PALACKÝ UNIVERSITY OLOMOUC

Faculty of Arts

Department of English and American Studies

BEHAVIOURAL AND NEUROPHYSIOLOGICAL CORRELATES OF SPEECH PROCESSING IN MULTILINGUALS

BEHAVIORÁLNÍ A NEUROFYZIOLOGICKÉ KORELÁTY ZPRACOVÁNÍ ŘEČI U MULTILINGVNÍCH MLUVČÍCH

Master's Diploma Thesis

Author:	Bc. Radka Hoková
Field of Study:	English Philology
Supervisor:	Mgr. Václav Jonáš Podlipský, Ph.D.
Consultant:	MUDr. Pavel Hok

Olomouc 2016

Behavioural and Neurophysiological Correlates of Speech Processing in Multilinguals

Master's Diploma Thesis

Author:	Bc. Radka Hoková
Field of Study:	English Philology, Faculty of Arts
Supervisor:	Mgr. Václav Jonáš Podlipský, Ph.D.
Consultant:	MUDr. Pavel Hok

Number of Pages: 132

Number of Characters: 274,238

Olomouc 2016

Declaration of Authorship

I hereby declare that I have written this diploma thesis independently and without the use of documents and aids other than those stated. I confirm that I have provided all sources used and that I have cited and paraphrased them correctly according to established academic citation rules, in the Reference Section.

In Olomouc..... ….....

Bc. Radka Hoková

Motto

Quot linguas calles, tot homines vales.
Those who know many languages live as many lives as the languages they know.
Kolik jazyků umíš, tolikrát jsi člověkem.
Autant de langues tu parles, autant d'hommes tu es.
So viele Sprachen du sprichst, so oft bist du Mensch.
Cuantas lenguas hables, tantos hombres vales.
Câte limbi ştii, de atâtea ori eşti om.
Iloma językami mówisz, tylekroć jesteś człowiekiem.
学一门语言，就是多一个观察世界的窗户。

Acknowledgements

I would like to express my gratitude to the supervisor Mgr. Václav Jonáš Podlipský, Ph.D., who accepted my project, supported me with enthusiasm, and provided many valuable comments; and to Mgr. Šárka Šimáčková, Ph.D., for her advice and approval.

I am also deeply indebted to the Functional Magnetic Resonance Imaging Laboratory at the Department of Neurology, the Faculty of Medicine and Dentistry, Palacký University Olomouc, where the brain imaging data were collected and the statistical analysis was performed. I am especially grateful to the head of the laboratory, Prof. MUDr. Ing. Petr Hluštík, Ph.D., who gave the blessing and to MUDr. Zbyněk Tüdös, Ph.D., who spent his free time in the scanner room.

My gratitude goes to my husband MUDr. Pavel Hok who designed the imaging protocol, performed the statistical analysis, prepared Figures 10-12, drafted sections 4.3 Imaging Data Acquisition; 4.4 Statistical Analysis; and 5.4 Imaging Data; edited the most challenging parts, namely: 2.5.1 Neurobiological Basis of Language and Speech; 2.5.5 Neurobiological Correlates of Language Switching; 6.4 Imaging Data; and patiently proofread and consulted the thesis.

My duty is to thank all the participants who voluntarily came without any reward to take part in the project. Many thanks go to my family for the support.

List of Acronyms

ACC	Anterior Cingulate Cortex
AG	Angular Gyrus
AoA	Age of Acquisition
AoAE	Age of acquisition of the English
ANOVA	Analysis of Variance
aMFG/FP	Anterior Middle Frontal Gyrus / Frontal Pole
ASL	Arterial Spin Labeling
aSMG	Anterior Supramarginal Gyrus
BET	Brain Extraction Tool
BIA+	Bilingual Interactive Activation Model
BOLD	Blood Oxygenation Level-Dependent
CEFR	Common European Framework of Reference for Languages
COG	Centre of Gravity
CS	Code Switching
CT	Computed Tomography
CZ	Czech Language
EEG	Electroencephalography
EF	Executive Function
EN/L2	English Language
ERP	Event-related Brain Potentials
FEAT	FMRI Expert Analysis Tool
FILM	FMRIB's Improved Linear Model
FL	Foreign Language
FLAME	FMRIB's Local Analysis of Mixed Effects
FLIRT	FMRIB's Linear Image Registration Tool
fMRI	Functional Magnetic Resonance Imaging
FNIRT	FMRIB's Nonlinear Image Registration Tool
FNOL	Fakultní nemocnice Olomouc (University Hospital Olomouc)
FSL	FMRIB (Oxford Centre for fMRI of Brain) Software Library
FWHM	Full-Width Half-Maximum
IC	Inhibitory Control

