The effects of multilingualism on executive processing.

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Abstract
In the first decades of the 20th century, research on bilingualism was just beginning. The first studies on bilingual children proposed a substantial disadvantage with respect to intelligence and learning abilities. This first proposition was later discarded when Peal and Lambert (1962) suggested that, on the contrary, speaking two languages was providing children with significant advantages in their cognition. At the present time, it is assessed that, while knowing more than one language is not negative, the supposition that bilingualism might have positive effects on executive processing is subject to controversy. The Bilingual Executive Advantage (BEA) hypothesis has been tested many times and in several ways. Nevertheless, it appears more like an overstated theory rather than a real and proven fact.

The purpose of this study is to contribute to this scholarly debate not only by conducting one more experiment but also by investigating a possible extension to the original hypothesis, more specifically, the possibility that additional languages might confer an even greater cognitive advantage than the one that has been claimed to exist for bilingual individuals. In the study, 23 young adults were tested on a version of the Attentional Network Task and a Colour-Shape switching task, both used in a previous study on professional interpreters (Babcock and Vallesi, 2017). The subjects were divided in two groups, bilinguals and multilinguals. The comparison of their performances in the two task revealed no significant difference in any of the examined measures.

Keywords
Bilingualism, multilingualism, bilingual advantage, executive processing, cognition, ANT, Switching task, attention, set-shifting.
1. Introduction

The majority of the population in the world speaks two or more languages. The ability to speak more than one language provides one with the possibility to communicate with a multitude of people across the globe. In these terms, bilingualism could be considered a social advantage.

In the past, researchers believed that being able to speak more than one language could be a disadvantage, especially for children. According to studies like Goodenough (1926), bilingual children would have an evident deficit in intelligence. In Holland (1960), bilingualism was considered as an educational problem and cause of a language barrier. Overall, studies in the first half of the 20th Century seemed to suggest that bilingual children with an immigrant background, would have been less intelligent than monolingual children. It has to be noted that in the majority of these studies, however, the researchers might have interpreted their findings from a rather racist point of view (for a review, see Hakuta, 1989). Successively, this very pessimistic proposition has been rejected. The first study announcing a surprising advantage in cognitive and linguistic performance by people who were able to speak two languages is the one conducted by Peal and Lambert (1962). They carried out a study with a cohort of bilingual children and, at the time, they came to the conclusion that the bilingual experience of having to manage two language systems at the same time appeared to have left the children with what they called superior "mental flexibility." Since then, an increasing number of investigations has been focusing on what is now generally called the Bilingual Executive Advantage (Henceforth, BEA).

It is well known that there are some factors that play a decisive role in the maintenance and the improvement of cognitive functions. These are practices such as exercise, social activities, level of education and type of occupation (Rossi & Diaz, 2016). Nevertheless, in recent years, many researchers have been trying to answer the question of whether bilingualism could constitute a gain concerning cognitive functions that are independent of the linguistic ones (Rossi & Diaz, 2016).

The primary hypothesis is based on one of the most important aspects of bilingualism: the fact that fluent bilinguals always have two (or more) languages active and available at the same time and, for this reason, they have to fight against the central conflict created
by the joint activation of the two competing language systems (Green, 1998). Because of this characteristic, bilingual individuals appear to have greater experience in the linguistic skill that requires the selection and activation of the chosen language, and in the inhibition of the non-selected one (Paap & Greenberg, 2013).

The literature on this topic has been steadily growing and, especially in the past twenty years, many researchers have been extremely motivated to investigate whether the considerable habit of controlling two or more languages at the same time might have beneficial effects on cognitive skills that are beyond the linguistic domains. In addition, there is evidence that later in life the benefits of bilingualism might be even greater. Studies on patients affected by different types of dementia have shown that the first symptoms appear to affect bilinguals a few years later than monolinguals and also that the bilingual brain is generally able to deal better with the symptoms such disease causes, as reported in Bialystok, Luk and Craig (2012).

The present study aims to contribute to this research debate by exploring the possible effects of multilingualism – as opposed to bilingualism - on executive functions. Could additional languages provide multilingual people with an even greater advantage than the one observed so far for bilingualism? In particular, the study will consider how a group of multilingual young adults would perform on two specific behavioural tests, namely the Attentional Network Task and the Colour-Shape Switching Task, and whether they reveal any difference in comparison to a group of bilingual young adults.

2. Previous Research

Generally, the studies in support of a cognitive advantage for bilinguals demonstrate that bilinguals achieve better results compared to monolinguals when tested on specific online tasks tapping on different domains of Executive Processing (Henceforth, EP) (Paap and Greenberg, 2013). Despite the very high number of studies that have been conducted in this field of research, a definite answer is yet to be found. The issue is highly controversial and the academic world is divided between those researchers who support it with their results and those who have failed to replicate such findings (e.g. Paap and Greenberg, 2013,) claiming that the bilingual advantage might not even be real. In this section, a few of the major studies that have used behavioural tasks will be reviewed and analysed.
One of the first studies of this kind is the one by Bialystok, Craik, Klein and Viswanathan (2004). Monolingual and bilingual adults were divided into two age groups and then tested on a Simon Task, one of the most common measures of inhibitory control. The test consisted in making left or right decisions using either the left or the right shift keys respectively. The participants had to press the left shift key when a blue square appeared on the computer screen and the right shift key when a red square appeared instead. In the congruent trials the square was presented on same the side of the answer they were supposed to give, while in the incongruent trials, for example, the participants saw a red square on the left side of the screen. In this case, they had to inhibit the spatial stimulus given by the location of the square and answer pressing the right shift key, only focusing on the colour red.

