

**Exploring the difference in the brains executive control between monolingual and bilingual Adolescents.**

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## *Abstract*

The aim of this study is to investigate the link between executive control and the number of languages an individual speaks. The study utilised a between subjects, correlational quasi experimental design. The independent variable is number of languages spoken and the dependent variable is the participants score on the Stroop task. A total of (n = 30) participants took part in the study with the age ranging between 13 to 19 years. Demographic details were also reviewed in relation to gender, age, and the number of languages the participant spoke daily. The executive control was measured on using a Victoria Stroop Task.

Results indicated a positive significant relationship between scores on the congruent and incongruent sub-trials of the Stroop task and the number of Languages a Person Spoke. ( $P = .017$ ), ( $P=.036$ ). There was a significant difference between the bilingual and monolingual group on the number of incongruent errors obtained by the participants ( $P=.027$ ). There was a significant main effect of the Stroop task obtained ( $P=.003$ ).

# **Introduction**

## ***Chapter 1: Introduction***

Language has been coined the “Jewel in the crown of cognition” (Pinker, 2000, P. 274). Language is so fundamental in the understanding of cognition as a whole, It is deemed as the “Human essence” (Chomsky, 1972). Due to humans being social creatures it is almost impossible to survive without language as it is such a core component of the human social lifestyle. Language is the primary distinguisher between humans and animals, due to findings which suggest that humans are the only species to have such an intricate way of communicating. In relation to this there is an increase in individuals who speak more than one language, there has also been an increase in bilingual environments around the world because of this. (Toppelberg et al, 1999). The increasing “global” nature in the world through the increase of multi-cultural companies, over sea recruitment, and the increase in travel for both recreational and business purposes have all led to the increase in the number of people learning to speak a second language. In saying this it is important to examine language proficiency as a whole, to examine those individuals who are bilingual, who speak two languages and how they switch between them.

Research into bilingual speakers is a relatively new area of cognitive research that emerged in the early 1900s. The first scientific study of bilinguals was carried out in 1913 by Jules Ronjat. “Today more of the world’s population is bilingual and multilingual than monolingual” (Marian et al, 2012). Due to the vast increase in immigration more and more of the current population speaks two or more languages, thus there has been a significant rise

in this area of cognitive research. The most common area of bilingual research is the link between bilingualism and executive functioning.

Defining who is bilingual is not an easy task. Language proficiency can best be defined as the ability to utilise both languages in a situation that is defined by the specific cognitive and linguistic demands, to a level of performance indicated by normative standard. (Bialystok, 2001, Pg.18). Grosjean in (1989, 1998) argued the statement that a bilingual is not just two monolinguals in one person and he proposed that a bilingual is someone who can function with each language according to their given needs.

### *Cognitive functions of bilingual processes*

Professor J. Cummins, a leading researcher in the field of bilingual cognition devised a theory to help better understand the underlying cognitive functions that bilinguals possess. Professor Cummins (1994) starts by dividing language proficiency into two parts the first part is known as Basic Interpersonal Communication Skills (BICS) and the second; Cognitive Academic Language Proficiency (CAPS). BICS is commonly known as surface skills such as basic listening and speaking which are typically acquired by individuals. CAPS is the more intricate part of the two and this is used as a basis for an individual's ability to cope with the academic demands which are placed upon them (Cummins, 1994). While many individuals develop native speaker fluency, also known as BICS within two years of immersion in the target language it usually takes the individual a further five to seven years to be at a working level with native speakers of the particular language in question. Cummins (1994) argues that when a person learns one language they acquire a particular set of skills and metalinguistic knowledge that can be used when working with or learning a new language. His theory also serves as an explanation as to why it becomes easier to learn additional languages later in life.

Cummins proceeds to draw a distinction between additive bilingualism and subtractive bilingualism. Additive bilingualism is where an individual acquires a new language but their first language and culture is not devalued in the process. They put as much value on the language they are beginning to acquire as they do their primary language and culture. Subtractive bilingualism is essentially the opposite of additive bilingualism; it is in the case where an individual learns a second language at the expense of their first language. The first language and culture becomes diminished as a consequence. (Cummins,1994). Cummins summarises these findings and proceeds to state that individuals working in an additive environment succeed to a greater degree than those individuals whose first language is devalued by their new values and the wider society they have become a part of. Speaking more than one language has many advantages to an individual. Apart from the apparent advantage of having the opportunity to communicate and express ones emotions in more than one language there are less obvious benefits of speaking more than one language. These include cognitive advantages. As numerous studies in the past have shown, bilinguals outperform their monolingual counterparts in various cognitive tests, problems solving tests, perceptual disembedding problems and SIMON task. (Bialystok, Craik,Klein, & Viswanathan, 2004) and (Cummins,1984).

### *Storing and processing language*

There are several areas in the brain that store and process language. The main area used by individuals is known as the executive control system. The executive control system is well known to be involved in situations where selection or conflict resolution is required. (Bialystok et al, 2011). A meta-analysis by (Abutalebi & Green, 2007) shows that there are six significant regions in the brain that are considered to be part of the executive control system. These include the left inferior frontal gyrus pars triangularis, left middle temporal gyrus, midline pre supplementary motor area, left inferior frontal gyrus pars orbitalis,bilateral

caudate nuclei, and right precentral gyrus. At least four of these regions are active at any one time the executive control system is being used.

Common results in executive control studies show that there is an overall advantage for bilingual participants in performing these tasks but it is not possible to attribute the success of the performance to a single component of the executive control system. (Bialystok et al, 2011). Bilinguals outperformed their monolingual counterparts in the conditions in which more effortful and controlled attention was required, particularly in their response to visual stimuli.

Abutalebi & Green in 2007 stated that an extraordinary feature of bilingualism is the ability to fluently switch between languages when conversing in different contexts. From an onlookers perspective bilinguals do so without any difficulty. An on-going topic in cognitive psychology today is the bilingual's ability to select the preferred language at the right time without any interference from the non-target language. However there has been an agreement, due to experimental evidence, to show that bilingual language control is achieved by a partial reliance on the "domain-general mechanisms of executive control".

In most cases to be a bilingual is not a choice. They are not selected due to a pre-existing talent or an interest in the particular language; they become bilingual due to the circumstances in their lives. To be bilingual is intense, it is sustained over a long period of time and it is demanding. (Toppelberg et al, 1999) Language switching is a normal part of the bilingual experience thus making the executive control system a crucial feature of language proficiency in bilinguals. (Bialystok et al, 2011). Executive functioning has a long developmental timetable but studies by Kopp and college (1982) showed that children make huge gains in self-control throughout school. There is more understanding to be gained on the effects of bilingual experience on individuals executive functioning. (Carlson et al, 2008).

Given that executive function is a critical component of cognitive development, research into bilingualism has implications on the understanding of the development of executive function as well as issues such as respect to second-language instruction in the home and society (Carlson et al, 2008). The further development of control processes such as executive control help to manage the increase in representational complexity. Both languages of a bilingual speaker are constantly active, even in strongly monolingual contexts where there is no reason to expect the use of the other language (Bialystok et al, 2011).