IQR	Inter-Quartile Range
ISI	Inter-Stimulus Interval
LC	Left Caudate Nucleus
LF UP	Lékařská fakulta UPOL (Faculty of Medicine and Dentistry UPOL)
LH	Left Hemisphere
LS	Language Switching
MCFLIRT	Motion Correction FLIRT
MEG	Magnetoencephalography
MNI	Montreal Neurological Institute
MPRAGE	Magnetization- Prepared Rapid Acquisition Gradient Echo
MRSI	Magnetic Resonance Spectroscopic Imaging
NIRS	Near Infrared Spectroscopy
P1 − P8	Participant 1 − Participant 8 (anonymous)
PCUN	Precuneous Cortex
PET	Positron Emission Tomography
PL	Polish Language
pre-SMA	Pre-Supplementary Motor Area
pMFG	Posterior Middle Frontal Gyrus
pSMG	Posterior Supramarginal Gyrus
PZKO	Polski Związek Kulturalno-Oświatowy w Republice Czeskiej
RH	Right Hemisphere
ROI	Region of Interest
RP	Radiofrequency Pulse
SAJ	Sekcja Akademickiej „Jedność”
%SC	Percent Signal Change
SL	Second Language
SMA	Supplementary Motor Area
SPL	Superior Parietal Lobule
UPOL	Palacký University Olomouc
WRST	Wilcoxon Rank-Sum Test
WSRT	Wilcoxon Signed-Rank Test
WW2	World War II

Table of Contents

1. Outline of the Thesis

The advent of non-invasive imaging methods, such as functional magnetic resonance imaging (fMRI), allowed for investigation of neurobiological basis of linguistic concepts based on previous behavioural evidence. Multilingualism is among those phenomena most intensively studied, but as discussed in this work, many controversies still remain, such as inconsistent reports of the brain structures involved in language switching. Studies in specific well-defined populations with unique sociolinguistic background were suggested to settle these disputes, calling for multidisciplinary cooperation forming a common ground for neurosciences and sociolinguistics.

The aim of the thesis is to outline results of contemporary neurolinguistic research and to study language switching by employing state-of-art neuroimaging methods in a unique sociolinguistic setting in Těšín Silesia. It is hoped this work will contribute to a better understanding of complex speech processes in the brain necessary to maintain a multilingual system.

This diploma thesis is organized into several parts, the first theoretical part, 2. Literature Review, offers definitions and brief overview tackling the issues associated with monolingualism, bilingualism, multilingualism, and mother tongue. It also deals with the stratification of the Czech language with a special focus on territorial dialects, and an introduction of the Polish language and the Polish minority in the Czech Republic. Since the English language is crucial for the purposes of the thesis, it is introduced as well.

Still in the Literature Review, aspects of multilingualism, such as metalinguistic awareness and cognitive skills, models of speech production, as well as typical features in the bi/multilingual speech are presented. The Literature Review closes with an overview of neurolinguistic methodology and research of bi/multilingualism with special emphasis on language switching. Next to follow are 3. Research Questions and Hypotheses. Methods, participants, and tasks are described in the corresponding section 4, including behavioural and fMRI data collection and analysis. The following part, 5. Results, presents outcomes of questionnaires, translation test, difficulty rating, as well as neuroimaging data correlates. The data with the stress on significant findings are evaluated in the 6. Discussion. Conclusions and Appendices follow.