The experiment’s results revealed three main patterns:

- a better performance of middle-aged adults over older adults across the board;
- a stronger bilingual advantage for the older adults compared to the middle-age adults;
- all bilinguals performed better and faster not only in the incongruent trials, showing a smaller Simon effect but also in the congruent trials.

These findings allowed the authors argue for a more general executive advantage for bilinguals over monolingual people (Bialystok et al., 2004). Another example of the many findings in support of the beneficial cognitive gains that come with bilingualism is the study by Craik, Luk and Bialystok (2008). They tested a total of 96 younger and older adults. The participants were distributed in four groups: young adult monolinguals vs. bilinguals and older adult monolingual vs. bilinguals and they were tested on a set of tasks tapping on working memory, lexical retrieval, and executive control. The latter is generally more complicated to examine. Because of this, they claim that using at least three different task types might be enough to control for the fact that Executive Control is not a unitary construct, in the sense that it comprises several subcomponents (Craik, Luk & Bialystok, 2008). Among the tasks they used to analyse Executive Control, the first one was a very common Simon arrows task, similar to the so-called Flanker task, in which arrows point either in the same direction (congruent trials) or in the opposite direction (incongruent trials) as the targets that are displayed to the participants. However, they did not specify which particular ability within the Executive Control complex this
task would measure. Furthermore, they presented the Stroop colour-naming task as the second part of the experiment, but without exactly specifying which particular component of executive processing this task would test. Generally, the Stroop task could be used to test inhibitory control. In this test, the participants are presented with words in coloured ink representing colour names. In the congruent trials, the name of a colour is the same as the colour of the ink, while in the incongruent trials they are different. However, the colour-naming task, which is a verbal task, could be considered questionable since they were looking for the bilingual advantage, a skill that they claim is supposed to go beyond the linguistic domain. Finally, they used the Sustained Attention to Response task, which, as it is explicitly clarified in the paper, looks at sustained attention as opposed to a more general inhibitory control (Craig, Luk & Bialystok, 2008). Consistent with other studies, their results showed no particular advantage for the bilinguals in the working memory tasks, a disadvantage in the tasks examining their lexical retrieval skills, and a small advantage on the tasks tapping on executive control. Despite the few methodological flaws in the study, they argued for facilitation for the bilinguals regarding executive control, in their words, a bilingual advantage that is “consistently replicable” (Craig, Luk & Bialystok, 2008).

As may already seem clear, one of the most influential researchers in this field is the Canadian psychologist and professor Ellen Bialystok. She is one of the strongest defenders and supporters of the positive effects of bilingualism. In her paper “Bilingualism: the good, the bad, the indifferent” (Bialystok, 2009), to mention one, she recapitulates the research about the effects of bilingualism on cognition and how it changes at the different stages of life (Bialystok, 2009). Her conclusions are, not surprisingly, in line with what was found by Craig, Luk and Bialystok (2008). In short, in her paper, it is argued that bilingual people suffer from a disadvantage in terms of verbal fluency and lexical access; however, they show an advantage in conflict resolution and executive control but no clear advantage when it comes to working memory (Bialystok, 2009). Remarkably, Bialystok (2009) also refers to Executive Control as a set of skills which include inhibition, switching, cognitive flexibility and working memory. However, she argues for a general cognitive advantage in executive control, despite the fact that her findings show no evidence of stronger working memory, one of the components of executive control, for the bilinguals compared to the monolinguals.
Along the same lines, Costa, Hernández, Costa-Faidella, and Sebastián-Gallés (2009) administered a very interesting study testing bilingual and monolingual young adults on two networks of attention. In the specific, the executive and orienting network. Their study is divided into two parts, each relating to one of the two principal aims. First, they used a different version of the Stroop task, the Numerical Stroop task, in order to examine executive control, avoiding the linguistic stimuli that are typically present in the original version. Secondly, they chose a visual cueing task, in which the participant had to choose whether the cue was a straight or a tilted line. The purpose was to understand whether bilingualism can positively affect certain components of cognition that are different from executive control. In other words, they refer to the orienting network. The first part of the experiment resulted in generally faster responses for bilinguals in all tasks. In contrast, the second part did not support any bilingual advantage: both monolingual and bilingual groups performed very similarly in the detection task. Nevertheless, it would appear that the authors might not have given this second finding enough importance, claiming that their overall results “alleviate concerns” (p. 322) regarding the reliability of the results in favour of the advantage.

Although it may be true that many of the empirical findings in this research field are very optimistic, some of them have been proven not to be so unquestionable in children and young adults (at the peak of their cognitive capacities) and to have been understudied in older age groups. (Paap & Greenberg, 2013). Some influential researchers challenge the whole advantage hypothesis, and they raise objections towards it. Hilchey and Klein (2011), for example, show that there have also been many failures to observe a bilingual advantage, especially when it comes to the inhibition component. After analysing a significant number of studies, they argue against the inhibitory control mode, claiming there is very little reliable evidence that could support the hypothesis of a bilingual inhibitory control advantage (the BICA hypothesis). For that reason, they propose a bilingual executive processing advantage (the BEPA hypothesis), which would be a general processing advantage hypothesis, admitting a more robust set of findings in that direction. However, this hypothesis still lacks theoretical foundation and it is not so reliable in cohorts of young adults.