### *Executive control system*

The structure of the executive control system in itself is controversial. A common interpretation is that the executive control system is a domain general system that consists of three core components; inhibition, updating also known as working memory and shifting (Miyake et al, 2000). It is difficult to confirm empirically the true function of the executive control system because tasks involve multiple core components of the system and performance across domains is generally correlated within individuals taking part in the particular tests. This involves the recruitment of the entire executive control network and not just one aspect of it therefore it is difficult to determine what area of the executive control system is utilised for the different aspects of language cognition. The importance of studying the relationship between bilingualism and executive control is to potentially disentangle some of the factors such as what area of the executive control system is responsible for what effect and this will give rise to a clearer understanding of the structure of the executive control system.

### *Stroop Effect*

The classic Stroop Task (Stroop, 1935) is one of the most cited examples for the use of automaticity and uncontrollability of word reading. In 1935 Stroop published this famous

article in the journal of experimental psychology but before Stroop there were other findings similar to that of the Stroop effect pioneered by James Mc Keen Cattell (1886).

There are many variables of the Stroop procedure, serial-colour-word test was the original one implemented by Stroop himself. In this Stroop procedure participants were only tested on the naming of colours of the incompatible words and of control patches. Interference was calculated in the 2 time totals of these cards, this can be viewed by total time per card divided by the number of stimulants. A number of control conditions such as word only and colour only conditions are included as well as the colour word interference conditions. The variable of interest in this case is the Stroop Effect itself. This is calculated as the additional time taken for participants to name the ink colour when the colour name conflicts with the colour it is written in compared to when the word and ink colour match. The Victoria Stroop task contains 3 sub-tasks the first is a practice trial where participants are asked to name the colour of the dots using the keypad. The second sub-trial is the congruent trial where participants are asked to name the colour the words are written in using the keypad, due to this being a congruent trial the colour name will match the ink colour in which it is written in. The last trial is an incongruent trial, in this sub-trial participants are asked to name the ink colour again and refrain from saying the colour name using the keypad. Due to this being an incongruent trial, the name of the colour will not match the ink that it is written in. The ink colour naming is faster when the two dimensions of the stimulus are congruent for example the word Green written in Green ink, then when they are incongruent for example the word Green written in Red ink. (Stroop, 1935). Word reading is instigated without intention and in spite of the subject's attempts to not say the word. In the Stroop paradigm control means to have the ability to inhibit the irrelevant reading processes that happen habitually. The Stroop Task is a very reliable way of measuring the structure of the bilingual representation and cognition. The Stroop Effect employs evidence to suggest that controlled processing reflects

the operation of the conscious and furthermore Carr and colleagues in 1979 emphasised the role of consciousness in the development of new behaviours.

### *Stroop and Gender*

A Study by Insua et al in 2002 showed that there was no difference on performance on the Stroop Task between males and females. This is important to note because, although there is a change between monolinguals and bilinguals this change is not seen across genders.

### *Stroop and Bilinguals*

Dalrymple-Alford (1968) was the first study done that focused on the Stroop task in relation to the bilingual population, this study wanted to test whether there was a Stroop effect if the 2 different languages of the bilingual were used. Dalrymple-Alford wanted to test whether Stroop interference was present and would the Stroop effect be seen if the colour name was in a different language. However this study was not a clear indication of this because Dalrymple-Alford used the same language for the incongruent trial and 2 languages in the congruent trial. This therefore does not permit a clear understanding of the Stroop effect within and between languages.

Preston and Lambert (1969) took this concept of Stroop and Language to different dimension, they measured English-Hungarian bilinguals using the 2 language task and found that there was a 68% interference rate when ink colour was to be named in the same language as the distracting words appeared then when they were named in the other language of the bilingual. The same was found with English-French bilinguals, in this study there was a 95% interference between languages and the Stroop effect. Lambert concluded that the interference caused between languages could be as great as that within languages but it all depends on the individual's familiarity with the language in question.

Dykers and colleagues in 1971 found that there was maximal interference when the naming language and the distracting language coincided. This same interference occurred when the languages did not coincide. English monolinguals had maximum interference when they were naming the words of colour names in English and the interference decreased as the similarity of the words to the English language decreased. Fang et al (1981) confirmed this finding that the ratio of between languages to within language interference declines as the similarity of the language decreases. Interference between the 2 languages of the bilingual is very robust although not as robust as that within the languages themselves. MacLeod 1991 stated that a dominant language has more potential for interfering than does a non-dominant one. Therefore it is interesting to study the impact having 2 languages makes on the individual when compared with their monolingual peers on the same Stroop task.

A possible explanation for the success of the bilingual's performance on the Stroop Task could be due to the executive control circuits needed to manage attention in the languages the individual speaks, they become integrated with other linguistic circuits used for language processing and language proficiency. This in turn develops into a more efficient network that promotes high performance levels. (Bialystok et al,2011). This concept was suggested by Hebb in 1949 when he stated that "Cells that fire together, wire together".

Monolinguals required significantly more time than bilinguals to resolve the conflict conditions such as the name of the colour with the competing ink of the colour than did their bilingual peers. (Bialystok et al, 2011). This was effective across all age groups. "What is clear is the evidence in controlled studies of cognitive performance across the lifespan that bilinguals constantly outperform their monolingual counterparts". The research with bilinguals provides evidence as to the plasticity of cognitive systems and its changing nature across the lifespan.

In 2002 Insua et al stated that there were a limited number of studies addressing performance of bilingual individuals on standardised neuropsychological instruments. However with the emergence of new studies in recent years this is not the case anymore. Ellen Bialystok and her colleagues in York University have pioneered modern bilingual research using up to date cognitive experiments and tasks.

### *Stroop effect and Age*

Brian & Goodenough, 1929 and Ligon 1932 thought that age in relation to colour and word form processing was of interest to science before the Stroop task was ever created. Cramer in 1967 supported Ligon's statement that form processing dominates over colour processing, however it was found by Arochova in 1971 that pre-schoolers show the opposite preference having not yet recognised letter forms very well. In the 1960's there was huge interest with regard to Stroop and the developmental life span. Comalli, Wapner & Werner in 1962 studied the Stroop task and its relation to the developmental cycle. They observed individuals from the age of 7 up to the age of 80. They found that interference was greatest in children; it decreased in adulthood and increased again in advanced adulthood. Rand et al in 1963 with their findings came to the same conclusion that interference is greatest before adolescence and again in advanced adulthood.

Schiller 1966 tested the age range of 5-9 and came to the same conclusion as did Comalli et al in 1962. They both believed that this is where interference becomes maximal and declines thereafter, increasing again in late adulthood. Comalli believed that the early onset and then fall of interference rates was down to the development of reading skills. The decrease in interference rates through adulthood and before the age of 60 has been confirmed by Wise, Sutton & Gibbons in 1975. Comalli summarised development in relation to the Stroop task as the emergence of interference in the early school years, rising to its highest between the ages

of 7-9 and until reading skills develop fully. With the continued development of reading skills interference declines through the years of adulthood until approximately the age of 60 at which point interference begins to increase again. Comalli concluded that everyone who can read shows a robust Stroop effect.