2. Literature Review

2.1. Introduction

Multilingualism and bilingualism[1] have been the most studied and researched language phenomena since the 1960s; they have drawn an increasing attention of specialists not only from traditional academic disciplines such as neurology, but lately also from interdisciplinary scientific fields such as psycholinguistics, neurolinguistics, and sociolinguistics who make use of the findings of clinical linguistics. A noticeable number of academic journals (such as *The International Journal of Bilingualism* or *Journal of Neurolinguistics*) and a large number of associations (e.g., Society for the Neurobiology of Language) were set up, and international conferences (e.g., ISB, International Symposium on Bilingualism) are held annually (Bhatia and Ritchie 2012, xxi). General awareness and a heightened interest in the phenomena are daily enforced by the media (Dreifus 2011; Bhattacharjee 2012; Athanasopoulos 2015; Olulade et al. 2015), innumerable prestigious magazines, and thousands of blogs (Cruz-Ferreira 2015; Moritz-Saladino 2015; Bosq 2014). Moreover, parents are instructed how to raise bi/multilingual children (e.g., by Linguistic Society of America) by online manuals (eg., Harding-Esch and Riley 2008), at multilingual schools (e.g., "CPLP Multilingual Schools – Our Schools" 2015) and lastly, by educational immersion programs such as Czech Schools Without Borders. In 2009, the European Commission launched the program *EU Civil Society Platform for Multilingualism* to support the trend and to raise awareness about the *Framework strategy for multilingualism, COM(2005) 596*. UNESCO started an initiative to increase the public perception of the importance of languages, mainly the "endangered languages" (Crystal 2011).

All these institutions and promoters called attention to bi/multilingualism and it became a prestigious international trend. Bi/multilingual educational guidelines and instructions are offered for teachers of the bi/multilingual classes (Houlton and Willey 1983; Cummins 1984; Bernstein 2003; Coelho and Rivers 2004; Cummins and Swain 2014). The list could go on indefinitely.

1 *Multilingual* is in this thesis understood to be a speaker of more than one language (Meuter 2009a, 27), the term is used interchangeably with the *bilingual* (as *bi/multilingual (Paulston 1978)*), however, these terms will be distinguished whenever studies present results specifically for *bilingual* or specifically for *multilingual* speakers.

Nevertheless, the number of resources and literature on bi/multilingualism in the Czech Republic (for instance, Novotná et al. 2015) falls behind. Moritz-Gasser and Duffau (2009) and (van Heuven and Dijkstra 2010) both emphasize that even though the research in bi/multilingualism is so far plentiful, there is still a lack of studies on language switching and its cognitive and neural aspects. The neurolinguists are still unlocking the secrets of bi/multilingualism using technical advances in the brain imaging methodologies, one of them being an fMRI.

2.2. Historical Perspective

Our understanding of bi/multilingualism has drastically changed over the past centuries. To exemplify how far back in time can we go, Crystal (2011) offers an observation which illustrates a preference for monolingualism, showing its long tradition and religious background. The legend "Tower of Babel" in the *Old Testament* was based on the fact that people spoke a single language and because they were self-centred and they wanted to build a very high tower reaching he skies, the God as a punishment confounded their languages so that they could not understand each other so they spread all over the world ("Tower of Babel" 2015).

In modern history, the research on bi/multilingualism has been shedding light on the bilingual language acquisition, cognitive development, and it has also clarified myths about intelligence, language proficiency, and academic achievement (Ikome 1994; Crystal 2011). For instance, there were issues and fears that children bilingualism was associated with its influence on intelligence, personality, correct language acquisition, integration of two cultures, worse school performance, language mixing, stammer, etc. (Štefánik 2000). In past, this has been very much discussed topic and it created a negative attitude, so called monolingual prejudice (Alladina and Edwards 1991, 1).

One of the extreme examples of the monolingual prejudice goes back to the 1960s Britain, when the bilingual parents were advised to speak only standard English (just one mother tongue) at home to their children which was based on the previous research arguing that children could under-perform at school, they could be held back compared to their monolingual classmates and the language confusion can have an impact on intelligence (Alladina and Edwards 1991, 6).

Scientists have been interested in these factors since the 1960s. One of the pivotal research was conducted by Peal and Lambert (1962) and it focused on the effects of

bilingualism on the intellectual functioning of children, school achievement, and attitudes towards the second language community. It focused on the bilingual general intellectual advantage, and contrary to previous findings, it reported that "bilinguals perform significantly better than monolinguals on both verbal and non-verbal intelligence tests […], they have a language asset, are more facile at concept formation, and have a greater mental flexibility [… and they have] a more diversified set of mental abilities than the monolinguals" (Peal and Lambert 1962).