Moreover, Paap and Greenberg (2013) criticize the almost too casual choice of measure many researchers seem to make. In particular, they argue that it is useless to test the participants on one specific task if one want to prove a general advantage in Processing.
In fact, they say that finding an advantage for bilingual over monolingual individuals when testing them on a task designed to tap exclusively on inhibitory control, for instance, does not give enough stable proof to argue for a general bilingual executive advantage. In other words, the authors argue that each task examines a specific component, therefore their respective results can only account for that particular ability and not for the entire executive processing. Therefore, not convinced by previous studies, the two researchers led another experiment, comprising several tasks, specifically chosen to analyse three aspects of the Executive Process: inhibition, monitoring and switching, with the aim to verify and confirm the previous findings. They explain that inhibition is thought to be an ability in which the bilinguals would have an advantage, and the proposition is that they are more trained and used to select the “goal-relevant information” while having to suppress the “competing and distracting” one. According to Green (1998), bilinguals can exercise this type of control on two levels. On high level of goal setting when one language is selected and the other is inhibited and on lower level where the lexical items of the target language are activated and the translation equivalents are inhibited.

In the study conducted by Paap and Greenberg (2013), inhibitory control would play a role in the Simon task, the antisaccade task and the Eriksen flanker task. The advantage in Monitoring, the second aim of the study, was examined through the Simon Task, mainly because Bialystok had previously proposed a bilingual advantage in the context of this particular task (Bialystok, 2004). The third aim of their experiment was to examine whether the bilinguals’ experience in code-switching as they shift from one language to the other, could be linked to an advantage in a more general switching ability.

Language switching is considered to be a complicated process because the lexicons of the two different languages are assumed to be connected to the same conceptual system. As a consequence, switching is strongly related to inhibition (Paap & Greenberg, 2013). Nevertheless, the general ability to switch from one task to a completely different one is assumed to require an executive process component, namely the set-shifting skill (sometimes mentioned as switching), that is different from inhibitory control and monitoring ones. For that reason, the possible switching advantage of the bilinguals was examined using a version of the Color-Shape switching task. Paap and Greenberg (2013) did not find any significant difference in the performances of the two groups in any of the measures, therefore they argued against the BEA: "In summary, fluent bilinguals have additional needs for monitoring, switching, and inhibitory control, but these unique
requirements may not be substantial enough to generate group differences in cognitive control” (Paap and Greenberg, 2013 p. 256). Overall, inhibitory control, as it has been mentioned previously in this section, is not the most straightforward skill to examine and it is also one of the most controversial themes in this debate.

Another example of evidence against the inhibitory advantage is the study on bilingual children by Duñabeitia, Hernández, Antón, Macizo, Estévez, Fuentes and Carreiras (2014). The study included two similar experiments, the first one being a colour-naming Stroop task. Similarly to Costa et al., (2009), the concerns regarding the verbal nature of the classic Stroop task resulted in adding a second task in which the participants were tested in a non-linguistic version, a numerical Stroop task. They tested an extensive sample of children (252 monolinguals and 252 bilinguals) matched on a series of variables, but the results showed no difference between the performances of the two groups, that is, no inhibitory advantage for the bilinguals over the monolinguals (Duñabeitia et al., 2014).

As previously mentioned, the issue regarding the effects of bilingualism on cognition is very much debated, and there still is more recent literature that strongly supports the hypothesis. Bialystok (2017) gives a very detailed overview of all the most relevant studies in the field and strongly critiques those which have failed to prove the existence of the bilingual advantage (Bialystok, 2017). She accounts for the unreliability of testing young adults by justifying it with the ceiling effect. In other words, the majority of the studies on young adults are unable to provide evidence for the advantage because the tasks they use are too simple for people at the peak of their cognitive capacities (Bialystok, 2017). In addition, she says that the negative evidence of certain studies is very likely to depend on wrong statistical analysis, excessively large or small samples, or the similarity of the language pairs (Bialystok, 2017). However, this critique seems to be directed only towards the studies arguing against the hypothesis. For instance, both Costa et al. (2009) and Duñabeitia et al. (2014) used very similar language pairs, but Bialystok critiques only the latter for this choice. Other variables that could have influenced the results negatively are the match of the participants according to their level of bilingualism, socioeconomic status, immigration status, or intelligence. Furthermore, Bialystok asserts that researchers who fail to replicate the positive findings should attribute it to their interpretation of the results, which she claims is wrong. Finally, Bialystok concludes that
the absence of evidence for the differences between groups is not a negative result. It is just a null result, and it does not negate the existence of the advantage (Bialystok. 2017).

Lehtonen, Soveri, Laine, Järvenpää, de Bruin and Antfolk (2018) recently published a vast meta-analysis on the bilingual advantage. It is a systematic review in which they compare and examine a great number of studies on this subject in order to clarify the current situation more objectively. The analysis takes into account 152 studies, including doctoral dissertations, postgraduate theses and other studies that, for one reason or another, have not been published. The investigation focuses exclusively on studies in which healthy adults were tested on mainly non-verbal behavioural tasks examining at least one of the six subdomains of the Executive Functioning defined as follows:

- Inhibitory control: the ability to suppress competing or irrelevant response (e.g., measured using the Simon Task or the Stroop task);
- Monitoring: the ability to monitor conflict when processing information (e.g., Flanker task, Simon task Stroop task);
- Set shifting: the skill to switch between tasks (e.g., different types of Switching Task; Test of everyday Attention)
- Working memory: the skill to maintain any information when its processing is still ongoing (e.g., various Complex Span tasks, Simple Span tasks)
- Attention, the ability to direct and maintain focus on stimuli (e.g., ANT, SART, TEA);
- Verbal fluency: intended as an executive control ability (especially tasks on letter fluency)

The main argument in the paper is the so-called "publication bias." The bias regards the evidence that the number of studies in favour of the bilingual advantage seems to be more prominent in the literature only because they have a higher chance of getting published. On the contrary, the reports that give evidence against the advantage are usually less likely to be published (Lehtonen et al., 2018).