There are minimal studies done to demonstrate the Stroop Effect on individuals in the adolescent age group therefore this age group will be used in the current study due to lack of emphasis placed on this sample in previous studies. This age group consists of individuals ages 13-19 due to the changes taking place at this time. These changes include the development in the ability to think abstractly and to reason more effectively. There is also an increase in the level of general knowledge held by the individuals. Developmental studies show that the effect increases and decreases throughout the course of the lifespan, thus as reading ability increases so does performance on the Stroop Test. (Schiller, 1966). Therefore it will be interesting to analyse the results of the current study using the adolescent age group.

The research aim of the current study is to demonstrate that monolingual and bilingual individuals perform the Stroop Task with different levels of success depending on the number of languages they speak. This can be measured through the use of executive control tasks such as the Stroop Task developed by J. Ridley Stroop in 1935. However none of the current studies have placed emphasis on an Irish bilingual population and compared them to their monolingual counterparts. The Stroop task is a valid and reliable measure of executive control functioning and therefore will be used as the measure of executive control in the current study. The participants will be split into groups depending on the number of languages they speak on a daily basis. The reason for this is because there are very few studies done in Ireland to measure differences such as executive control on individuals who speak 2 languages and studies like the current one are vital for the understanding of how bilingual individuals learn and develop throughout the lifespan. If there are more studies like such conducted in Ireland this would be hugely beneficial to the education system in this country as they could gain a much better understanding of what it means to be bilingual and how this impacts on students learning of other languages and indeed on learning other subjects as well.

The second reason this study was conducted was due to the lack of general studies on the adolescent age group. This is a crucial age in the developmental lifespan and there needs to be more studies in place to gain knowledge of how to best educate those students who are currently of that age so that they could learn more efficiently. By better understanding how some of the key mechanisms of learning function at this time in the lifespan this could benefit the age group so that they could have a more enjoyable experience whilst at school and in turn learn more material in a more efficient and concise manner due to the research that is found and implemented in this country.

The two hypotheses implemented by the current study are as follows;

**Hypothesis 1:** It is Hypothesised that there will be a difference in the brain's executive control between monolingual and bilingual adolescents using a Stroop Task.

**Hypothesis 2:** It is Hypothesised that there will be a difference between age groups and the number of errors they obtain in the incongruent sub-trial of the Stroop task.

*Note*, the first null hypothesis is understood that there will be no difference between executive control and the number of languages a person speaks.

The second null hypothesis is that there will be no difference between age groups and the number of errors made in the incongruent trials.

# **Methodology**

## ***Chapter 2: Methodology***

### ***Participants***

The study was based on data collected from 30 adolescent individuals attending Irish secondary schools, (14 male and 16 female) ranging in age from 13-19 (M 17.13, SD 1.07) were randomly selected and volunteered to take part in this experiment. Fifteen participants were bilingual (8 Male and 7 Female) and 15 monolingual (6 Male and 9 Female). Informed consent was obtained from all participants and no reward was issued for their participation.

Snowball sampling was used to recruit the participants. Participants belong to one of two groups; they were randomly assigned to groups based on the number of languages they spoke. Participants who spoke two or more languages were allocated to the bilingual group while participants who only spoke one language were allocated to the monolingual group. The study was restricted to include only individuals ranging in age from 13-19. The study eliminated those who only those who didn't speak English fluently and on a daily basis.

### ***Design***

The study utilised a between subjects, correlational quasi experimental design. The independent variable is number of languages spoken and the dependent variable is the participants score on the Stroop task. The experimental group are the bilingual participants, those who speak more than one language on a daily basis, specifically those who acquired both languages at the same period of time e.g. childhood. The control group are monolingual participants, those who speak only one language on a daily basis.

Participants were assigned to the groups depending on the number of languages they spoke on a daily basis. The participants who spoke more than one language on a daily basis and

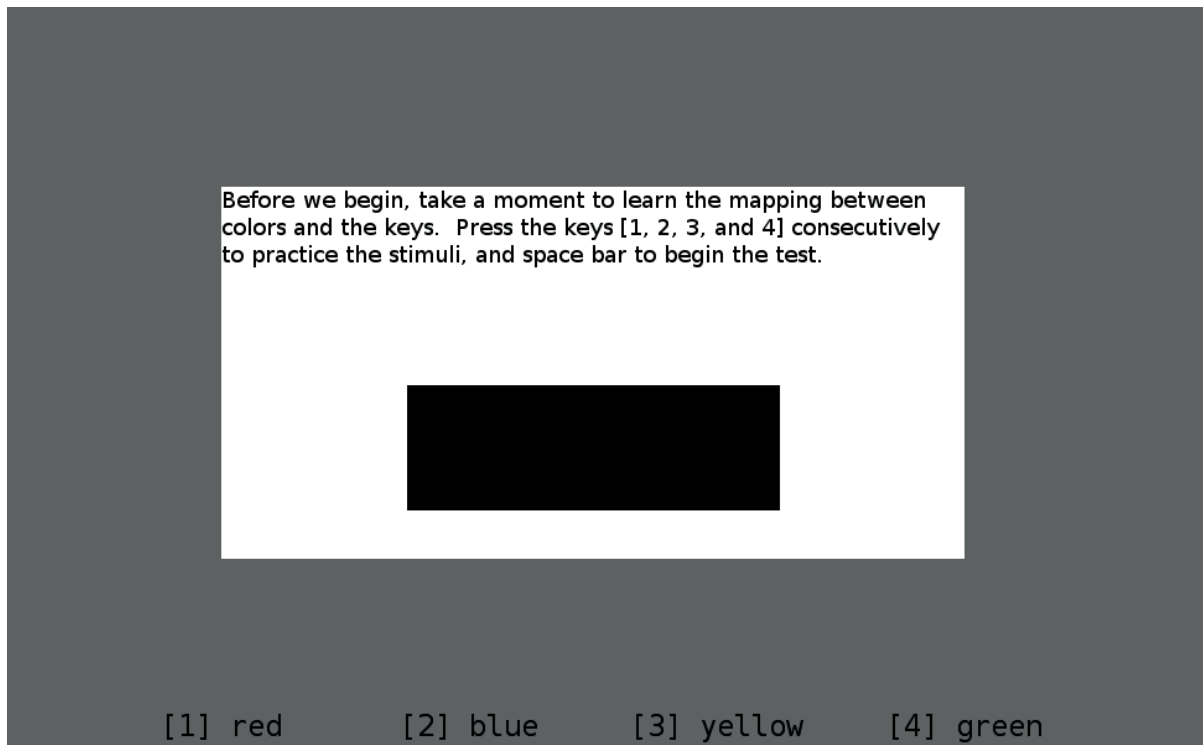
who acquired the languages in question at roughly the same period in time were assigned to the bilingual group. The participants who spoke only one language daily were assigned to the monolingual group.

