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THE EFFECTS OF BILINGUALISM AND MULTILINGUALISM ON EXECUTIVE FUNCTIONS*

OS EFEITOS DO BILINGUISMO E DO MULTILINGUISMO NAS FUNÇÕES EXECUTIVAS

LOS EFECTOS DEL BILINGÜISMO Y DEL MULTILINGÜISMO EN LAS FUNCIONES EJECUTIVAS

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RESUMO: Pesquisas têm constatado que bilíngues e multilíngues tem desempenho superior em comparação com monolíngues em tarefas não linguísticas que envolvem processamento executivo. Contudo, os estudos sobre vantagem bilíngue ou multilíngue em tarefas linguísticas são mais escassos, e os resultados, menos consensuais. No Brasil, os benefícios das funções executivas no bilinguismo não têm sido consistentemente identificados nas populações bilíngues, sobretudo nos falantes da língua minoritária Hunsrückisch (uma variedade da língua alemã). O objetivo geral deste estudo foi investigar o desempenho de adultos bilíngues e multilíngues, falantes de Hunsrückisch comparados a monolíngues, numa tarefa não linguística, a *Attentional Network Task*, e numa tarefa linguística, a Tarefa de Compreensão de Frases. Os resultados demonstram que os multilíngues foram mais rápidos do que os monolíngues na tarefa não linguística. Os resultados da tarefa linguística, em parte, mostram que os monolíngues tiveram mais facilidade em inibir a interferência linguística.

PALAVRAS-CHAVE: Bilinguismo; Multilinguismo; Processamento Executivo; Línguas Minoritárias.

RESUMEN: Investigaciones encontraron que bilingües y multilingües tienen un rendimiento superior en comparación a monolingües en tareas no lingüísticas de procesamiento ejecutivo. No obstante, las investigaciones sobre ventaja bilingüe y multilingüe en tareas lingüísticas son más escasas y los resultados son menos consensuales. En Brasil, los beneficios del bilingüismo en las funciones ejecutivas no se encuentran efectivamente, incluso en los hablantes de la lengua minoritaria Hunsrückisch (una variedad de la lengua alemana). El objetivo general de esta investigación es buscar el rendimiento de adultos bilingües y multilingües hablantes de Hunsrückisch en una tarea no lingüística, la *Attentional Network Task* y en otra lingüística, la Tarea de Comprensión de Frases, y compararlos con monolingües. Los resultados demuestran que los multilingües hicieron más rápido la tarea no lingüística que los monolingües. Parte de los resultados de la otra tarea enseñan que los monolingües tuvieran más facilidad de inhibir la interferencia lingüística.

PALABRAS CLAVE: Bilingüismo; Multilingüismo; Procesamiento ejecutivo; Lenguas minoritarias.

ABSTRACT: Studies have shown that bilinguals and multilinguals have superior performance compared to monolinguals in nonlinguistic tasks that tap into executive functioning. However, studies of bilingual and multilingual advantages in linguistic tasks are fewer and the results are less consensual. In Brazil, the positive effects of executive functions in bilingualism have not been consistently identified in the bilingual populations, especially in speakers of the minority language Hunsrückisch (a German dialect). The main goal of this study was to investigate the performance of bilinguals and multilinguals speakers of Hunsrückisch compared to monolinguals in a nonlinguistic task, the Attentional Network Task, and in a linguistic task, the Sentence Comprehension Task. The results show that multilinguals were faster in comparison to monolinguals in the nonlinguistic task. The results for the linguistic task, in turn, show that the monolinguals had more facility to inhibiting the linguistic interference.

KEYWORDS: Bilingualism; Multilingualism; Executive Functioning; Minority Languages.

1 INTRODUÇÃO

The cognitive advantages of bilingualism/multilingualism have been investigated by several researchers (e.g., BIALYSTOK et al., 2004; BIALYSTOK et al., 2008; COSTA; HERNÁNDEZ; SEBÁSTIAN-GALLÉS, 2008; LAUCHLAN, PARISI; FADDA, 2013; POARCH; VAN HELL, 2012). One of the main objectives of the studies is to identify the positive effects of bilingualism on human cognition, especially

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executive functions (an umbrella term for functions such as planning, working memory, inhibition, mental flexibility, as well as the initiation and monitoring of action (CHAN et al., 2008)).

The phenomenon of bilingual advantage is primarily found in early bilinguals and suggests that something about the unique bilingual language experience gives rise to improvements in more general executive processes. According to Bialystok, Craik and Luk (2012), lifelong experience in managing attention to two languages reorganizes executive functions, creating a more effective basis and sustaining better cognitive performance throughout the lifespan. Bialystok and colleagues (2009) have reported robust evidence that the bilingual experience has a systematic and significant impact on cognitive functioning.

The most parsimonious explanation for the bilingual advantage for executive functions is that bilinguals are often in situations in which selection and conflict resolution are required: bilinguals must select one language and inhibit another. The bilingual advantage is identified in faster reaction times for nonlinguistic tasks (identifying whether an arrow is pointing in the direction congruent or not with a set of arrows, for example). They are better at handling situations that involve mixing trials of different types, for example, in experimental contexts that have congruent and incongruent items in the same block (COSTA et al., 2009).

The bilingual advantage has been robustly identified in studies with nonlinguistic tasks; but there is a lack of studies that identify the positive effects of bilingualism in linguistic tasks, especially in tasks that investigate executive functions and auditory comprehension (FILIPPI et al., 2012). The bilingual advantage has been identified in tasks in which competing auditory stimuli has to be suppressed for successful comprehension of target stimuli. Studies have yet to establish a more clear relation between advantages in comprehension processes and in executive functions in bilinguals (BLUMENFELD; MARIAN, 2011).

In Brazil, research on the cognitive aspects of bilingualism and multilingualism is still incipient. Researchers (for example Billig (2009) and Kramer (2011)), have investigated Brazilian speakers of the German variety called Hunsrückisch (ALTENHOFEN, 1996), a minority language in the Brazilian context. The positive effects of bilingualism on executive functions, found in bilinguals around the world, have not been consistently identified in this group of Brazilian bilinguals. Therefore, it is necessary to carry out more research with linguistic and nonlinguistic tasks that tap into executive functions to evaluate this population.

The present study aims to investigate the performance of bilinguals and multilinguals on executive function tasks. We carried out two studies, the first study was aimed at investigating nonlinguistic abilities, the Attentional Network Task (ANT). This task was developed by Fan et al. (2002) and was used by Costa and his colleagues (2008 and 2009) for evaluating bilinguals. The other task, in turn, was aimed at investigating linguistic abilities, the Sentence Comprehension Task (SCT). It is based on Filippi et al. (2012), who developed the linguistic task with auditory stimuli. We evaluated the response times (RTs) and the accuracy of bilinguals, multilinguals and monolinguals in these tasks.