Their meta-analysis consisted not only in analyzing the BEA hypothesis objectively but also in trying to "correct" the publication problem through very sophisticated statistical analysis and see if the observed results would remain the same. The results showed almost no real signs of the bilingual advantage across the board. The effects of bilingualism were only present in three specific domains: positive for inhibition, shifting and negative for
verbal fluency. In other words, the original effect sizes were already small and after the statistical correction for publication bias, no effect could be found at all. Overall, these conclusions seem not to be very optimistic towards the existence of such bilingualism advantage.

Clearly, bilingualism is quite a vague concept. As seen in Bialystok (2017), it has been claimed that certain variables linked to the different types of bilingualism might have influenced the results both in positive and in negative ways. Similar to the argument made in Paap and Greenberg (2013), the reasons behind the task choices are not very straightforward. Lehtonen et al. (2018) took into consideration many different factors that might have prejudiced the validity of the studies, however, according to them, there is no real and consistent evidence in support of the beneficial effects of bilingualism on cognition.

One of the reasons why the bilingual advantage is at the centre of this academic debate is the fact that the definition of bilingualism does not seem to be entirely clear. In the majority of the studies mentioned in this section, not only is there variability in the bilingual samples with regard to age of acquisition or L2 proficiency, but also, there seems to be almost no mention regarding the fact that the bilingual groups could actually include participants who speak additional languages, a factor that might influence the results. Along the same lines, it is very difficult to control for the knowledge the monolinguals might have of foreign languages. This issue has been raised by Bialistok, Craik and Luk (2012) as well. In this paper, the authors say that the different degrees of bilingualism could affect the findings in several ways. Most importantly, they suggest that multilingualism might have specific effects on executive processing and that such effects might be substantially different from the ones provided by bilingualism. In Lehtonen et al. it is claimed that several factors regarding, for instance, the age of acquisition, language pairing, proficiency and so on, do not really affect the overall findings as much as it had been argued before (i.e Bialystok, 2017). Nevertheless, could the knowledge of multiple languages lead to a different type of results?

Very interestingly, the different types of bilingualism seem to require a different type of cognitive effort and therefore, it might be possible that the higher the level of bilingualism, the higher the cognitive advantage. Managing more than two languages might require a greater effort compared to bilingualism, thus a more prominent advantage
In support of this idea, it has been shown, for example in Perquin et al. (2013) that additional languages might give stronger and better protection against dementia compared to the already studied effects of bilingualism on ageing.

The aim of the present study is to contribute to the research on the Bilingual Executive Advantage (or BEA) by examining the possible association between additional languages and executive functioning in bilingual and multilingual young adults.

3. The present Study

The study examines the plausibility of a cumulative cognitive advantage for multilinguals over bilinguals, specifically in relation to two of the six subdomains of Executive Functioning identified by Lehtonen et al. (2018) and enumerated in the previous section. In particular, the present study will examine the cognitive abilities of attention and set-shifting. As mentioned in the previous section, it has been claimed that performance of bilingual young adults in behavioural tasks rarely differ from the performances of their monolingual counterparts and it has been argued that it might be because during early adulthood human beings normally have their cognitive abilities at their best (Paap & Greenberg 2013). Therefore, it might be interesting to see if this difficulty in observing the bilingual advantage in young adults would persist or disappear when testing multilingual individuals.

The study consisted of an experiment, conducted in the Multilingualism Laboratory of the Centre for Research on Bilingualism at Stockholm University during the month of April 2018.

3.1 Participants

A sample of 26 students (mean age 23) attending different types of courses at Stockholm University took part in the study; however, 3 participants could not complete the experiment due to technical problems occurred during the testing session. Therefore, 23 participants were able to take part in the entire study. The recruitment of participants happened through the circulation of a message advertising the study that had been shared with all the students at the departments of Swedish language and Multilingualism and of Romance Studies and Classics as well as with other international students. Those who
showed interest in the study received more information about the experiment and a questionnaire to fill in via email. Participants were non-paid volunteers. They were asked to provide information about all the languages they knew or/and studied and when was the last time they had used each language (see Appendix). They were divided into two groups according to their answers to a questionnaire, which was created to determine Functional Fluency (adapted from Babcock, Capizzi, Arbula and Vallesi, 2017). Participants were considered functionally fluent in a language when answering ”yes” to seven or more questions. According to Babcock et al. (2017), this would correspond to a proficiency level of B2 or above, in relation to the Common European Framework of Reference for Languages (CEF). Therefore, the participants were assigned to either the bilingual group or the multilingual group according to the number of languages they were functionally fluent in. In other words, no more than two languages in the bilingual group and three or more languages in the multilingual group. Native languages were automatically considered as functionally fluent. 10 students were assigned to the bilingual group and 13 were assigned to the multilingual group. Before starting the experiment, all participants signed a consent form. Doing so, the participants confirmed that they had seen and read a copy of the participant’s information sheet and had been given the opportunity to ask questions about the study.

3.2 Tasks and Procedure

As discussed in the previous section of this work, there is a wide range of ways of testing the different cognitive abilities and each task has many versions. For this particular study, the tasks that have been chosen are generally used to test the abilities of attention and set shifting and they are: respectively, the Attentional Network task and the Colour-Shape Switching task. 1 The actual experiment consisted of 30 minutes testing sessions during which the participants performed the two online cognitive tasks. Participants were allowed to take a few minutes break between the two parts of the experiment. The experiment had been piloted twice before the start of the data collection.