The between subject variables are the number of languages the participants speak regularly. These were assigned as 1 (one language spoken daily) and 2 (two or more languages spoken daily). The within subject variables is the Stroop Task. From the Stroop Task the score (in milliseconds) on the congruent and incongruent test trials will be taken along with the number of errors in the incongruent task.

### ***Materials/Apparatus***

A Sony Vaio Laptop was used to run the PEBL (Psychology Experiment Building Language) programme. On the PEBL programme, the Victoria Stroop Colour-Word test was used as a measure of executive control. The first measure used was the Victoria Stroop Test that was used to measure executive control among the participants. The second measure was to collect general demographics such as age, gender, number of languages spoken etc. The demographics were collected using paper and pen.

PEBL (The Psychology Experiment Building Language) was used to administer the Victoria Stroop Task. The Stroop task in question had 4 colours; blue, yellow, red and green. The keyboard numbers 1-4 were used to enable the participant to press the corresponding colour. Adhesive bookmarks in the colours blue, yellow, red and green were placed on the keyboard numbers that matched to the colours on the screen in order to make the Stroop task easier for the participants. A picture of the task can be viewed below. The task consisted of 3 sub-trials, the practice sub-trial, the congruent sub-trial and the incongruent sub-trial. The practice sub-trial consisted of 26 dots that ranged in colour from blue, yellow, red and green. The congruent trial which was when the colour of the word matched the colour name consisted of 23 colour words. The incongruent task which was when the colour of the word did not correspond to the colour name also includes 23 colour words.



**The first prompt on the PEBL Victoria Stroop task experiment**

SPSS Version 21.0 statistical software was used to analyse the data collected from the study by means of descriptive statistics and inferential statistics.

### ***Procedure***

In order to obtain a specific sample for this study (13-19) and due to the sample being one where there are participants under the age of 18, statutory declaration was sought and granted first and foremost. After this document was received the letter of permission was created and attached to the demographics form. The letter of permission was only used for those participants who were under the age of 18 (N=18).

Due to this study using snowball sampling as a method of recruiting participants and collecting data the participant count started at only 4 participants. The first 4 participants that were recruited were all scheduled a date and time to do the experiment. Due to the fact that

they were all under the age of 18, permission was sought from parents/guardians before the scheduled date of experimentation. When the participants arrived for the experiment they sat down in a quiet room and began to complete the demographics form which had in the top right hand corner the code letter and number for each participant in order for the experiment to be anonymous, e.g. M1 for monolingual and B1 for bilingual. They were then called one by one into another room for the experiment to commence.

Firstly they sat down on a chair with a desk in front of it. On the desk there was a Sony Vaio Laptop and log book. The participants then got a brief description of the Stroop task. The description included what the Stroop task was, why it is used, what it measures, how long it takes, the difference between the congruent and incongruent trials and lastly they were explained that they have a practice sub trial before they are tested on the congruent and incongruent trials that will not be recorded. After the general information of the Stroop task was given, participants were then showed the 4 numbered key pads on the laptop. The numbers 1-4 were used as the keys they will be pressing throughout the duration of the experiment.

PEBL was then launched and the participant's number was logged in and was made sure it corresponded with the code number on their demographics. The very first part of the experiment prompts the participant to look at the order of the colours on the screen and see do the numbers match the colours of the adhesive tabs on the keypads. For example the colour blue will be achieved by pressing the number 1 on the keypad and the colour red could be achieved by pressing number 2 on the keypad. The order of the colour/number combination changed for every experimental trial so it was important that when the participant began, the colour order on the keypads matched the colour order on the screen. PEBL does not allow participants to move forward in the experiment unless they press the correct key, the errors for the incongruent trials were then recorded and analysed.

Participants then began the practice trial which included 26 coloured dots with no words incorporated into it. The second sub trial was the congruent sub trial where the colour of the ink matched the word, e.g. the colour blue written in blue ink. There were 23 colour/word combinations in this trial the last sub trial was an incongruent sub trial which also consisted of 23 colour/word combinations but in this trial the colour of the ink and the name of the colour did not match e.g. the colour red written in blue ink. When the incongruent trial finished and the PEBL launcher was closed.

Throughout the participants experiment notes were written in a log book. The notes written included anything from the participant asking a question, struggling in a particular sub trial or being faster or slower than average or any other minor detail of the experiment from start to finish. This was done in order to be able to look back and analyse the participant's trial further when running the data analysis.

When the participants finished their experiment, they were thanked and any questions they may have had were answered. Lastly they were asked for any names of friends/family within the age range of 13-19 that they know who could take part in the experiment. This was how the rest of the participants were recruited and snow ball sampling was taking place. The following 24 participants went through the same procedure if they were under 18. The ones who were over 18(N=12) went through the exact same procedure except parental permission was not sought.

When all of the data from the 30 experiments was gathered data analysis took place. In order to conduct data analysis for the Stroop task on SPSS the mean and interquartile range ( quart 1 and 3) was taken for each participants congruent and incongruent task. This was calculated on Microsoft Office Excel 2010. The mean and interquartile range was calculated twice for each participant once for the congruent task and once for the incongruent task. When the

interquartile range was found the outliers were removed based on the number of the interquartile sum. There were then 4 variables in SPSS for each participants Stroop scores. Congruent and Incongruent trial means with the outliers and Congruent and Incongruent means with the outliers taken out. After analysing both instances separately, e.g. doing one analysis for the means with the outliers and one analysis for the means without the outliers it was found that the mean without the outliers produced best results therefore this was the one used when analysing the data and presenting it in the results section.

# **Results**

### ***Chapter 3: Results***

Descriptive and inferential analysis was conducted using SPSS (version 21). Descriptive statistics such as, means, standard deviations, variance, and range were calculated for the variables of the Stroop task which included both the congruent and incongruent trials, incongruent errors, age of participant, sex of participant and number of languages spoken. The inferential analysis included non-parametric tests such as the Friedman test, Mann-whitney U, Wilcoxon, and a Kruskal Wallace.

#### ***Descriptive statistics***

There were 30 participants in total that took part in this study (14 male and 16 female). 15 of the participants were monolingual (6 male and 9 female) and 15 of the participants were bilingual (8 males and 7 female).

*Table 1.* Gender of the Respondents

<b>Gender of the Respondents</b>	<b>Percentage</b>
Male	46.7%
Female	53.3%

*Note:* *p* significant at .05 level.

The breakdown of males and females as seen above in Table 1, is 46.7% (N=14) male and 53.3% (N=16).