2 THEORETICAL FRAMEWORK

In this section, we review and discuss the main characteristics of what it means to be bilingual and multilingual, and establish the definition of the construct executive functions. Finally, we review studies on the positive effects of bilingualism and multilingualism on the executive functioning in nonlinguistic and linguistic tasks.

2.1 Bilingualism and multilingualism

Bilingualism is present in the most countries, in every social classes, and age groups. Bilingualism is thus a common, worldwide phenomenon (BUCHWEITZ; PRAT, 2013). As the authors explain, data by the European Commission show that over half of European can hold a conversation in at least one additional language, and approximately a quarter are able to speak at least two additional languages. Bialystok et al. (2009) argue that the bilingualism is the rule, not the exception. Therefore, it makes sense to investigate the phenomenon of bilingualism in relation to its social, cultural, linguistic and cognitive consequences.

Bilingualism is complex and multifaceted; the makeup of bilingualism involves a several factors that "make the bilingual experience deeply heterogeneous" and that "potentially alter its consequences" (BIALYSTOK et al., 2009, p. 90). The word *bilingualism*, therefore, does not refer to a uniform set of features, but can be assessed along a continuum of the level of skill development and the frequency of use of the language (BUCHWEITZ; PRAT, 2013).

The definition of bilingualism is controversial. Early studies of bilingualism defined this population according to their abilities in each language, as if they were one person who had to achieve monolingual-like proficiency in two languages. Grosjean (2008) argues that this monolingual view of bilingualism creates a standard for bilingualism that is practically unachievable. This author considers bilinguals "those who use two and more languages (or dialects) in their everyday lives" (GROSJEAN, 2010, p. 22). The emphasis is put on the regular use of the languages and not on language skills, such as pronunciation, which are at times unachievable compared to monolinguals.

The study of multilingualism is even more recent than the one of bilingualism. In this study, in order to differentiate between the groups of participants, we defined *bilinguals* as speakers of two languages, and *multilinguals* as speakers of three or more languages. The language of interest in multilingualism will be referred to as L3 regardless if it is the third, fourth, or sixth language they have acquired (DE ANGELIS, 2007). In this sense, investigating multilingualism contributes to the understanding of the effects of multiple languages on human cognition because learning an L3 is different from learning a first or second language. L3 learners have more linguistic experience with acquisition or learning of another language than second language learners. These learners usually have developed more learning strategies and higher levels of metalinguistic awareness (CENOZ, 2003).

2.2 Executive functions

The term *executive function* (EF) refers to a complex cognitive construct that involves a set of processes underlying controlled, goal-directed responses to novel or difficult situations (HUGHES, 2005). They are also essential for cognitive processes and behavioral competences and they are associated with the performance of goal-related behavior (GAZZANIGA, IVRY; MANGUN, 2006); for example, the ability to perform tasks that involve suppression of unnecessary or distracting streams of information while focusing on one source of pertinent information involves executive function.

Executive functions involve processes that help organize goal-directed actions. These functions are fundamental for, for example, tasks that involve switching attention between them (such as switching between languages in a bilingual community). Miyake et al. (2000) proposed three primary, or fundamental, EF: *shifting*, *updating* and *inhibition*. The first function relates to mental set shifting (e.g., in the Iowa Gambling Task the participants have to sort the cards between sorting principles); the second one is closely linked to the working memory, which requires monitoring and coding incoming information for relevance to the task; and the last function involves inhibition of irrelevant stimuli.

These three functions are separable constructs; they contribute differently to the performance of complex executive tasks. Though the proposed fundamental executive functions are separable, the abilities to shift, update and inhibit information are interrelated at some level: the ability to shift from one set of rules to another while performing the well-known Iowa Gambling Task (BECHARA et al., 2005) is also, at some level, associated with the ability to update the set of rules, and inhibit the previous rule identified for the selection of cards.

Maintaining the coherence and temporal organization of goal-directed actions is underpinned by prefrontal cortex function. The organization of actions in time (the most general characteristic of prefrontal functions) depends on prefrontal cortex (PFC) function (FUSTER, 2008). The PFC connects the motor, perceptive and limbic regions; it coordinates processing across large regions of the central nervous system (GAZZANIGA, IVRY; MANGUN, 2006). According to Hughes (2005), it is now known that EF: (i) begin to emerge in the first years of life; (ii) mature in late adolescence and decline with aging; (iii) sub-divides in children and adults in similar ways (in each case the three most widely reported factors are inhibitory control, shifting, and updating) (iv) have important consequences for other cognitive functions (such as attentional system and working memory).

Costa, Hernández and Sebástian-Gallés and (2008) postulated that, the executive functions are seem to be more closely affected by bilingualism; it is involved in choosing the appropriate action in relation to a goal, such as communication in different languages. Bilingualism researchers have also investigated the role of inhibitory control in relation to cognitive functions that may be better-developed by the bilingual population. Inhibitory control is related to cognitive flexibility: Miyake et al. (2000) proposed that inhibitory control is related to the ability to deliberately inhibit a dominant or automatic response when needed. A prototypical inhibitory control task is the Stroop Task, in which the participant must inhibit or override the tendency to produce the most dominant or automatic response, i.e., naming the ink color of the font of a word while the word itself is the name of another color (e.g., naming the color of the word "blue" written in red font). In sum, there seems to be a relationship between speaking two or more languages and the EF.

2.3 Empirical studies of the effects of bilingualism and multilingualism on executive functions

One of the hotbeds of empirical studies of second language acquisition is the investigation of the effects of bilingualism on participants' performance on tasks of cognitive assessment. Below, we address studies carried out with bilinguals abroad and in Brazil. Most studies identified of the bilingual executive function advantage compared to monolinguals. We also review studies with multilinguals and with linguistic tasks.

2.3.1 Studies with nonlinguistic tasks

Bialystok et al. (2004) carried out one of the early studies that aimed to investigate whether older bilingual groups (adults and elderly) would show cognitive benefits associated with EF. The researchers compared early bilinguals from Indian and Hong Kong with Canadian monolinguals and found bilingual advantages (in Simon Task performance) in all bilingual groups, cross-culturally. The authors carried out a second study in which Simon Task had more trials compared to study 1 (192 compared to 28). In the study, the bilingual advantage persisted. The study has served as a basis for other bilingual studies, including those performed by Brazilian.

Later studies corroborated the results from Bialystok et al. (2004), i.e. the advantage of bilingual adults and seniors in performance on Simon Task (BIALYSTOK et al., 2008). Researchers have also applied other tasks, such as the Stroop Task and flank tasks, such as the ANT. These tasks had congruent and incongruent trials, and the participant have to deal with the alternating of the trials. Costa, Hernandez and Sebástian-Gallés (2008) explain that differences in the efficiency of the executive network would be more evident under high processing demands, as the use of the languages in bilingual conversations in which two languages are used with different interlocutors. In these conversations, as Costa et al. (2009) explain, the speakers need to keep in mind what language to speak and to whom; this language control may involve monitoring processes of the type involved in executive functioning in general.