Up to the 1970s, it was still believed that bilingualism brings along some risk of wrong language systems separation and that there might be a danger of language mixing (Meisel 2005, 136), problems with competence in both languages, delayed language acquisition in comparison to monolinguals, etc. Subsequent studies focused on the comparison of monolinguals and bilinguals and the peak of bilingual research was in 1980s (Meisel 2005, 137).

A change in attitude towards bilingualism is apparent, for instance, from the report carried out in London by Rampton (1981) who suggested that the usage of the dialect at home "helps to develop awareness in children how the language system works in general and it also strengthens the sense of appropriate situations in which dialect or standard form should be used".

Attitudes towards bi/multilingualism have been changing over the years. In the past, it used to be regarded as a *deficiency,* a potential danger which might lead to language impairments. However, this view has now been surpassed and the apparent positives of bilingualism have prevailed. A considerable interest in bilingualism is given by the fact that this phenomenon is of political, social, and cultural importance and relevance and, as Meisel (2001, 12) pointed out, it should not be understood as odd or abnormal any more since "the human language faculty predisposes the individual to become bilingual" and it is natural to acquire and learn several languages. Crystal (1987) stated that bi/multilingualism became a necessary part of our everyday life and it "is the natural way of life for hundreds of millions all over the world". Smith (2005, 601) also stresses the fact that bi/multilingualism developed to be, to a certain extent, the norm and demands on language competences are rapidly increasing. It is estimated that the percentage of the multilingual population from all over the world falls between 50% and 70% (Baker 2004, 64) and three-quarters of the world's population use at least two languages every day (Crystal 2011). In

fact, it is difficult to find a society in the world that is truly monolingual, there has always been a language contact within and between countries, social classes, minorities, and different age groups (Grosjean 1984, 1). Historically, bi/multilingualism arises mainly as a consequence of colonization, military invasion, intermarriage, education, urbanization, and lately immigration (Grosjean 1984, 2; Edwards 2012, 7). Among other reasons, it appears in the linguistic minorities and communities living in the border areas where the languages get into contact.

2.3. Defining Mono/, Bi/multilingualism, and Mother Tongue

The definitions of bilingualism and multilingualism have been changing in correspondence with the ongoing research and the disciplines. Distinctions should be drawn to make clear the understanding of these key terms with regard to the language competence of the participants in this study. For this purpose, I shall offer an overview of some of the definitions of bi/multilingualism and related phenomena, such language mixing, transfer, language dominance, proficiency, and last but not least, language switching.

2.3.1. Monolingualism

The Encyclopedia of Linguistics (Meisel 2005, 136) provides the definition of monolingual speakers to be a "speaker[s] of just one language", Cruz-Ferreira (2010a, 2) defines them as "exemplary exponents of their language"; another explanation is that monolinguals are speakers functioning in a "single language" (dialectal variation included, thus one speaker may be bidialectal but monolingual) (Skutnabb-Kangas and McCarty 2008). Monolingual speakers are also called monoglots (Jha 2011).

Nations with colonial history, such as the UK, tend to keep the "egotistical monolingualism" and "anti-bilingual" antagonistic approach towards bilingualism (Crystal 2011). From this point of view, monolingualism is (at both the individual and societal levels) normal, desirable, and sufficient for most purposes (Skutnabb-Kangas and McCarty 2008).

What is still topical and well-discussed in the language research is the comparison of the monolingual and bi/multilingual speakers in terms of acquisition, learning, cognitive and metalinguistic skills. Cruz-Ferreira (see 2010a, 1–2) and Meisel (2001, 13) share the opinion that monolingualism is often in the research presented as the norm of the language

against which the multilingual is usually gauged. It is often wrongly assumed that multilinguals should use the language as monolinguals, they "must match monolingual-like proficiency in several languages" (Cruz-Ferreira 2010a, 2) and if they do not, it is considered (i.e., Shi 2011) to be a failure or a deficit. Cruz-Ferreira (2010a, 6) further argues that attention should be paid to not what is missing in multilinguals but what is present in everyday spontaneous situations, and what is most important, separately from the monolingual comparison.