1 The two behavioural measures had been very kindly offered by Laura Babcock, a researcher at the Department of Neuroscience at Karolinska Institutet. She had used the two tasks in her recent study on professional interpreters. (Babcock and Vallesi, 2017).
3.2.1 Attentional Network Task

The first task used was the Attentional Network task (henceforth, ANT). The ANT is a modified version of the traditional flanker task (Eriksen & Eriksen, 1974) and it was originally designed by Fan, McCandliss, Sommer, Raz and Posner (2002). In this version of the task, adapted from Babcock and Vallesi (2017), the participant sees a row of five black arrows on a white screen, and has to indicate the direction of the central arrow only by pressing either the left or the right arrow key on the keyboard. The direction of the external four arrows could be either congruent (same direction as the central arrow) or incongruent (different direction). Moreover, the row of arrows could appear either above or below a centre of fixation (a cross sign, always in the centre of the screen) and four possible cues could appear before the target stimuli:

- no cue, the participant sees the cross sign only;
- central cue, the participant sees an asterisk instead of the cross sign, in the centre of the screen;
- double cue, the participant sees the cross sign and two asterisks -both above and below the cross sign;
- spatial cue, the participant sees the cross sign and one asterisk -either above or below the cross sign, where the central arrow will appear.

The configuration of the experimental paradigm is illustrated in the figure below. The image is from Wang, Guo and Zhou (2016), a study on attentional networks of table tennis athletes.

Figure 1. Configuration of stimuli (ANT)
The ANT comprises two experimental blocks with an equal number of trials (128 trials each). The two experimental blocks were separated by a short break. The first experimental block was preceded by a practice block including eight trials, one for each possible combination. For each trial, the participants looked at the cross sign for 400ms and then they looked at one of the four different types of cue for 100ms, followed by the cross sign again for 400 ms. Immediately after, the row of arrows appeared on the screen, and it remained until the participant made a decision during a maximum of 1700 ms. Before starting the task, participants were asked to carefully read the instructions, displayed on the computer screen, and they were told that they were allowed to ask for further explanations if needed. The instructions were in English. This test analyses three independent attentional networks: alerting, orienting and executive attention, which are defined by Fan et al. (2002) as follows: “Alerting consists of achieving and maintaining the alert state; orienting is the selection of information from sensory input; and executive control is defined as resolving conflict among responses” (Fan et al. 2002 p 340)

Following Babcock and Vallesi’s (2017) design, the alerting effect is analysed by subtracting the mean reaction time of the double cue trials from the mean reaction time of the no cue trials. The orienting effect is measured by subtracting the mean reaction time of the spatial cue trials from the mean reaction time of the central cue trials. Finally, the conflict effect is examined by subtracting the mean reaction time of the congruent trials from the average reaction time of the incongruent trials. The measures of these effects would respectively indicate the alerting, orienting and executive networks of attention. The rationale behind this task is that smaller effects in the multilingual group compared to the bilingual group would reveal an advantage for the former with regards to the three networks of attention. Importantly, in accordance with the design used in the study by Babcock and Vallesi (2017), in order to increase the feasibility of finding a significant conflict effect, the number of congruent trials was much higher than the number of incongruent trials. Nevertheless, the four different types of cue were evenly distributed throughout the task creating eight different conditions, presented to the participants in a counterbalanced order.
3.2.2 Colour-Shape Switching Task

The second task used in this study is the Colour-Shape Switching Task, also adapted from Babcock and Vallesi (2017). The test examines the cognitive ability of set-shifting by looking at the mixing costs and the switching costs, representing the sustained control and the transient control, respectively. According to a study by Braver, Raynolds and Donaldson (2003), the two control systems not only activate two separate regions of the brain but also represent two substantially different types of skill. Explicitly, the sustained control is measured through the mixing costs, which are more informative of the ability to maintain active multiple tasks at the same time and to increment responsiveness to the given cues. On the other hand, the transient control is examined through the switching costs, which refer to the ability to promptly change the entire task and/or the specific goal.

In this task, the participants looked at four different types of stimuli:

- a red heart;
- a blue heart;
- a red star;
- a blue star.

Similarly to the first task, the participants were asked to make left or right decisions by clicking on the left or right arrow keys on the keyboard respectively. According to the instructions, they had to make such decision depending on either the colour or the shape of the visual stimulus.

The task consisted of three different types of blocks: colour/ shape / mixed. In the mixed blocks, the participant had to make a left/right decision according to a visual cue located above the stimulus:

- a row of black shapes indicated that the participant had to make a decision about the shape of the stimulus;
- a row of coloured rectangles indicated that the participant had to make a decision about the colour of the stimulus.

The colour and the shape blocks consisted of single trials only, while the mixed block included repetition and switching trials for a total of 264 trials. When examining and comparing three different trial types, it is possible to measure the mixing cost and the switching cost. In particular, the difference in mean reaction times between the repetition trials and the switch trials reveals the switching cost, whereas the difference in mean
reaction times between the repetition trials and the single trials reveals the mixing cost (Babcock and Vallesi, 2017).

Similarly to the Attentional Network task, the rationale behind the Colour Shape Switching task is that smaller costs, both switching and mixing costs, for the multilingual groups would reveal an advantage in the component of executive functioning related to the task, namely set-shifting, for multilinguals over bilinguals in terms of the transient control and the sustained control.