A study by Lauchlan, Parisi and Fadda (2013), is of special relevance for the present paper. The study was carried out with speakers of minority languages: bilinguals from Sardinia (Italy) and Scotland. When evaluating the bilingual groups, the researchers found that bilingual children from Scotland and Sardinia were faster than their monolingual counterparts on the Block Design (an inhibitory control task). However, the difference between bilingual and monolingual children from Sardinia was not significant. The authors explain this difference based on the level of bilingualism of Scottish children who receive formal education in the minority language. On the other hand, children from Sardinia receive formal education only in Italian and their second language is predominantly used in the oral form.

The studies reveal that bilingualism can have significant consequences for cognitive performance (BIALYSTOK, 2009). However, studies conducted by Brazilian researchers have not successfully replicated this finding. Brazilian researchers have investigated mainly the southern population of bilinguals, who are speakers of minority languages (Hunsrückisch, Pomeranian and Veneto).

Although the methods of the Brazilian studies are similar to the Canadian ones, the bilingual advantage has been not always found. Three Brazilian studies found no significant differences between early bilinguals and monolinguals; though they did identify that there was a tendency of faster performance among bilinguals. The first study was carried on by Pinto (2009), who evaluated Portuguese and Hunsrückisch bilinguals performing a nonlinguistic task (Simon Task). Billig (2009) applied the Simon and Stroop Tasks, also nonlinguistic. Either study did not identify a significant bilingual advantage. The study carried out by

Kramer (2011) showed similar results: and the results showed no bilingual advantage among early bilinguals compared to their monolingual counterparts. However, the late bilingual speakers of Portuguese and English showed significantly faster response times than their monolingual peers in the task.

In the absence of finding convincing bilingual advantage results, Billig (2009) hypothesized that the lower level of schooling of the bilinguals, compared to the Canadian ones, could have been a factor associated with the absence of bilingual advantage. Kramer (2011), in turn, postulated additional factors that may have influenced the results: the absence of literacy practices in Hunsrückisch and the low proficiency in reading and writing in the Hunsrückisch language, which is mainly used in oral form.

The inconsistent results suggest that it is still not possible to determine the precise circumstances in which the bilingual advantage is found. Hilchey and Klein (2011) formulated two hypotheses in this sense: BICA (Bilingual advantage inhibitory control) and BEPA (Bilingual executive processing advantage). According to the first hypothesis, the frequent use of inhibitory processes involved in language selection in bilingual result in more efficient processes, which confers advantages in tasks that require conflict management. In contrast, the BEPA hypothesis proposes that bilinguals enjoy advantages in the general domain of executive functioning, as indicated by superior performance in all conditions (congruent and incongruent) in tasks with no linguistic interference. This hypothesis involves monitoring and managing the trial to trial variation regarding the presence or absence of conflict; it is associated to the bilingual advantage on global RTs and not the interference effect.

According to Costa et al. (2009), bilinguals can more efficiently go back and forth between stimuli that require dealing with conflict resolution. Indeed, bilinguals seem to be faster than monolinguals in experimental contexts that involve congruent and incongruent items in the same block. The ability to successfully alternate between stimuli involves monitoring processes required to implement mechanisms for conflict resolution, when it is needed.

In sum, speakers of two languages deal with high levels of competition between languages. In this sense, we might ask: The speaker of three or more languages deals with even higher levels of linguistic competition? The trilingual/multilingual advantage would thus be greater compared to that shown in bilinguals? These questions require answers, according to Bialystok and Craik (2010), which may be found in the investigation of speakers of one, two or more languages.

2.3.2 Studies with linguistic tasks

As described above, several studies have found advantages in bilinguals over monolingual in tasks involving executive functions. Most studies investigated executive functions using nonlinguistic tasks. According to Filippi et al. (2012), few studies have considered the performance of bilinguals in tasks with linguistic stimuli. For the purpose of this paper, we review only the studies with linguistic and auditory stimuli (which are pertinent in comparison to the task used in the present study).

Studies show that bilinguals may have advantage over monolinguals in tasks with linguistic stimuli (BLUMENFELD; MARIAN, 2011; FILIPPI et al, 2012). The advantage is shown in tasks in which interference must be suppressed for successful processing of the target stimulus. In all studies, researchers were able to simulate the linguistic competition that happens in bilingual environments.

In order to investigate listening comprehension with competition between two languages, Blumenfeld and Marian (2011) developed a priming experiment. Participants listened to the words in their first language (English) and identified the target word in four figures. Each target picture appeared (e.g., hamster) with a distractor, which has a similar sounding word in the same language (e.g., hammer) and two neutral pictures. In this task, the eye movements were tracked. Results show that bilinguals may return to a baseline activation state faster than monolinguals after inhibiting irrelevant information. Bilinguals managed to completely inhibit the distractors.

Filippi et al. (2012) investigated the comprehension of syntactically canonical and non-canonical sentences, with or without linguistic interference[1]. The canonical sentences were in the subject-verb-object order, and

[1] More details about this task are in the Methods.

non-canonical sentences had a different order of constituents: object-verb-subject. They were formulated in the active voice and passive, respectively. The task was a dichotic listening task; the participants had to inhibit one of the sentences, which require executive processing. In this task, bilinguals showed a better performance than monolingual speakers of Italian in non-canonical sentences. The authors also found that monolinguals were more affected by interference in their L1 than bilinguals. These results suggest that bilinguals are better at inhibiting distracting spoken language. On the other hand, when the authors compared bilinguals with monolinguals speakers of English, the advantage disappeared. Filippi et al. (2012) interpret this result with respect to bilingual proficiency in English, because part of the sample of participants had no high proficiency in English. Further analysis revealed that the higher the English proficiency, the better the bilinguals were in filtering out irrelevant sentences.

Although some studies indicate bilingual advantage, we found a study which contains a bilingual disadvantage, which refers to processing sentences when interference does not need to be inhibited. Shi (2010) investigated the listening comprehension of acoustically degrading sentences. One possible interpretation for the disadvantage would be that bilinguals are less efficient in extracting meaning and thus suffer more from interference when the cues to meaning in speech are more degraded.

Thus, studies show executive function advantages in linguistic and non-linguistic tasks, though the evidence is controversial. Bialystok et al. (2009) suggest that the nature of the influence of bilingualism on the cognition is not clear. Many factors can interfere in linguistic tasks, such proficiency, quantity and quality of language use and frequency of usage of the words presented in the task. With this framework in mind, we present the study design.

3 METHODS

We carried out a study aimed at investigating the bilingual and multilingual advantage in a dichotic listening task, and in a nonlinguistic task. The study was carried out in a small bilingual community of the state of Rio Grande do Sul. The study was approved by the *Pontifícia Universidade Católica do Rio Grande do Sul* research ethics committee (process number CAAE: 12406313.3.0000.5336) and every participant gave a signed informed consent approved by the committee.