2.3.2. Bilingualism

2.3.2.1 Definitions of Bilingual Speakers

The literature on bilingualism shows a variety of approaches and rich terminological apparatus. The definitions of bilinguals are discipline-dependent (psycholinguistic, sociolinguistics, ethnolinguistics, neurolinguistic, etc.), context-dependent (a prestigious/standard variety vs. a substandard variety), situation-dependent (official vs. home language), and individual-dependent.

From a linguistic point of view, there is a whole array of terms describing a bilingual speaker. For example, being bilingual means to "speak two languages without constraints" (Průcha, Walterová, and Mareš 2001, 25), to have the "ability to use two languages" (Altarriba 2005, 140; Baker 2004, 64), to have a "communicational competence enabling the smooth communication in both languages" (Průcha, Walterová, and Mareš 2001, 25), to have "command of more than one language" (Altarriba and Basnight-Brown 2009). These definitions indirectly imply that it is possible to approximate the bilingual competency through the process of language learning (i.e., second language acquisition, L2) (Meisel 2001, 11). Bi/multilingual language ability is also understood to be "a continuum"(Crystal 1987, 362), or a scale, and the speakers are at different levels in different stages of their lives, getting closer or further to the ideal, a native-like state.

Conversely, there are definitions pointing out that some bilingual speakers possess an active usage of two languages at the level of the respective mother tongues (Linhart 2005, 58; Crystal 2007a, 412), that is, mastering two languages at the monolingual level. The reality is after all far from the ideal and the group of people meeting this condition is very small. The majority of bi/multilinguals do not have an equal command of their languages since one language can be more fluent than the other, it can interfere with the other, impose

accent on the other, or it could be preferred in certain situations (Crystal 1987, 362; Jordà 2005, 24).

The term *bilingual* is not uniformly used within the scientific community. Some authors serve the term for the acquisition of the languages in infancy and early childhood (e.g., Werker, Byers-Heinlein, and Fennell 2009), some for balanced bilinguals (e.g., Yow and Li 2015), others use it for late bilinguals (e.g., Kalia, Wilbourn, and Ghio 2014), or L1-dominant bilinguals (e.g., Oganian et al. 2015).

2.3.3. Criteria for Classification of Bilingualism

There are several criteria important for classification of bi/multilingual speakers, namely time of acquisition, critical period, proficiency, and language dominance, among others.

The first important criterion is the time of acquisition or "age of onset of learning" (Meisel 2005, 136) which differentiates simultaneous and successive bilinguals. Simultaneous bilinguals have learned two languages from their birth, there is the same time of acquisition for L1 ad L2. In other words, simultaneous children bilinguals have "more than one first language"; at the same time, "individuals who acquire their second language little 'later', within the first 2-3 years of life" (so called first-language bilinguals) are sometimes ranked in this group as well (Costa and Sebastián-Gallés 2014; Meisel 2005, 134). Those few years after the birth until the puberty are referred to as a *critical period*, that is sensitive for language acquisition because of the brain maturation and the lateralisation process (Yule 2014b). Wartenburger et al. (2003) argue that the term is ill-defined. The paradigm of a critical period is controversial in the adult Second Language Acquisition (Abrahamsson and Hyltenstam 2009), since some researchers claim that it is possible for adults to attain a native-like proficiency in L2 (White and Genesee 1996) no matter when the acquisition started, some argue that it is not possible at all, or it is rare (Abrahamsson and Hyltenstam 2009; Yule 2014a, 188).

Second criterion for defining types of bilingualism is language proficiency. Baker (2004, 64) highlights that bi/multilinguals have a different degree of proficiency and competence in language skills; based on this, passive and active bi/multilingualism can be distinguished (cf. Table 1). In fact, one language is almost always more proficient, but the levels of proficiency are not equally high in all bi/multilinguals (Skutnabb-Kangas and McCarty 2008, 3–17).