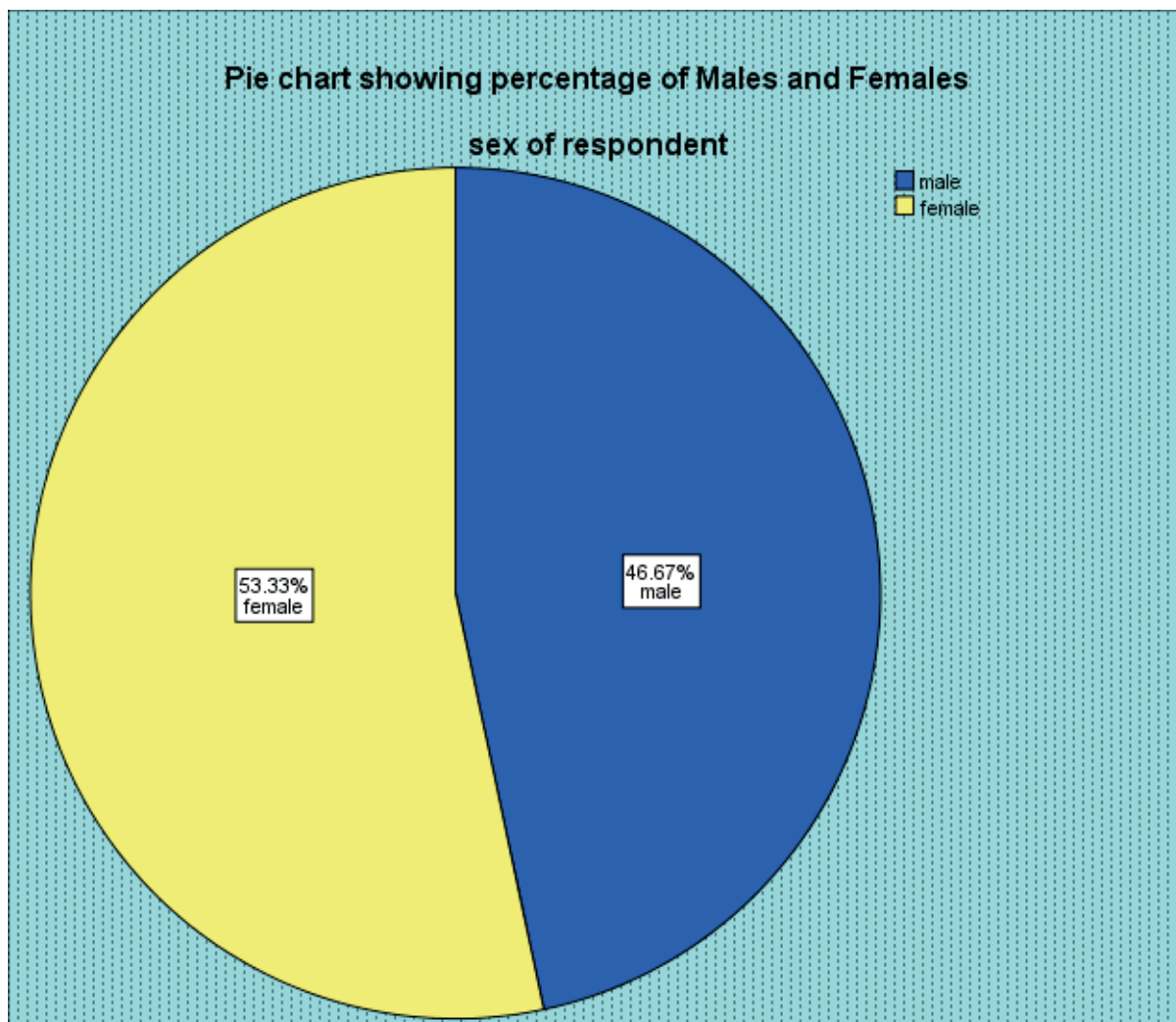


Figure 1: Showing the breakdown of males and females

The breakdown of participant's age is presented in Table 2. The analysis showed that the highest number of participants were 17 years old (N=46.7) the second highest was age 18 with 40.0% (N=40) of the total population being represented by this age. Only 6.6% (N=6.6) of participants were aged 15 and younger. Six point seven percent (N=6.7) of participants were aged 16.

Table 2. *Age of the respondents*

<b>Age range of the respondents (in years)</b>	<b>Percentage</b>
13	3.3%
15	3.3%
16	6.7%
17	46.7%
18	40.0%

*Note: p significant at .05 level.*

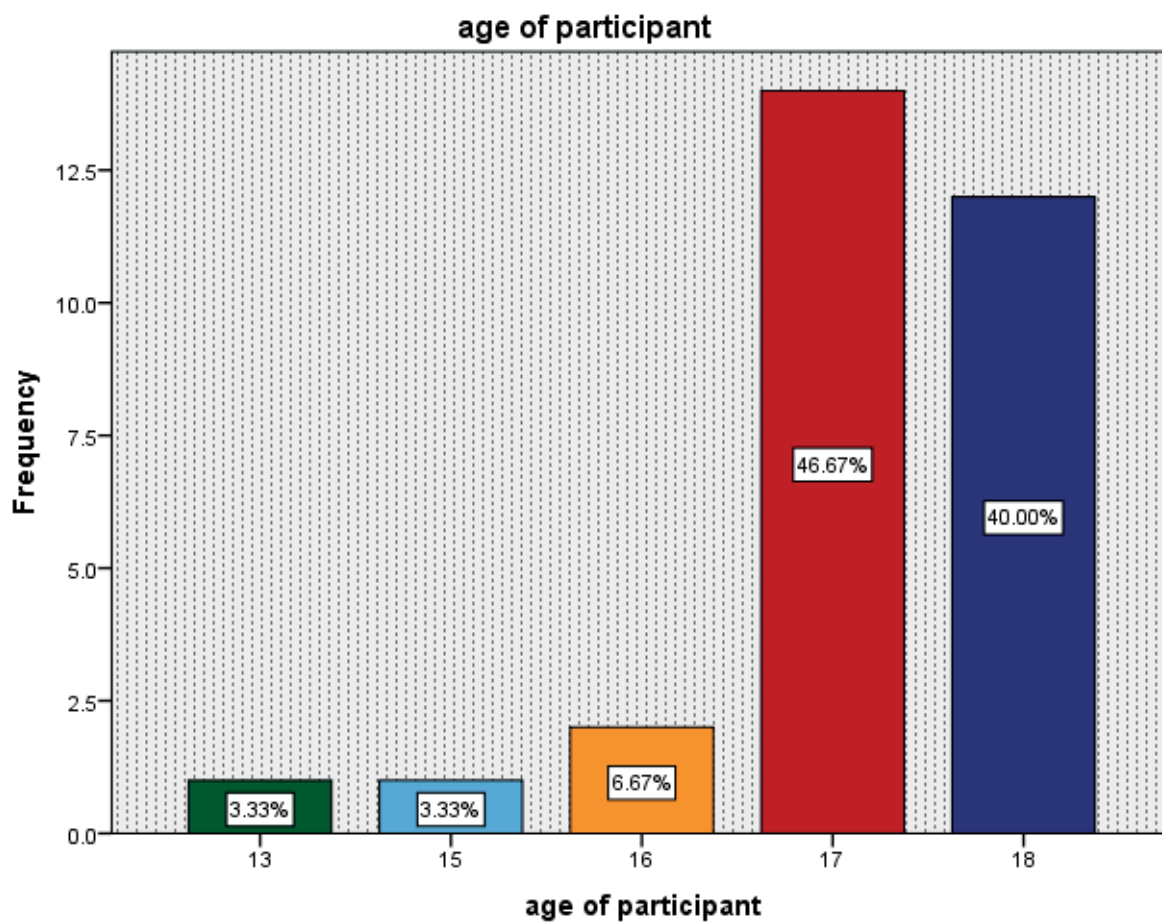


Figure 1. *Distribution of age within participants*

Bilingual and Monolingual participants were split equally in terms of the number of participants in each group. Bilingual (N=15) and monolingual (N=15).