Each trial started with the same fixation cross sign as in the first task, always presented in the centre of the screen, which remained on the screen for 1500 ms. It was then followed by the visual stimulus which remained on the screen until the participant made a decision by clicking on either the left or the right arrow keys. During the performance of this second task, participants were asked to wear the headphones because mistakes were indicated by a beep (100 ms). The task was designed in a way that the system of counterbalance affected not only the order the in which the different conditions were presented in the single blocks, but also the instructions (e.g. red=right/left) and the order in which the participants had to complete the different types of block. The participants were first asked to read the instructions displayed on the computer screen carefully. They were allowed to ask for further explanation if needed. The instructions were in English.

4. Results

4.1 Attentional Network Task

Independent t-tests were run to statistically investigate the differences between the bilingual group and the multilingual group in relation to the alerting, orienting and conflict effects measured in this task. The results of this part of the experiment are shown in Table 1.

Table 1:
Group comparisons of mean RTs (ms) on the Attentional Network Task

<table>
<thead>
<tr>
<th></th>
<th>Bilinguals</th>
<th>Multilinguals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central cue</td>
<td>438.1076 (35.11925)</td>
<td>491.8089 (86.74608)</td>
</tr>
<tr>
<td>Double cue</td>
<td>443.5258 (35.80832)</td>
<td>488.331 (77.66593)</td>
</tr>
<tr>
<td>Condition</td>
<td>Mean Reaction Time</td>
<td>Standard Deviation</td>
</tr>
<tr>
<td>-------------------</td>
<td>--------------------</td>
<td>--------------------</td>
</tr>
<tr>
<td>No cue</td>
<td>453.3349 (48.16773)</td>
<td>502.5187 (91.29343)</td>
</tr>
<tr>
<td>Spatial cue</td>
<td>434.5636 (37.4671)</td>
<td>475.1002 (81.04042)</td>
</tr>
<tr>
<td>Congruent</td>
<td>420.8403 (44.46242)</td>
<td>467.1295 (85.59566)</td>
</tr>
<tr>
<td>Incongruent</td>
<td>504.4765 (31.14633)</td>
<td>553.7455 (78.33596)</td>
</tr>
<tr>
<td>Orienting Effect</td>
<td>3.543938 (9.826072)</td>
<td>16.70862 (25.31902)</td>
</tr>
<tr>
<td>Executive Effect</td>
<td>77.42082 (37.13894)</td>
<td>85.9647 (18.44523)</td>
</tr>
</tbody>
</table>

(standard deviations in parentheses)

The difference between the mean reaction times of the no cue trials and the mean reaction times of the double cue trials was used to calculate the alerting effect. The statistical analysis showed no significant difference between the two groups, bilinguals (M = 9.80909, SD = 14.80205), multilinguals (M = 14.18766, SD = 21.82959): t(22) = 0.544, p = 0.59217.

The orienting effects were measured as the difference between the mean reaction times of the central cue trials and the mean reaction times of spatial cue trials. The difference between the mean orienting effect of the bilingual group (M = 3.543938, SD = 9.826072) and the multilingual group (M = 16.70862, SD = 25.31902) was not statistically significant: t(22) = -1.55007, p = 0.136066.

Finally, the executive effects were calculated by subtracting the mean reaction times of the congruent trials from the mean reaction times of the incongruent trials for each individual. The statistical analysis revealed no significant difference between the mean conflict effects of the bilingual group (M = 77.42082 SD = 37.13894) and the multilingual group (M = 85.9647 SD = 18.44523): t(22) = -0.72473, p = 0.476614.

Comparisons of the mean alerting, orienting and conflict effects by groups are reported in Figure1.
On the whole, the results suggested that the two groups did not differ in any of the three attentional effects examined by the task.

4.2 Colour Shape Switching Task

The same statistical tool was used to analyse the results of the second task. Independent t-tests were used to examine the differences in the switching and mixing costs between the bilingual group and the multilingual group. Table 2. shows the results of this second part of the experiment and it includes the mean reaction times of all the different trial types and the relative costs.

<table>
<thead>
<tr>
<th></th>
<th>Bilinguals</th>
<th>Multilinguals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Repetition trials</td>
<td>918.1747 (314.0926)</td>
<td>1061.523 (309.8842)</td>
</tr>
<tr>
<td>Single trials</td>
<td>474.1469 (47.96285)</td>
<td>519.0432 (92.18148)</td>
</tr>
<tr>
<td>Switch trials</td>
<td>1043.355 (323.1936)</td>
<td>1252.199 (365.6765)</td>
</tr>
<tr>
<td>Switching cost</td>
<td>125.1799 (44.1069)</td>
<td>190.6753 (193.6468)</td>
</tr>
<tr>
<td>Mixing cost</td>
<td>444.0278 (279.0122)</td>
<td>543.6573 (258.5518)</td>
</tr>
</tbody>
</table>
Switching costs were calculated through the subtraction of the mean reaction times of the repetition trials from the mean reaction times of the switch trials. A statistical analysis revealed that the difference between the mean switching cost of the bilingual group (M = 125.1799, SD = 44.1069) and the mean switching cost of the multilingual group (M = 190.6753, SD = 193.6468) was not significant: t(22) = -1.04361, p = 0.308531.

Similarly, the difference between the mean mixing costs of the bilinguals (M=444.0278 SD=279.0122) and of the multilinguals (M=543.6573, SD=258.5518), calculated by subtracting the mean reaction time of the single trials from the mean reaction time of the repetition trial, appeared not to be statistically significant: t(22) = -0.88543, p = 0.385954.

Comparisons of the mean mixing and switching costs by groups are reported in Figure 2.