3.1 Participants

Sixty-five participants contributed to the study, initially; six were excluded for a low performance (less than 50% accuracy in all conditions of Sentence Comprehension Task). The remaining 59 participants were divided into three groups: 19 monolinguals, 20 bilinguals and 20 multilinguals. Most participants were from São José do Hortêncio (4.201 inhabitants), a township located 70 kilometers from Porto Alegre, Rio Grande do Sul. All participants were between 19 and 42 years old, had at least 12 years of schooling and were of middle-class income.

The groups were matched with respect to age, gender, education and working memory capacity. Thus, any differences between the group performances would not be associated with these differences, especially working memory, which is predictor of the ability to inhibit information, and a predictor of listening comprehension. We present below (Table 1) the demographic data of the sample[2] and their working memory capacities.

In the monolingual group, participants were speakers of Portuguese and were not fluent in any other language. In the bilingual group, participants were speakers of Portuguese and Hunsrückisch, and used both languages daily in the community. These bilinguals learned both languages from childhood and almost all bilingual speaker considered Portuguese as their dominant language. The multilinguals spoke at least three languages: Hunsrückisch, Portuguese and standard German. Almost all speakers considered Portuguese as their dominant language. The number of languages of multilingual participants ranged from three to seven. All multilinguals showed high proficiency levels in standard German (C1 level - Common European Framework of Reference for Languages).

[2] A one-way ANOVA did not show significant differences between the groups on the demographic data and the working memory capacity.

Table 1 – Demographic data and working memory span

	Monolinguals (n = 19)	**Bilinguals (n = 20)**	**Multilinguals (n = 20)**
Age (SD)	30 (6.1)	28 (5.9)	28.9 (6.3)
Age group	19 – 42	19 – 41	19 – 42
Gender – M/F	3/16	4/16	4/16
Schooling in years of education (SD)	16.6 (2.5)	16.2 (2.7)	16.7 (1.9)
Working memory span (SD)	30.9 (28.9)	29.6 (25.3)	33.1 (26.9)

SD = Standard Deviation; M = Male; F = Female.

Both bilinguals and multilinguals spoke the minority language Hunsrückisch. It is a dialect continuum formed by the dialects brought by German immigrants since 1824 (ALTENHOFEN; FREY, 2006). Hunsrückisch is predominantly used in oral form; the skills developed by these bilinguals are usually restricted to oral communication. For Altenhofen and his colleagues, Hunsrückisch is distinct from *Hochdeutsch* (German standard) and is considered a Brazilian language.

3.2 Materials

In this section, we describe the materials that we used to collect the data: the questionnaires, and the task: a Working Memory Task, the Attentional Network Task and the Sentence Comprehension Task. The two last tasks were designed using the *software E-Prime® 2.0* (Psychological Software Tools, Pittsburgh).

3.2.1 Questionnaire

The participants answered a questionnaire about their language experience and use (MARIAN et al., 2007; PREUSS, 2011). The version for monolinguals is a simplified version of the questionnaire for bilinguals and multilinguals. The questionnaire is composed of questions about general information, linguistic aspects, life experience and health.

3.2.2 Working memory task

The participants' working memory span was measured using a test battery (*Bateria de Avaliação da Memória de Trabalho*, BAMT) validated for use in Brazil (WOOD et al., 2001). The aim of the test is to answer questions and simultaneously memorize the last word of a sentence, which is read aloud to participants. The task, thus, measures a listening span.

3.2.3 Attentional network task

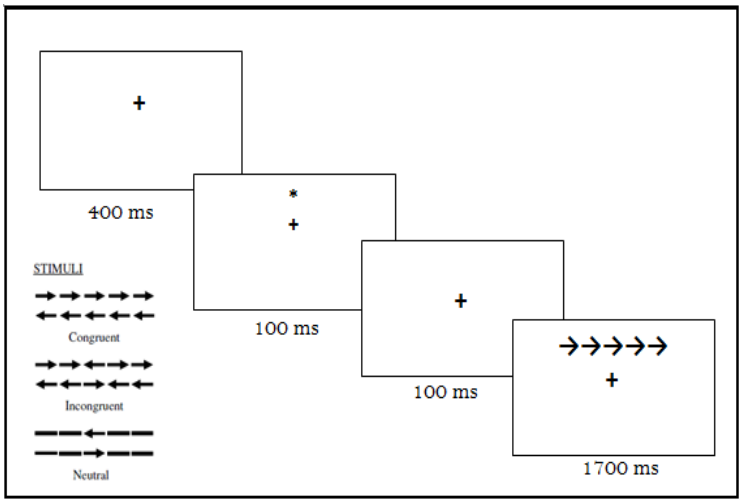
The Attentional Network Task (ANT) was developed by Fan et al. (2002). This task measures attention (POSNER; PETERSEN, 1990) and EF. The participants see a central arrow on the computer screen which points either left or right. The central arrow is displayed with two flanked arrows pointing in the same direction (congruent items: → → → → →) or in different directions (incongruent items: ← ← → ← ←) as the target arrow. The target can also be presented in neutral conditions (→). These arrows may be preceded by orienting or alerting cues. The example in Figure 1 represents a congruent stimuli proceeded by a orienting cue (asterisk above the fixation point).

The presentation of the stimuli was as follows: (1) a fixation point appeared on the center of the white screen for 400 milliseconds (ms); (2) a cue was presented along with the fixation point for 100 ms; (3) another fixation point appeared for 400 ms; (4) the target arrow appeared until the participant's response to 1700 ms; (5) the arrows disappeared after the answer and the next began.

Participants were instructed to focus on the fixation point and press the right key (9) when the central arrow pointed to the right, and left key (2) when the central arrow pointed to the left. They were also warned about the cues. Before the experiment, participants performed a training task that included 12 trials. The ANT allows the measurement of effects of alerting, orienting and conflict. These effects are measured by subtracting the RTs of the conditions with double cue from the RTs without cue (alerting effect), the RTs of the conditions with a central cue from those with a spatial cue (orienting effect). Finally,

the effect of conflict is calculated based on the difference between the mean RTs of incongruent and congruent trials.

Figure 1 - Representation of the ANT stimuli



Source (adaptation): Fan et al. (2002) and Costa, Hernández e Sebástian-Gallés (2008).

3.2.4 Sentence comprehension task

The Sentence Comprehension Task (SCT) was developed based on the study by Filippi et al. (2012). The authors used 96 English sentences with canonical syntactic structures (active voice) and non-canonical (passive voice). We translated the sentences from English to Portuguese and Hunsrückisch. The sentences in Hunsrückisch were read, reviewed and recorded by two speakers from the community. The sentences were recorded by a Portuguese speaker from the community and one of the authors (B.L.). Next, the sentences were edited using the Audacity 1.3 Beta software.