*Table 3:* Table showing the number of bilingual and monolingual participants

<b>Number of languages spoken</b>	<b>Percentage of Participants</b>
Monolingual (1 language)	50%
Bilingual (2 languages)	50%

*Note:*  $p$  significant at .05 level.

## *Inferential Statistics*

### *Friedmans*

After conducting the test of normality and gaining significant results, a repeated measure ANOVA was not able to be conducted due to the significant results. A Friedman's test was run instead of the ANOVA to accommodate for the results in the test of normality.

The variables Stroop congruent and Stroop incongruent both excluding outliers were used as the variables to run the Friedman. A Friedman test showed that the related conditions, which evaluated differences in medians among the two Stroop conditions, Congruent and incongruent differed significantly ( $\chi^2(2) = 4.80, p = .028$ ).

*Table 4: Friedmans analysis breakdown*

<b>Number of participants (N)</b>	30
<b>Chi-Square</b>	4.8
<b>DF</b>	1
<b>Asymptotic Significance</b>	.028
<b>Congruent mean</b>	1.30
<b>Incongruent mean</b>	1.70

*Note: p significant at .05 level.*

### *Man-Whitney U*

A Mann-Whitney U test was used to test the hypothesis that there will be a significant difference between the Stroop scores of the participants in the congruent sub-tasks. Congruent condition had a mean rank of 11.61 with the participants who spoke one language compared to the mean rank of 19.33 for the participants who spoke 2 languages. The Mann-Whitney revealed that the people who spoke one language scored better on the Stroop task than those who spoke more than 1 language. The participants who spoke 1 language had a significantly lower response time than those who spoke 2 languages. ( $U = 55.00$ ,  $p = .017$ ).

*Table 5:* Descriptive statistics of a Mann-Whitney U for number of languages spoken and congruent sub trial

<b>Variables</b>	<b>Languages</b>	<b>N</b>	<b>M</b>	<b>U</b>	<b>P</b>
Number of languages Spoken	One	15	11.61	55.00	.017
	Two or more	15	19.33		

*Note:*  $p$  significant at .05 level

A Mann-Whitney U test was used to test the hypothesis that there will be a significant difference between the Stroop scores of the participants in the in-congruent sub-tasks. In-Congruent condition had a mean rank of 12.13 with the participants who spoke one language compared to the mean rank of 18.87 for the participants who spoke 2 languages. The Mann-Whitney revealed that the people who spoke one language scored better on the Stroop task than those who spoke more than 1 language. The participants who spoke 1 language had a significantly lower response time than those who spoke 2 languages. ( $U = 62.00$ ,  $p = .036$ )

*Table 6:* Descriptive statistics for a Mann-Whitney U showing number of languages spoken and incongruent sub-trial

<b>Variables</b>	<b>Linguism</b>	<b>N</b>	<b>M</b>	<b>U</b>	<b>P</b>
Number of languages	One	15	12.13	62.00	.036
Spoken	Two or more	15	18.87		

*Note:* P is significant at .05 level

A Mann-Whitney U test was used to test the hypothesis that there will be a significant difference between the Stroop errors of the participants in the in-congruent sub-tasks. In-Congruent error trials had a mean rank of 18.27 with the participants who spoke one language compared to the mean rank of 12.73 for the participants who spoke 2 languages. The Mann-Whitney revealed that the people who spoke 2 languages had fewer errors on the in congruent trials on the Stroop task than those who spoke 1 language. The participants who spoke 2 languages had a significantly amount of incongruent errors than those who spoke 1 language. ( $U = 71.00, p = .027$ ).

*Table 7:* Descriptive statistics showing the number of languages spoken and incongruent errors

<b>Variables</b>	<b>Linguism</b>	<b>N</b>	<b>M</b>	<b>U</b>	<b>P</b>
	1 Language	15	18.27	71.00	.027
	2 Languages	15	12.73		

*Note:* p significant at .05 level.

*Wilcoxon*

A Wilcoxon test was used to see was there a difference between the congruent and incongruent sub-trial. The Wilcoxon found that there was a statistically significant difference between the congruent Stroop sub-task and the incongruent Stroop sub-task. ( $z=-2.95$ ,  $p=.003$ )

*Table 8:* descriptive statistics showing differences between congruent and incongruent sub-trials

Variables	<b>N</b>	<b>M</b>	<b>SD</b>	<b>Z</b>	<b>P</b>
Congruent	30	802.53	243.69	-2.95	.003
Incongruent	30	912.83	429.81		

*Note:*  $p$  significant at .05 level.

*Kruskal Wallace.*

A Kruskal Wallace was used to test the hypothesis that there will be a difference between age groups on the incongruent errors. A Kruskal-Wallis one-way ANOVA showed that the age groups (13-15), (15-17) (17-19) and the number of errors in the incongruent sub-trial of the Stroop task did not differ significantly ( $X^2(2) = 1.28, P=.526$ ).

*Table 9: Descriptive statistics of a Kruskal Wallace showing difference between age groups and errors in incongruent trial*

	<b>Age Group</b>	<b>N</b>	<b>Rank</b>
Errors on	13-15	2	20.75
Incongruent trial	15-17	16	15.28
	17-19	12	14.92

*Note: p significant at .05 level.*

# **Discussion**

## ***Chapter 4: Discussion***

### *Research aim*

The aim of this study was to investigate whether there is a difference between the number of languages a person speaks and executive control within the executive functioning system. The participants who took part in this experiment were sampled from the general Irish population of adolescents between the ages of 13-19 attending Irish secondary schools. The sample included both males and females and both bilingual and monolingual speakers. Differential analyses was conducted to identify whether there is a significant link between the number of languages spoken and executive control, executive control was measured by means of a Stroop Task. The Victoria Stroop Task was used on all of the participants.

### *Findings of the Study*

The findings of the analysis showed that 50% (N=15) of the participants were bilingual and 50% (N=15) were monolingual. It was found that 53.3% of the participants were females and 46.67% of the participants were male. The study showed that a significant number of participants 46.7% (N=13) were aged 17.

The first test run was the Friedman test; due to the non-normal distribution of the data repeated measures ANOVA was not able to be conducted therefore a Friedman was conducted in place of it. The Friedman test showed a positive significant difference between the two medians of the two Stroop conditions, congruent and incongruent. (P=.028).

Leading on from the Friedman test, a Man-Whitney U was conducted to test would the Man-Whitney U support what the Friedman test found. The Mann-Whitney U was also run to see was there a difference between Stroop Scores between the participants on the Congruent Sub task. The results showed a positive significant difference between the participant's scores on the congruent sub trial of the Stroop task and the number of languages the individual speaks. The 1 language participant group had a median score of 11.61 while the participants who spoke 2 languages had a median score of 19.33 ( $P=.017$ ).