Figure 3. Switching and Mixing costs by groups (ms)

Ultimately, the results of the switching task revealed no difference between the multilinguals and the bilinguals in either of the two costs investigated in the task.

5. Discussion

The overall results of the study revealed no significant advantage in any of the subcomponents of executive processing examined through the two tasks. In the same way, the alerting, orienting and executive effects, as well as the mixing and the switching costs,
were measured by subtracting the mean reaction times of the facilitating trial, in which the majority of the participants were faster, from the mean reaction times of the respective misleading trials. The differences were then analysed and compared by groups using 5 separate independent t-tests. The results of the statistical analysis confirmed that the bilingual group and the multilingual group performed very similarly and although a very small difference in mean reaction times between the groups could be noticed (figures 1 and 2), no differences were statistically significant. In other words, before the statistical analysis, an apparent small multilingual disadvantage could be spotted by simply looking at the figures: in both tasks, the reaction times appeared to be slightly longer in the multilingual group than in the bilingual group across the board, meaning that the effects of the ANT and the costs of the Colour Shape switching task were slightly more prominent for the multilingual group compared to the bilingual group. At first glance, the results appeared to reveal an overall negative result. However, the apparent bilingual, rather than multilingual advantage was non-significant and it remained so even when potential outliers were removed from the dataset. These findings can only lead to one possible speculation: the cumulative executive advantage speculated by Bialystok et al. (2012) and Diamond (2010) does not seem to be in line with the present study, at least not in terms of attention and switching skills.

Although it might be true that the present study only looked at two of the subcomponents of executive processing, they were the same two that in the past have shown more consistent positive findings in relation to the bilingual advantage. As explained by Lehtonen et al. (2018), in fact, the studies on attention and set-shifting seem to be less subjected to the publication bias. The question of a multilingual advantage that has been raised in this study, is in fact based on the assumption of the existence of the bilingual executive advantage in the first place. It functions as a sort of extension of the BEA hypothesis itself. However, as seen in the literature review section, a growing number of studies are reporting null results in terms of no differences between performances of groups of bilinguals and monolinguals either. Accounting for all these findings together with the results of the present study, it can be speculated not only that it is not easy to observe any bilingual executive advantage in a consistent way, but also that, not very surprisingly, a multilingual advantage is not easy to observe either.

Another key point is the choice of testing young adults, as at that stage of their life humans can benefit from their cognitive abilities being at their maximum strength. Indeed,
consistent with the previous literature, the present study found no difference in any of the performances of the multilingual and bilingual young adults. The only conclusion this type of outcomes allow for is that the constant work multilinguals do in order to manage and monitoring several additional languages does not reliably provide any attentional nor set-shifting aid, or if it does, it is not strong enough to be observed, not even through complex cognitive tasks.

5.1 Limitations

The study has some limitations. First, it would have been interesting to compare the two groups of bilingual and multilingual participants with an additional group consisting of monolingual people. This move would have provided the study with a control group and a comparison of a monolingual sample’s performance on the same tests would have been useful in understanding whether the absence of a multilingual advantage shown by the results means that multilinguals have the same advantage as the bilinguals in relation to the monolinguals or whether there is simply no difference and therefore no advantage at all for any of the three groups. Therefore, the presence of a monolingual sample as a control group would have added important value to the study. However, the absence of a control group was not purposely part of the design and it was actually determined by an external factor: an almost complete absence of monolingual students or young adults in the area of Stockholm. The education system in Sweden, just like in the majority of countries in the world, provides their students with high-quality courses on foreign languages, thus, everyone who was eligible for the participation in the study knew at least one L2 (second language) at a very high level of proficiency. In addition, Stockholm University is characterized by a very high percentage of international students, which means that a great part of the students attending courses at Stockholm University has a different mother tongue than Swedish, a certified high proficiency of the English language, as it is required by the university and most likely some knowledge of Swedish and/or other languages.

Under those circumstances, not only is it almost impossible to find a student who speaks only one language, but it is also very unlikely to find pure bilinguals either. For this reason, almost every participant who was assigned to the bilingual group had some basic knowledge of a third or even a fourth language. This is one of the reasons why the criterion for the assignment of the participants to each of the two groups had to be limited
to the functional fluency questionnaire. One possible limitation of this study is, therefore, that the even the languages in which the bilinguals have classified themselves as non-functionally fluent by responding "yes" to less than 7 questions in the questionnaire, might have had some influence on the final results. On the other hand, excluding the bilingual participants who had basic knowledge of further languages would have resulted in a bilingual group of only two participants.

Furthermore, another reason why functional fluency was chosen as the criterion to control for the number of proficient languages is that it would have been almost impossible to officially assess the proficiency of each language for each participant in the given time. An alternative way to assess the participants' proficiency might have been a self-assessed proficiency test, similar to the one used in Paap and Greenberg (2013), in which participants had to rank their level of proficiency using a 7 point scale. The participants were assigned to either the bilingual or the monolingual group according to the number of languages they had classified themselves as advanced-intermediate or above. However, self-assessed proficiency tests could be considered not very reliable as the responses might be influenced by the speaker's personal self-esteem and confidence. In addition, the scale used in their study focused exclusively on the participants’ listening and speaking skills. For the same reason, the present study had no control for language pairing, neither in the bilingual group nor in the multilingual group. The languages spoken by the participant were various and it would have been very challenging to find the same language pairs spoken by a number of participants substantial enough to conduct a statistically relevant investigation.