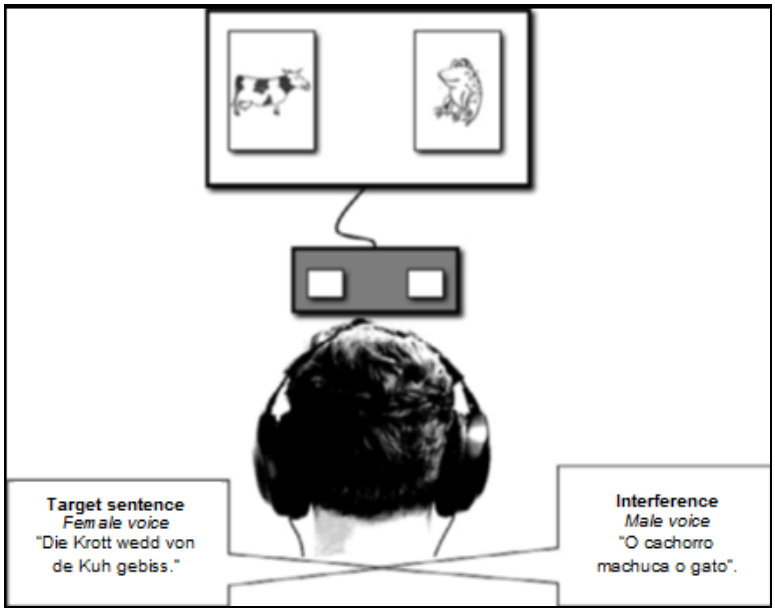
The sentences were divided equally between canonical sentences (passive structure) and non-canonical (active structure). Each sentence describes an action between two known animals, one agent and another patient (e.g., The *whale* is pushing the frog, The whale is pushed by the *seal*). A given action is associated with a pair of animals. The verbs have a subtle negative meaning, so that the participants identify what animal has a negative attitude toward others (e.g., biting, pushing and scratching).

The sentences were coupled with visual stimuli, i.e., computerized drawings of animals in black and white. Each drawing had a size of 7 cm x 5 cm, and each animal was housed in a rectangle with white background and gray borders. The names of the animals were not cognates between languages. During the SCT (Figure 2), participants listened to two sentences simultaneously, one in each ear (dichotic listening): one was the target sentence, the other the interference sentence. The interference was always spoken by a speaker of the opposite gender of the target sentence (target - male voice; interference - female voice and vice versa). Thus, male or female voice was a cue to identify the target sentence immediately.

The visual stimuli appeared in pairs on the computer screen. After the participants' response, a fixation point was displayed for three seconds and next the stimuli were displayed. As the example above shows, participants were instructed to pay attention to the phrase spoken by the female voice; they had to press the left (2), which corresponds to the cow, since it is the agent of the target sentence "Die Krott wedd von de Kuh gebiss" (The frog is bitten by the cow).

First, the participants completed a training session with 12 trials. Then, they completed the task, which consisted of three parts. In the first part, participants listened to the target sentence without interference. In the second part, participants listened to two sentences in Portuguese (monolingual dichotic listening). Both parts had twelve trials. In the third part, the trials were bilingual: in twelve, the target sentences were in Portuguese, and in another twelve, in Hunsrückisch. The order of presentation of sentences was randomized between participants. The number of target sentences presented to the right and the left headphone were balanced.

Figure 2 - Illustration of the sentence comprehension task



Source (adaptation): Filippi et al. (2012).

The participants were informed that they would see two draws of animals on a computer screen, and would hear two sentences at the same time, to identify the animal that is doing the action. They were also informed about the languages they would hear in each block. They were asked to ignore what the other person was talking and respond on the sentence spoken in the voice indicated on the computer screen at the beginning of each session. In case of bilingual trials, monolinguals were asked to focus on and respond on the target sentences in Portuguese, ignoring the sentence in Hunsrückisch.

3.3 Data collection and analysis

The data collection procedure lasted about one hour. There was only one meeting with each participant. Data collection was divided into two stages: 1) pilot study (between 27th June and 04th July 2013) and the experimental study (between August 19th and October 14th, 2013).

We analyzed the performance of the three groups on the ANT and the SCT (SPSS® 19.0) tasks. The mean RT and the accuracy were the dependent variables. First, we eliminated the outliers and carried out a descriptive analysis of the data. The analysis of accuracy on the two tasks was carried out with the nonparametric Kruskal-Wallis test; the analysis of the RT was carried out with the parametric test one-way ANOVA. For the purpose of the presented study, we considered the p-value of 0.05 as significant.

For the ANT, the independent variables were groups of participants (between-subjects factors) and all conditions of the experiment (within-subject factors): the cue type (none, center, double and spatial) and the flanker type (neutral, congruent and incongruent). There were twelve experimental conditions; in a subsequent analysis, we investigated the attention networks.

For the SCT, the within-subject factors were sentence type (canonical or non-canonical) and linguistic interference (no interference, monolingual dichotic listening, interference in Portuguese and in Hunsrückisch); there were eight experimental conditions. The between-subjects factor was the performance of the three different groups.

4 RESULTS

The results show faster response times for the multilinguals in the ANT than the other two groups. The overall RTs show significant differences between the groups only for the comprehension of sentences in Hunsrückisch with interference in Portuguese. We present the results of the performance of groups in ANT in subsection 3.1, and the results of SCT in subsection 3.2.

4.1 Faster multilingual response time on the nonlinguistic task (ANT)

Multilinguals were generally faster than monolinguals. There were significant differences between multilinguals and monolinguals ($F(3,764)$, $p = 0.030$) considering the overall RTs. There were also significant differences between these groups on the flanker type: neutral ($F(5,159)$, $p = 0.007$), congruent ($F(5,079)$, $p = 0.008$) and incongruent ($F(3,563)$, $p = 0.050$). There were no significant differences between the bilinguals and monolinguals on the flanker type task.

Table 2 – Mean response times (RTs) and accuracy for the ANT

	Flanker					
	Congruent			Incongruent		
	Bil.	Mon.	Mult.	Bil.	Mon.	Mult.
	Response times (ms) (SD)					
a) Cue						
Nome	557 (56)**	625 (97)	523 (70)**	627 (78)	674 (113)	567 (58)*
Double	533 (42)	581 (96)	511 (72)***	592 (62)***	668 (121)	558 (71)*
Central	530 (61)	577 (85)	509 (61)***	600 (55)	621 (87)	551 (65)***
Spatial	528 (53)***	600 (110)	487 (65)*	573 (65)	619 (103)	534 (81)**
	Accuracy (SD)					
b) Cue						
Nome	0.99 (0.02)	0.99 (0.02)	0.99 (0.02)	0.98 (0.03)	0.98 (0.02)	0.98 (0.02)
Double	0.99 (0.01)	0.99 (0.02)	0.99 (0.01)	0.99 (0.01)	0.97 (0.04)	0.97 (0.03)
Central	0.99 (0.01)	0.99 (0.01)	0.99 (0.02)	0.98 (0.03)	0.98 (0.03)	0.98 (0.02)
Spatial	0.99 (0.01)	0.99 (0.02)	0.99 (0.02)	0.99 (0.02)	0.99 (0.02)	0.99 (0.02)

Bil. = Bilingual; Mon. = Monolingual; Mult. = Multilingual; * = $p < 0.001$; ** = $p < 0.01$; *** = $p < 0.05$.

