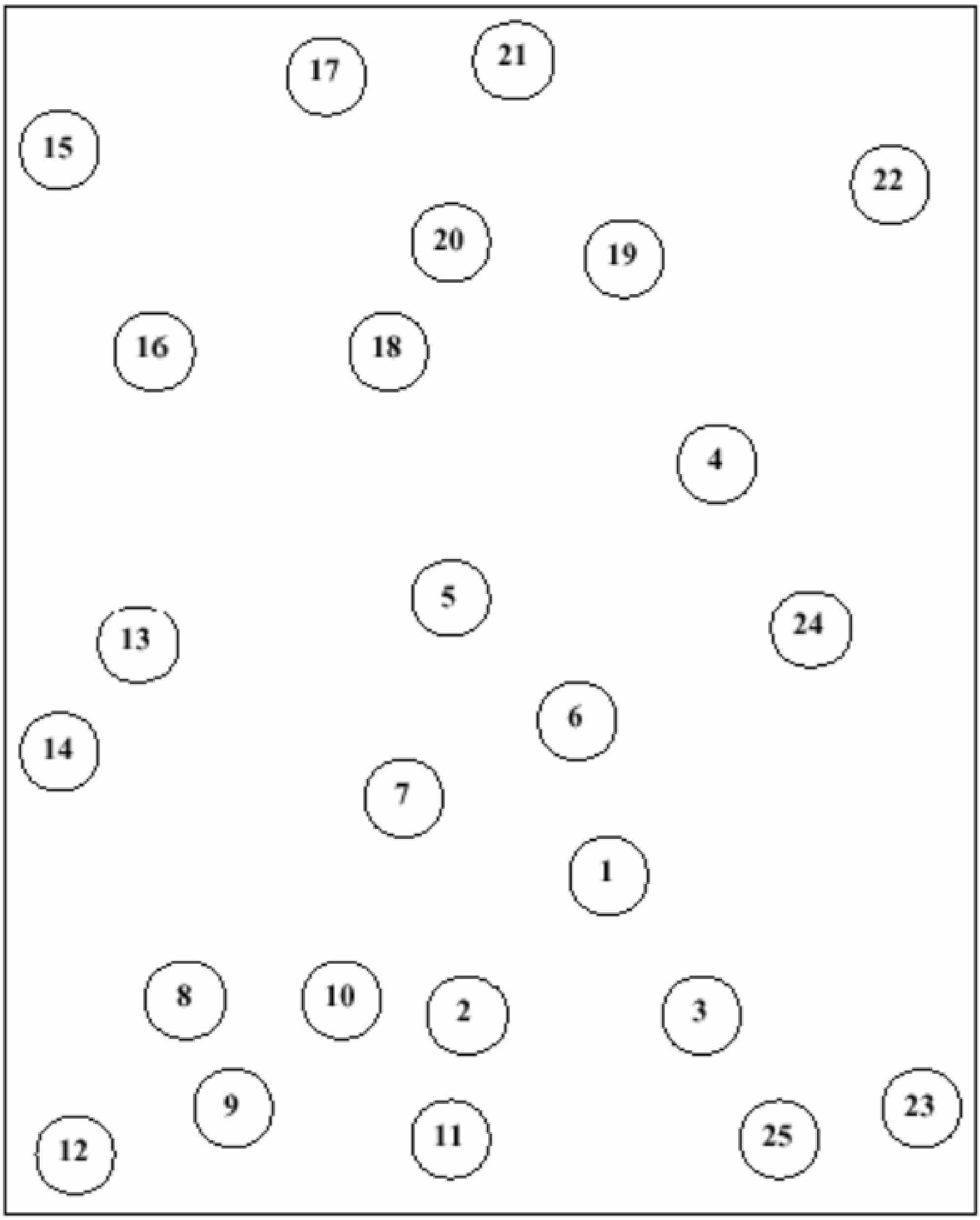
Appendix B



Appendix C

Trail Making Test Part A

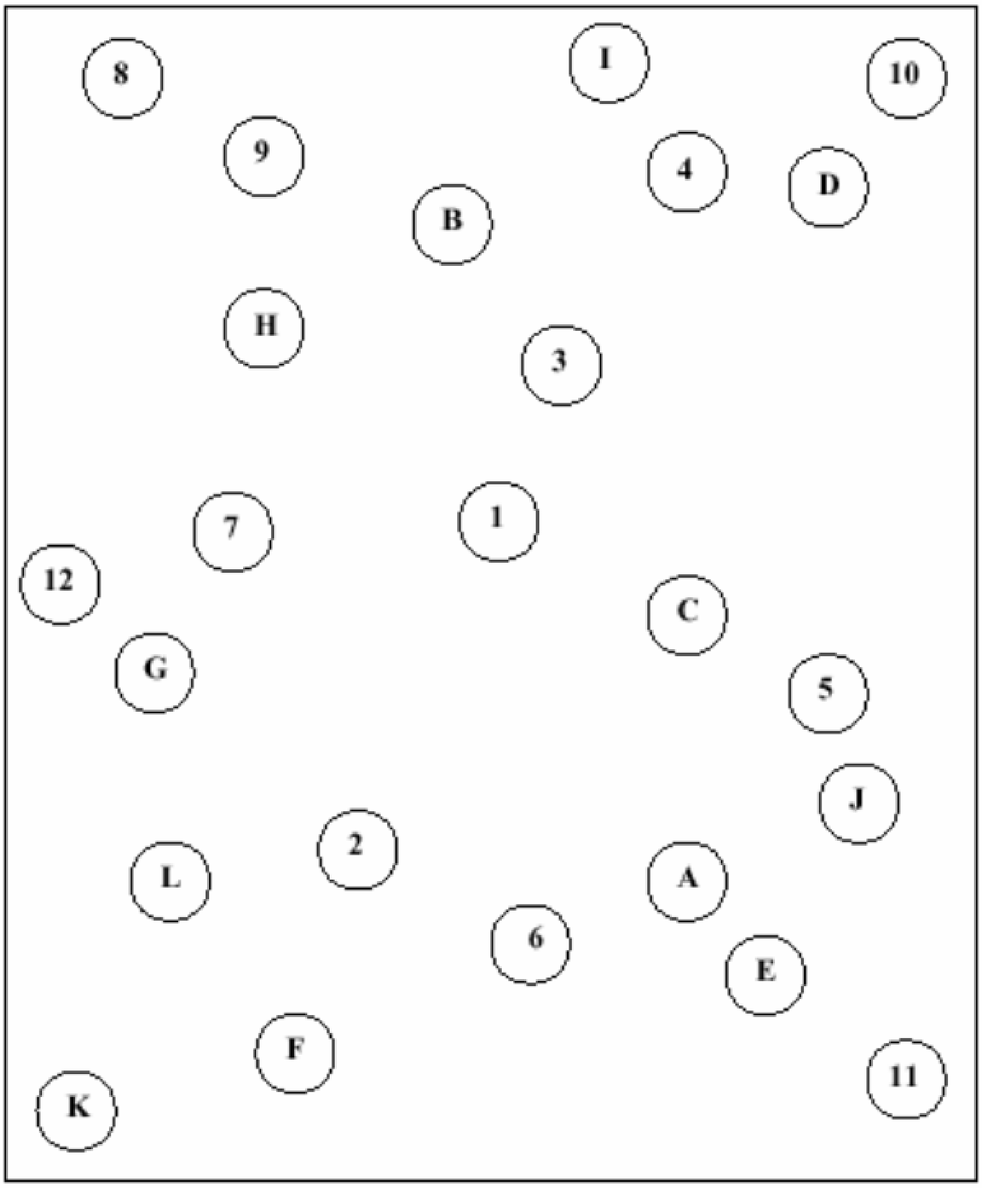
Patient's Name: ______________________________ Date: ____________________



Appendix D

Trail Making Test Part B

Patient's Name: ______________________ Date: ______________



Appendix E

Stroop Task

GREEN	WHITE	PURPLE
BLUE	RED	GREEN
PINK	ORANGE	BLUE
PURPLE	YELLOW	GREY
RED	GREEN	ORANGE
BLACK	BLUE	RED
WHITE	YELLOW	PINK

Congruent Condition Test 1.

Appendix F

Stroop Task

GREEN	WHITE	PURPLE
BLUE	RED	GREEN
PINK	ORANGE	BLUE
PURPLE	YELLOW	GREY
RED	GREEN	ORANGE
BLACK	BLUE	RED
WHITE	YELLOW	PINK

Incongurent Condition Test 2.