Another key point is that the choice of selecting exclusively students from Stockholm University is a double-edged sword. On one hand, it is justified and motivated by the need to match the participants as much as possible. Those who participated in this study, in fact, were not only studying at the same university but the majority of them were also from the same department of studies. As mentioned above, this characteristic was used as an indirect measure of their educational level. On the other hand, university students are not exactly the most accurate representation of the multilingual and bilingual population of the world.

By the same token, the number of participants is perhaps too small and slightly unbalanced between the two groups in comparison to other studies on this topic. The
study by Duñabeitia et al. (2014), for instance, tested a cohort of 504 bilingual and monolingual children, whereas the present study examined a total of 23 young adults. However, it has to be taken into consideration that they were all non-paid volunteers and the maximum length of the period dedicated to the data collection was limited to less than 30 days. If seen from a different point of view, this is actually a valid characteristic of this study because it allows controlling for the claim that has been made (e.g. in Bialystok, 2017) that, in general, smaller samples are more likely to show positive results regarding the bilingual advantage. Nevertheless, although this study comprises a quite small sample of the bilingual and multilingual population, its results are null and they suggest that the effects of multilingualism on attention and set shifting are non-existing and that speaking multiple languages does not add anything to these two subdomains of cognition in comparison to bilingualism. On the whole, all these limitations might raise a question of generalizability of the study.

6. Conclusion

The aims of the present study were to explore the possible effects of multilingualism on a set of subdomains of executive processing in young adults. In this case, in fact, the bilingual executive advantage hypothesis was not the direct object of the investigation and the focus was to investigate the feasible different effects, possibly cumulative executive benefits, that further languages might provide. As mentioned in section 2, this idea was also proposed in Diamond (2010) and Bialystok et al. (2012). In this work, the term multilingualism is defined as the knowledge of three or more highly functionally fluent languages. The design of the study followed the tradition of the research on the BEA hypothesis. A sample of the bilingual and multilingual population of Stockholm University was tested on two online cognitive measures. Participants were matched not only according to the number of languages but also on age and on educational level. The online tasks tested two of the six components that constitute the executive processing: attention and set-shifting (see Literature Review section). The results of the Attentional Network task allowed for three different attentional networks to be examined, each serving a different scope. The alerting network, related to the ability to reach and preserve the alert state, the orienting network responsible for the selection of informative input and a more general executive network, related to the ability to manage conflict between
facilitating and misleading responses. The Colour-Shape switching task, on the other hand, examined two control systems related to the set-shifting skill, the transient control and the sustained control.

A sample of 23 bilingual and multilingual young adults studying at Stockholm University were tested on two online cognitive tasks tapping on the cognitive abilities of attention and set-shifting. The Attentional Network task examined the alerting network, the orienting network and the executive network. The Colour-Shape switching task measured the transient control and the sustained control. The participants from the multilingual group performed very similarly to the participants from the bilingual group in all the measures. Although a small advantage was noticeable for the bilingual group, none of the comparisons between the two groups reached significance. Therefore, the study suggested that there is no difference between the effects provided by bilingualism and multilingualism. To a certain extent, the study replicated and confirmed the results of the most recent studies on the Bilingual Executive Advantage Hypothesis, showing that speaking several languages do not provide people with any cognitive gain, at least not in terms of attention and set-shifting.

Considering the uncertain nature of the bilingual advantage hypothesis in general, further investigations are definitely necessary in order to fully understand the issue. Future studies could take two different but equally valuable paths. On one hand, the kind of cross-sectional, naturalistic design that has been presented in this paper would benefit from taking into consideration the factors strictly related to the linguistic aspects of bilingualism that might influence the results. To point out, the participant’s proficiency should be tested using more precise and official measures, the number of languages spoken in each group should be more carefully matched and in a future study, bilingual participants who know some basic aspects of a third language should be excluded from the experiment. A monolingual control group would be necessary to account for both the effects of bilingualism and multilingualism and more tasks.

Another possibility would be the one suggested by Laine and Lehtonen (2018), who propose a longitudinal, intervention design over a natural, crosssectional design. In the specific, this other type of study would account for the problem of double causality and the possibility for the results to be interpreted in two ways. On one hand, it could be the exercise of managing more than one language at the same time to give beneficial effects
to the various components of cognitive functioning. Nevertheless, it could also be possible that bilingual and multilingual people might have superior cognitive abilities and because of this, they would be better at acquiring languages. For instance, Laine and Lehtonen (2018) suggest testing two groups of students who would start learning a new language in different moments of their academic career: one group would start taking language classes in the first year while the control group would start during the second year. If the experiment takes place before the control group starts learning the foreign language, an intervention design like this would be able to control for all the factors that usually differentiate the various types of bilingualism that tend to influence the results such as proficiency, number of languages, language pairing and age of acquisition.

References


Appendix: Questionnaire

Please list all the foreign languages you have studied or know.
For each language, please answer to the following question with that language in mind. When was the last time you used this language?

Now, for each language, please answer yes or no to the following questions with that language in mind.

1. Do you know the A1, A2, B1 etc. system of classifying language levels? If yes, what is your level in this language?
2. Could you discuss a topic in which you are not an expert, such as politics, in this language?
3. Can you understand news programs in this language?
4. Could you read a novel or short story for pleasure in this language?
5. Could you tell a story about events in the past, present, and future to a group of people in this language?
6. Could you write a letter in this language to a friend about an important event in your life and how it affected you?
7. Would you be able to understand an announcement about a canceled train in this language and follow the directions given about where to refund or change your ticket?
8. Could you write an essay in this language on a work of literature?
9. Could you understand a textbook passage on your field of study in this language?