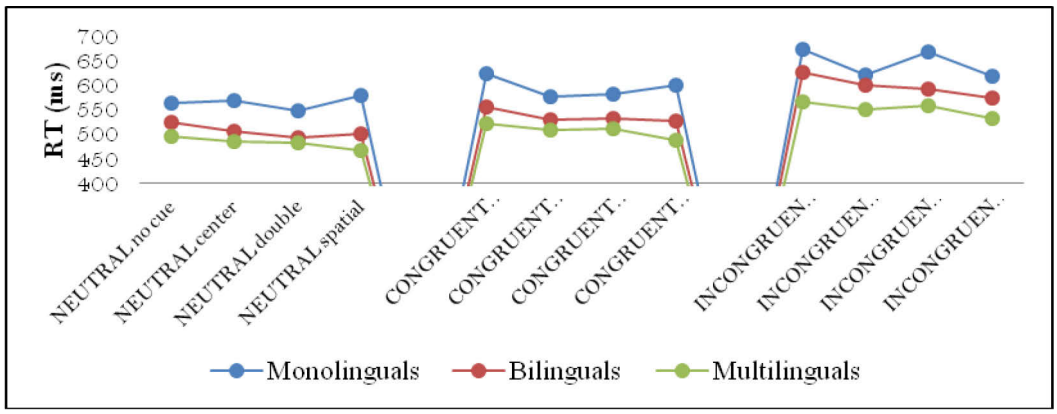
The results for the cue type indicate that the multilinguals were significantly faster than monolinguals on the trials preceded by three cue types: none ($F(6.080)$, $p = 0.004$), double cue ($F(3,562)$, $p = 0.036$) and spatial cue ($F(7.336)$, $p = 0.002$). There were no significant differences between bilinguals and monolinguals on the cue type.

There were significant differences between the RTs of the groups on all experimental conditions (Figure 3). In congruent trials, the following differences were observed between multilinguals and monolinguals: *congruent trials* without cue ($F(8,872)$, $p = 0.001$); with central cue ($F(4,337)$, $p = 0.020$); double cue ($F(4,480)$, $p = 0.018$) and spatial cue ($F(9,721)$, $p = 0.000$). On the incongruent trials, there were the following differences among the multilinguals and monolinguals: incongruent without cue ($F(7.491)$, $p = 0.001$); with central cue ($F(4,184)$, $p = 0.043$); double cue ($F(7.684)$, $p = 0.001$) and spatial cue ($F(4.679)$, $p = 0.014$).

There were also significant differences between monolinguals and bilinguals, namely on the congruent condition without cue ($F(8,872)$, $p = 0.030$), congruent with spatial cue ($F(9,721)$, $p = 0.031$) and incongruent with double cue ($F(7,684)$, $p = 0.040$). The mean RTs of bilinguals were lower than the RTs of the monolinguals (Figure 3). The results of the bilingual group indicate the trend that speaking two languages can also influence the speed of processing in this type of task, though the differences were not always significant. Figure 3 shows the performance of groups on the ANT.

The accuracy of participants was comparable between the monolingual (0.98), bilingual (0.99) and multilingual (0.99) groups. There were no significant differences for the accuracy measures for the cue type and flanker type tasks. Thus, the three groups of participants were able to perform the task comparable accuracy. Figure 3 shows accuracy and mean RTs for the ANT.

Figure 3 - Overall RTs of monolinguals, bilinguals and multilinguals on the experimental conditions of the ANT



The results show that multilingualism has a significant positive effect on the speed of processing and executive function, as measured by the ANT. This can be verified by the overall RTs. In addition, there is a tendency for a bilingual advantage in relation to monolinguals as well: bilinguals were always faster than monolinguals, though the difference between the two groups was not always significant. There were no significant differences on the alerting, orienting and conflict effect[3].

4.2 Lack of interference in monolinguals is associated with better accuracy for the linguistic task (SCT)

The results show a significant difference between groups on accuracy. The overall accuracy of the monolinguals (0.97) was higher than the accuracy of the bilinguals (0.96) and multilinguals (0.93). The accuracy was significantly different between monolinguals and multilinguals (p = 0.012). The results generally suggest that monolinguals comprehend sentences more easily when interference is in another language; this is to be expected, considering that monolinguals do not understand Hunsrückisch and, thus, the sentences in the German dialect do not cause interference in listening comprehension. In relation to types of sentences, the groups showed higher accuracy in comprehension of canonical sentences, though the differences were not significant. Table 3 presents the results for comprehension of the canonical sentences.

Table 3 – Means and standard deviations for response time (in milliseconds) and accuracy when the groups comprehended target *canonical sentences* in the presence or absence of language interference

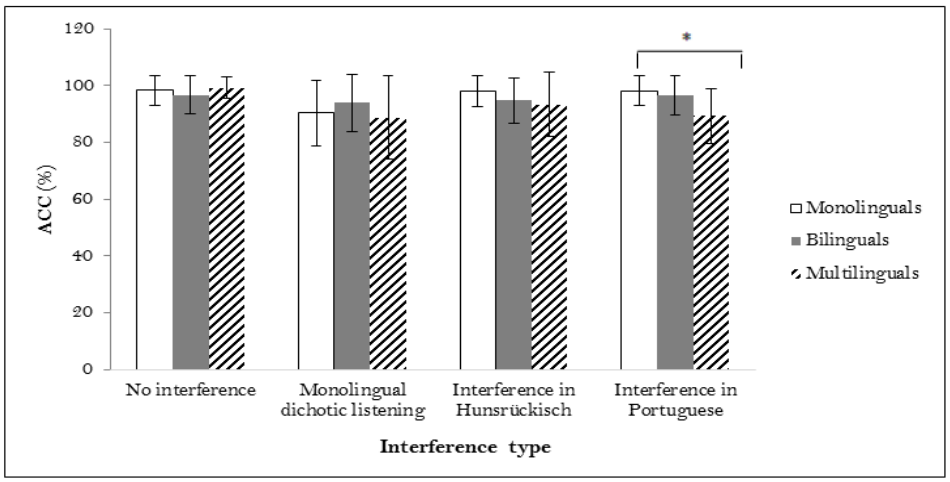
	No interference		Monolingual listening dichotic task with interference in Portuguese		Bilingual listening dichotic task with interference in Portuguese		Bilingual listening dichotic task with interference in Hunsrückisch	
Group	ACC (SD)	RT (SD)	ACC (SD)	RT (SD)	ACC (SD)	RT (SD)	ACC (SD)	RT (SD)
Bilingual	0.97	2676	0.94	3090	0.96	2969	0.95	3068
	(0.06)	(479)	(0.10)	(484)	(0.07)	(428)	(0.08)	(560)
Monolingual	0.98	2483	0.90	3062	0.98*	2723	0.98	2694
	(0.05)	(216)	(0.11)	(565)	(0.05)	(508)	(0.06)	(436)
Multilingual	0.99	2550	0.88	2945	0.90	2994	0.93	3084
	(0.04)	(443)	(0.15)	(443)	(0.08)	(513)	(0.11)	(587)

ACC = accuracy; SD = Standard Deviation; RT = Response Time; * p = 0,002

[3] Therefore, we did not present the results of the attentional networks. For more details, see Limberger (2014).