Another Man-Whitney U was conducted to see would this be the case for the incongruent trials too. The Man-Whitney U showed that there was a significant difference between the monolingual and bilingual participant groups on the incongruent sub task of the Stroop task. Those participants who spoke 2 languages (bilinguals) scored higher in the incongruent sub trial than those who only spoke one. The bilingual group had a median score of 18.87 and the monolingual group had a median score of 12.13 ( $P=.036$ ).

The last Man-Whitney U was conducted to test whether there was a significant difference between the numbers of errors obtained by the different groups on the incongruent sub-trials. The Man-Whitney U showed that there was a positive significant difference between the number of errors made in the sub-trial and the number of languages the participant speaks. The bilingual group ( $M=18.27$ ) made less errors than the monolingual group ( $M=12.73$ ) ( $P=.027$ ).

Wilcoxon, the non-parametric version of the paired samples T test was conducted. The reason for the Wilcoxon was to test was there a main effect of the Stroop task, to test whether there is a difference between the congruent and incongruent test trials regardless of the number of languages an individual speaks. The Wilcoxon showed positive significant results between

the two sub-trials. The congruent had a median score of 802.53 while the incongruent sub-trial had a median score of 912.83 ( $P=.003$ ).

The last test conducted was the Kruskal Wallace. The reason the Kruskal Wallace was run was to test the second hypothesis that there will be a difference between the Age groups (13-15, 15-17, 17-19) on the number of errors obtained in the incongruent sub-trial of the Stroop task. The kruskal Wallace found that there was no significant difference between the age groups on the number of errors obtained in the incongruent sub-task ( $P=.526$ ).

The main hypothesis of the current study is that there will be a difference in the brain's executive control between monolingual and bilingual adolescents using a Stroop Task. The second Hypothesis was testing whether there was a difference between age groups and the number of errors obtained by the bilingual and monolingual participants in the incongruent Sub-trial of the Stroop task.

### *Hypothesis 1*

The first hypothesis was supported by the statistical analysis of the Friedman, Mann-Whitney U and Wilcoxon. The findings obtained in the statistical analysis are in support of the previous findings by Bialystok et al and Cummins et al. Bialystok and colleges in 2011 found that there was an overall advantage for participants who were bilingual in those tasks that require the use of executive control such as the Stroop task. Executive control has a strong relationship with conflict resolution therefore those participants who are bilingual and have a naturally better established executive control system usually outperform there monolingual peers. Bilinguals outperform their monolingual counterparts in all tasks requiring the use of executive control. An interesting finding by Bialystok et al 2011 was that both of the languages of a bilingual are constantly active no matter if they are in a completely monolingual setting that does not require the use of their second language. Due to the

previous findings that bilingual participants outperform their monolingual participants on tasks requiring executive control it is important to note that the current study gained the same results with bilinguals scoring significantly higher in both the congruent and incongruent sub-trials of the Victoria Stroop task.

### *Hypothesis 2*

The second hypothesis found no significant difference between the different age groups on the number of errors obtained in the incongruent sub-trial. There was very few studies to that examined the Stroop task and age group and even fewer studies that examined the adolescent age group but studies in the past on Stroop task and age group showed that interference is highest in the ages between 7-9 and continues to get stronger as the reading capabilities of the child increases. It then becomes to decline in adulthood and increase again in advanced adulthood which is over the age of 60. Comalli in 1962 stated that everyone who can read will at some point show a robust Stroop effect.

### *Limitations of the Current Study*

There are a number of limitations in this study that are worth mentioning in order for this study to be more stringent and significant in the future. The sample size used (N=30) is a considerably small sample size and perhaps if the sample size was larger the data would have been distributed more normally and possibly parametric tests could have been conducted. In saying this; a higher significance between the variables could emerge due to the different method of analysing the data.

On PEBL (Psychological Education Building Language) the congruent sub-trial did not have data collected on the number of congruent errors obtained by the participants. The Victoria

Stroop task on PEBL only calculated the number of errors obtained by participants on the incongruent sub-trial. If the congruent sub-trial had the number of errors recorded it would be beneficial to the experimenter due to the fact that they are able to run more analysis to test for significance between the variables. If the congruent errors were recorded then tests could be run to explore the difference between the number of errors in both the congruent and incongruent sub-trials.

### *Strengths of the current study*

As well as limitations there are a number of positive strengths about this study. The first strength and one of the reasons for conducting this study was due to the fact that there are no known studies in Ireland examining the differences between participants score on the Stroop task and the number of languages the participant speaks. Although there are worldwide experiments studying the differences of monolingual and bilingual individuals and there link with executive control using a Stroop task or other forms of measurement, there hasn't been studies in Ireland to test for this. Another advantage of the current study was the age group that was tested. The adolescent age group which is between the years of 13-19 has been very rarely tested in previous studies. There is very little mention of this particular age group in previous experiments studying the relationship between the stages of development and the Stroop effect. The adolescent years are crucial years in the lifespan due to the changes that take place such as the ability to think abstractly and to reason effectively. The adolescent age group has rarely been studied worldwide and especially not on a smaller scale such as Ireland thus the strong point of the current study was that the population was used minimally in the past and that the age group was an unusual choice compared to the past studies.

### *Implications of future research and future direction*

The main implication of this research is the bilingual population will score higher on tests of executive control not only on the Irish population but globally. For future research, apart from the need of a larger sample size and the recording of congruent error count, it would also be interesting to make the study language specific. Instead of using the bilingual population in a particular age group, use those individuals who all have the same second language. An example of this would be using an English-Italian bilingual versus monolingual study. The reason for using a specific language in the test is that it would not only be more stringent, it would also have a higher control and it prevents language syntax and proficiency, as reasons behind obtaining insignificant results. Using bilingual participants who speak the same 2 languages would make it easier to interpret the results and compare the results more effectively. Studies in the past by Preston and Lambert in 1969 and Dyers in 1971 have all used Stroop tests that incorporated both languages of the bilingual into the same Stroop task and tested for the percentage of interference but there were no noted studies on the Stroop task that was compiled of only 1 language but recruited only those bilinguals who spoke 2 specific languages.

The current study could possibly be applied into a real life scenario would be in Irish primary and secondary schools. With the findings of this study and indeed the findings from previous studies, this could be real grounds for more emphasis placed on the way in which the children and adolescents are thought a new language and indeed how bilinguals in the education system are educated. The research on the executive control system and its relationship with language and language switching could help assist those students who are bilingual or who have emigrated and are only beginning to be immersed and speak a new language.

### *Conclusion*

To conclude, the current study has found some interesting results that are in conjunction with those that have been found in the past. Although the study has limitations and downfalls, it also has some positive aspects and is a good foundation for future studies of bilinguals and executive control in Ireland. It was an interesting experiment to run and a lot of knowledge was gained from conducting this experiment. There were both significant and insignificant results gained from the data analysis of the study as well as some interesting findings. There are many ways in which this study could be replicated on a wider scale. Perhaps with more emphasis placed on the actual languages that the bilingual speaks and more emphasis placed on when the second language was gained, at birth or at a later stage of development. The study conducted some pioneering work in Ireland due to its experimentation on the Irish secondary schools and on Irish students.