Figure 4 shows the accuracy of the three groups on the four conditions of the SCT with canonical sentences.

Figure 4 - Accuracy of the groups on the comprehension of canonical sentences



*p = 0,002

Comparison of the conditions with and without interference shows higher performance in the condition without interference (Tables 2 and 3). The performance was comparable between the groups in the condition without interference. In relation to non-canonical sentences (Table 4), the results show a difference (p = 0.042) between monolinguals (0.96, SD = 0.04) and multilinguals (0.92, SD = 0.06). This suggests that the monolinguals were generally more accurate understanding non-canonical sentences than the multilinguals and the bilinguals (0.95, SD = 0.07). If the bilingual dichotic listening conditions are not considered, there was no significant difference between groups.

Table 4 – Means and standard deviations for response time (in milliseconds) and accuracy (in percentage) when the groups comprehended target *non-canonical sentences* in the presence or absence of language interference

	No interference		Monolingual listening dichotic task with interference in Portuguese		Bilingual listening dichotic task with interference in Portuguese		Bilingual listening dichotic task with interference in Hunsrückisch	
Group	ACC (SD)	RT (SD)	ACC (SD)	RT (SD)	ACC (SD)	RT (SD)	ACC (SD)	RT (SD)
Bilingual	0.98 (0.05)	2988 (445)	0.92 (0.13)	3104 (422)	0.92 (0.11)	3372 (506)	0.90 (0.15)	3155 (515)
Monolingual	0.99 (0.04)	2865 (325)	0.97 (0.07)	3119 (520)	0.91 (0.06)	2950* (487)	0.97 (0.06)	2992 (338)
Multilingual	0.97 (0.06)	2762 (344)	0.95 (0.06)	2998 (502)	0.88 (0.13)	2848** (477)	0.91 (0.10)	2848 (457)

ACC = accuracy; SD = Standard Deviation; RT = Response Time; * p = 0,040; ** p = 0,008

The comprehension of non-canonical sentences resulted in more errors for all groups (Table 4). There was no significant difference between groups, but the monolinguals were slightly more accurate than the other groups in comprehension of non-canonical sentences. Thus, the results indicate differences between groups on the accuracy, especially when the sentences are canonical and have bilingual interference.

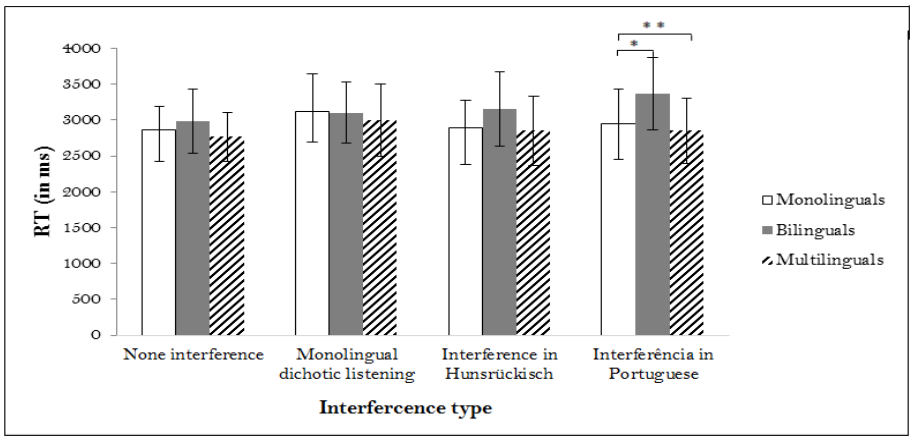
On the response times (RTs) of the sentence comprehension, the groups had comparable performances. Generally, there were no significant differences between monolinguals (Mean = 2777 ms, SD = 279 ms), bilinguals (Mean = 2979 ms, SD 314 ms) and multilinguals (2842 ms, SD 312 ms), although the monolinguals were slightly faster. Furthermore, the mean RTs revealed that the three groups were slower to comprehend non-canonical sentences and sentences with interference. There was no significant difference between groups considering the type of sentence and presence or absence of interference.

The bilingual dichotic listening conditions show there was a significant difference ($F(3,334)$, $p = 0.043$) between monolinguals (Mean = 2793 ms, SD = 371 ms) and bilinguals (Mean = 3094 ms, SD = 316 ms), but not between monolinguals and multilinguals (Mean = 2895, SD = 375 ms). Thus, bilinguals were slower in the presence of linguistic interference that multilinguals. In addition, bilinguals (3215 ms, SD = 394 ms) were slower to understand non-canonical sentences than multilinguals (2984 ms, SD = 424 ms). A one-way ANOVA revealed a significant difference between groups ($F(4,868)$, $p = 0.016$).

Comparison of the monolingual dichotic listening conditions with the bilingual dichotic listening conditions shows that the mean RTs of the monolinguals was considerably higher in the monolingual condition (3091 ms, SD = 485 ms). There was a significant difference between the bilingual and the monolingual conditions ($t(16) = 4{,}943$, $p = 0.0001$). This suggests that monolinguals took longer to resolve the trials in which they understood the interference, compared to the condition in which they did not understand the interference. The performance of the bilingual and multilingual groups was similar in monolingual and bilingual conditions.

Analyses of each experimental condition separately show that on the comprehension of canonical sentences, there were no significant differences between the groups. On the RTs of non-canonical sentences (Figure 5), it was found that the multilinguals were faster at deciding the agents of non-canonical sentences in Hunsrückisch than the bilinguals, in the presence of Portuguese interference ($F(5,932)$, $p = 0.008$). There was also a significant difference between monolinguals and bilinguals ($F(5,932)$, $p = 0.040$) on this condition. This difference may suggest that (1) the monolinguals did not need to inhibit the unknown Hunsrückisch language and (2) that the multilinguals were faster than the bilinguals.

Figure 5 - Means of the response times of the groups on the comprehension of non-canonical sentences



$^{*}p = 0{,}040$; $^{**}p = 0{,}008$

Thus, the groups did not differ significantly when responding on non-canonical sentences in Portuguese, in three conditions. However, at the sentence in Hunsrückisch with interference in Portuguese, there was a significant difference between all groups: multilinguals were faster, a trend which is confirmed in all conditions with non-canonical sentences.

5 DISCUSSION

In the present study, we examined the performance of bilinguals and multilinguals on a nonlinguistic task, the ANT, and on a linguistic task, the SCT. We compared the performance of these two groups with monolinguals. We discuss the results in turn.

5.1 Effects of bilingualism and multilingualism on executive functions as investigated by nonlinguistic stimuli

Based on previous studies of bilingualism and on our hypothesis about multilingualism, it was expected that the multilinguals would have faster RTs on the ANT task than the bilinguals and monolinguals. This hypothesis was confirmed: the multilinguals were significantly faster than the monolinguals in all experimental conditions of the task. Our results corroborate Bialystok and colleagues (2004; 2008), and Costa and colleagues (2008; 2009).

There are differences between the participants of this study and the participants of Bialystok's and Costa's studies. In those studies, the participants were early *bilinguals* who spoke and wrote in two languages. In the present study, a similar advantage was found in a population of multilinguals which consisted of speakers of Portuguese, Hunsrückisch (a language that has no written standard) and an additional language (standard German).

Our results give further support to the hypothesis that acquisition of more than one language can be associated with a positive effect on measures of executive function, especially in formal, instructional settings (i.e. in the present study, learning standard German). According to Bialystok et al. (2009), the bilingual advantage is related to the fact that bilingual speakers face situations that require selection of relevant information or resolution of conflicts, i.e., inhibition of one language and selection of another. The enhanced EF of bilinguals may be the result of constant monitoring of the context necessary to use appropriate language.

The advantage of the multilingual participants found in the present study is not specifically on inhibition processes, but in executive functioning in general, as Costa et al. (2009) and Hilchey and Klein (2011) postulated, because there were no differences on the conflict effect (as measured by the ANT). They enjoy advantages in the general domain of executive functioning, not the interference effect. Because the multilinguals speak and write more languages, they may be involved in contexts that require more control of the irrelevant language(s). Opportunities for language use and the need to exercise more often the executive functioning seem to be decisive for more enhanced abilities on this construct.

On the other hand, the bilingual speakers of Hunsrückisch investigated in this study characterized their way of speaking as "mixed". They use both languages in different contexts, because most people of the community speak both languages. Code-switching is, thus, common and acceptable. We did not find a bilingual advantage for the bilingual Hunsrückisch speakers compared to monolinguals. This result is consistent with the results of Brazilian studies (BILLIG, 2009; KRAMER, 2011; PINTO, 2010). Similarly, Lauchlan, Parisi and Fadda (2013) found that bilingual speakers of the Sardinian language, which also does not have a writing pattern, had no advantage over monolinguals. However, the results of our study and the results of the mentioned studies show a trend of lower RTs of bilinguals compared to monolinguals.

5.2 Effects of bilingualism and multilingualism on executive functions as investigated by nonlinguistic stimuli

We also investigated whether there were differences between the groups in comprehension of sentences. For this purpose, we adapted a task used by Filippi et al. (2012). We expected that bilinguals and multilinguals would be better able to recognize the agent of the sentences and also to better inhibit interference. Our main results show that (1) monolinguals made fewer errors than the other groups on the SCT; but, when we removed the bilingual dichotic listening conditions, the differences on the accuracy disappeared and (2) the three groups were slower and less accurate to comprehend non-canonical sentences in comparison to canonical ones and to comprehend sentences with interference; moreover, the multilinguals were faster than the other groups to comprehend non-canonical sentences with Hunsrückisch interference in Portuguese.

Neither the bilinguals nor the multilinguals showed the predicted advantage on the task with linguistic stimuli. This hypothesis was formulated with relation to the studies of Blumenfeld and Marian (2011) and Filippi et al. (2012), who found that bilinguals have superior to monolinguals in tasks involving linguistic interference suppression performance.

However, in the study by Filippi et al. (2012), monolinguals had to guess the agent of the sentences in the language that they not understood. The performance of the bilingual task by monolinguals may have helped the finding of a bilingual advantage; monolinguals are merely guessing and, therefore, are more likely to make mistakes. But the authors' explanation for the bilingual advantage was faster detection of the cue, i.e., the voice of the participant. When there is a cue, bilinguals would be faster because of its improved ability to monitor the context.

In the version of the task used in this study, however, monolinguals had to respond to the sentences in Portuguese only, inhibiting the sentence in Hunsrückisch (but which they did not comprehend). This difference in task may be associated with the monolingual advantage in accuracy. For bilinguals and multilinguals, however, even with instruction and a cue (listen to the male or female voice), it is impossible to avoid the processing of linguistic auditory linguistic information (NEWMAN, KELLER; JUST, 2007).

Multilinguals were significantly less accurate than monolinguals on the SCT. The main difficulty of multilinguals compared to monolinguals and bilinguals was to understand sentences in Hunsrückisch, because of their lower accuracy. This may be related to the use of this language: the multilinguals reported fewer opportunities to use Hunsrückisch (25%) than bilinguals (34%), based on information provided in the questionnaire. Lower frequency of language use can cause be associated with lower accuracies, as shown by Marian et al. (2013).

Multilinguals showed faster responses compared with bilinguals for the non-canonical sentences in Hunsrückisch, with interference in Portuguese. One possible explanation for the superior multilingual performance may refer to the explicit grammatical knowledge they have about a similar variety, the standard German. Recognizing the agent of a sentence in Hunsrückisch and in standard German is not as immediate as recognizing the agent of a sentence in Portuguese; in those languages, the agent was placed in the middle of the sentence, between the auxiliary verb and the main verb. In Portuguese, it was placed at the end of the sentence, which may facilitate identification. In this sense, the knowledge about the syntactic structure of a language with a structure identical to Hunsrückisch may have helped multilinguals.

The results of the linguistic task were not as uniform as the results of non-linguistic task, since there was not a group that had an advantage over others, but there were specific performance of the three groups. Some factors seem decisive on the task, as the impact of interference, the opportunities for use of Hunsrückisch and explicit knowledge of structures.

6 FINAL CONSIDERATIONS

The present study contributes to the understanding of the nature of the effects of speaking two or more languages in the context of minority languages. The benefits in non-linguistic executive processing appear to be more significant for the multilinguals.

The limitations of this study relate mainly to methodological aspects. The first limitation is the number of trials of the SCT. The inclusion of more trials could have altered the results. Another limitation is the lack of a research laboratory. Therefore, sometimes, the research conditions were not ideal, but all participants could performance well the tasks.

In relation to future directions of the research, there is a need for future investigations involving minority language speakers in Brazil. Other cognitive abilities could also be examined through other tests and also by neuroimaging methods, especially the various memory systems and task-switching with different types of stimuli.

The present study showed that speaking Hunsrückisch can bring cognitive benefits, and learning a third, standard language brings yet further advantages. The early bilingual speakers of Hunsrückisch may have more enhanced levels of metalinguistic awareness than monolinguals (BIALYSTOK et al., 2009). Thus, parents should not give up raising their children bilingual. Learning the dialect in a community can be a shortcut to multilingualism, since it facilitates learning standard German standard for these children.

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