As stated earlier, studies into bilinguals is a relatively new area of cognitive psychology and although there is a lot of break through research from Bialystok, Collins, Macleod and colleges and of course with the help of Stoop in 1935, but there is still a lot more research to be conducted and more knowledge gained in the whole area of bilingual language processing.

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# **Appendix 1**

## **Difference between monolingual and bilingual adolescents on executive control**

Dear participants,

My name is Nerina Hrvacic and I am a final year psychology student in Dublin Business School. As part of my studies I am conducting research in the department of psychology that explores the difference in the brains executive functioning system between monolingual and bilingual adolescents.

The brains executive functioning system is a set of mental processes that helps connect past experience with present action. People use it to perform activities such as planning, organising, paying attention, remembering details and managing time and space.

I will be conducting a short experiment on adolescents that are bilingual (speak two languages) and monolingual (speak one language). The experiment is a very brief computerised test where I am asking the children to complete a Stroop task. The Stroop task is an electronic list of the names of colours but in one instance the font matches the colour that is being read. For example the word “green” is written in “green” and the second instance will be where the name of the colour does not match the colour it is written in for example “red” written in “blue”. The aim of the study is for the child to say the colour the word is written in and ignore the name of the colour, so like in the previous example, to say the word “blue”. I will then time how long it takes them to complete the task and the number of correct responses they had.

Participation is completely voluntary; your son or daughter is not obliged to take part.

Participation is anonymous and confidential, thus the responses cannot be attributed to any one participant. The participants will be given code names based on the number of languages they speak. For example a bilingual child might have B1 as their participant name; similarly a monolingual child might have M1 as their participant name. The results of the study will be securely stored on a password protected computer and will later be destroyed when the study is complete.

If you are under 18 please have a parent or guardian sign the permission form below, if you are over 18 please disregard this statement.

If you have any further questions or would like to be informed on the results of the study, please do not hesitate to contact me by email

Thank you for your time,

Kind regards,

Nerina

---

**Please Sign and Date below:**

**Signature:**

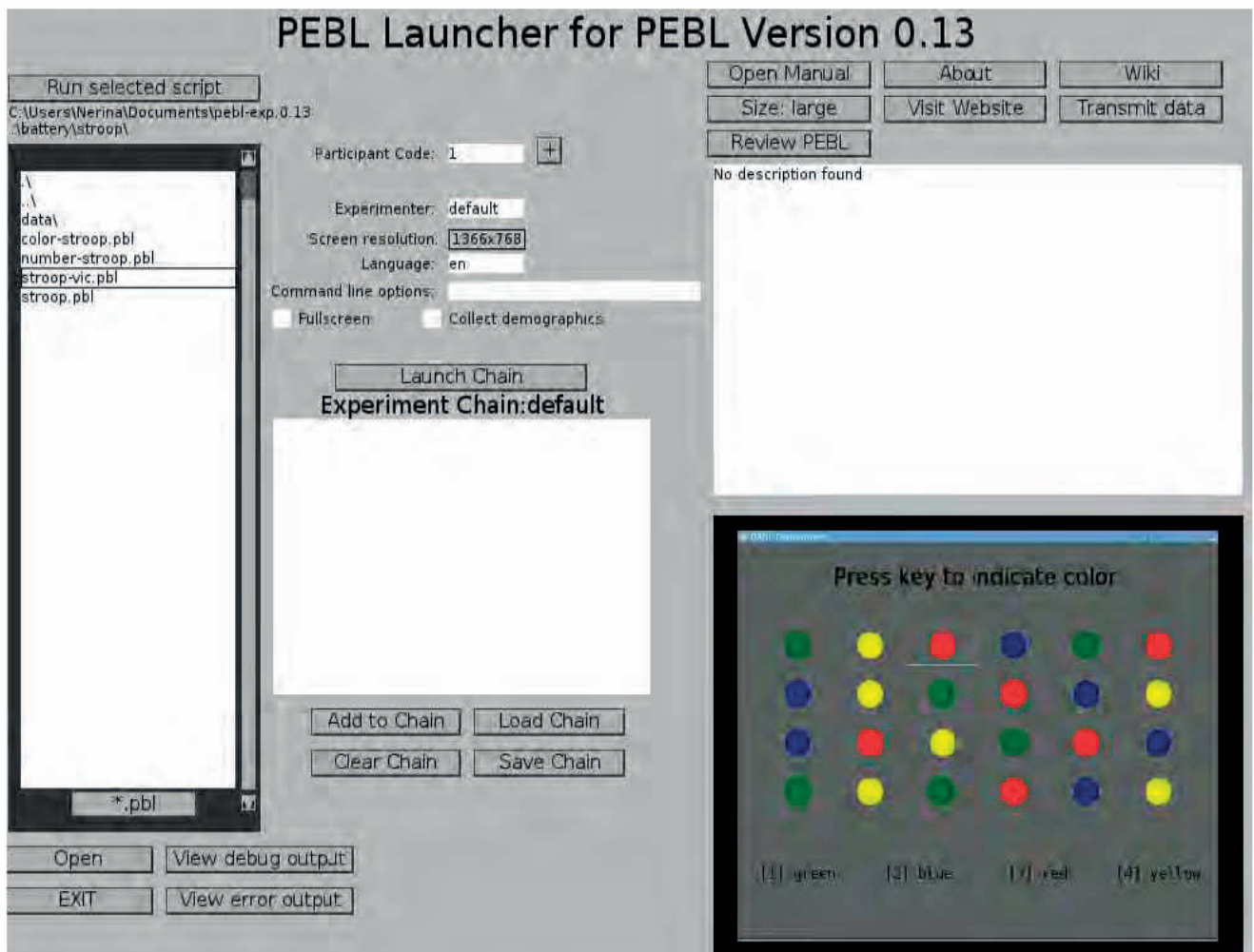
**Date:**

## **Appendix 2:**



## **Appendix 3**

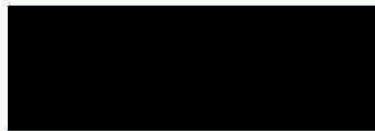
## The first prompt on PEBL (Psychology Experiments Building Language)



## **Appendix 4**

**PEBL prompt to check does the colour/number combination match that on the keyboard**

Before we begin, take a moment to learn the mapping between colors and the keys. Press the keys [1, 2, 3, and 4] consecutively to practice the stimuli, and space bar to begin the test.



[1] red

[2] blue


[3] yellow

[4] green

## **Appendix 5**

**Practice sub trial on PEBL**

Press key to indicate color.



[1] red      [2] blue      [3] yellow      [4] green

## **Appendix 6**

### Incongruent sub trial on PEBL

Press key to indicate color.

green	yellow	red	blue
yellow	red	blue	green
yellow	blue	red	green
blue	red	yellow	green
red	blue	yellow	green
blue	green	yellow	red

[1] red      [2] blue      [3] yellow      [4] green