Another criterion is language dominance. A dominant language is defined according to Meisel (2005, 137) as the one preferred in choice, and/or the one that enables faster recall of words. Language dominance is also generally assumed to reflect that communicative competence in one language is usually stronger in some domains than in others (Baker 2004, 65). Thus, a self-enforcing pattern can be identified: Bi/multilinguals tend to use their languages for different purposes, in various contexts and with different people (Baker 2004, 64), but it is language exposure that determines whether the languages are equally developed/balanced and equally proficient or whether one language is dominant, more active or more needed (Meisel 2005, 137). It is thus natural that the language that the bi/multilingual needs more frequently develops to be dominant. It is an often overlooked point that the language dominance can change over the lifespan (Grosjean 1982a, 238).

However, recent conceptions of bilingualism, such as individual bilingualism, also incorporate other criteria, such as purposes and situations of language use (cf Table 1), stating that *degree* (an umbrella term for proficiency and language competences such speaking, listening, reading, and writing) and *function* of the language are not separable (Baker 2004, 64).

Furthermore, from a sociolinguistic perspective bi/multilingualism can be understood as a societal phenomenon (Hoffmann 2014). Fundamental empirical studies of multilingual communities come from 1960s (Jordà 2005, 23) and the pioneer is considered to be Uriel Weinreich (1968, 1), who defined bilingualism in a community as a "practice of alternately using two languages". Following Hoffman (2014), the best way to describe bilingualism is to focus on a specific bilingual community taking into account the following factors (Jordà 2005, 24–26): 1) language development, maintenance, and attrition; 2) order of language acquisition; 3) proficiency levels; 4) particular characteristics of the situations in which are the languages used; 5) attitudes towards the languages; 6) motivational, social, and psychological factors; 7) environmental circumstances surrounding the bilinguals; 9) language minorities; 8) degree of familiarity with the two cultures.

Table 1. Classification of Bilingualism

ascendant bilingual	An ability to function in a second language, that is developing due to increase in use.
balanced bilingual (ambilingual, equilingual, symmetrical)	Mastery of two languages is roughly equivalent. Equal languages development it is seen as an artificial concept since one language might be dominant and dominance can change during the life (Meisel 2005, 137).
compound bilingual	Languages learned simultaneously, in the same context, typically from birth (Altarriba 2005, 140).
coordinate bilingual	Languages learned in distinctively separate contexts, such as parents with different mother tongues or different home language (Lust 2008; Altarriba 2005) and official language.
diagonal bilingual	Bilingual in a non-standard language or a dialect and an unrelated standard language.
dominant bilingual	A greater proficiency in one of the languages, this language is used significantly more that the other one(s).
dormant bilingual	Little opportunity to keep the first language actively in use.
early bilingual	Two languages acquired early in the childhood.
horizontal bilingual	Languages are distinct but they have a similar or equal status.
maximal bilingual	Near native control of two or more languages.
natural bilingual (primary)	No specific training, the bilingual is not in the position to translate or interpret with facility.
productive bilingual	A speaker understands and also speaks and writes in two or more languages.
receptive bilingual (asymmetrical, passive, semilingual)	A speaker understands a second language well in either its spoken or written form, or both, but does not necessarily speak or write it well Baker (Baker 2004, 64).
recessive bilingual	Difficulty either in understanding or expressing himself easily due to the lack of use.
semilingual	Insufficient knowledge of either language.
simultaneous bilingual	The languages are present from the onset of speech.
vertical bilingual	Bilingual in a standard language and a distinct but related language or dialect.

Table 1 *is based on Jordà* (2005, 26–27) *and Wei* (2000, 6–7) *depicting various degrees of competence of the bilinguals. Only definitions relevant to the participants in the thesis were chosen.*

2.3.4. Bilingualism and Multilingualism

The growing body of research caused, to a certain extent, terminological confusion that accompanies the definitions of bilingual and multilingual language phenomena.

Fouser (1995, 391) remarked, the terms *bilingualism* and *multilingualism*, also labelled as *plurilingualism* (Clyne 2003; Skutnabb-Kangas and McCarty 2008), are vague since they can refer to "two or more languages being taught and used in a given geopolitical unit, or to a person who is highly proficient in two or more languages" (Fouser 1995, 391).

Further inconsistency of definitions of bi/multilingualism stems from the concept of L2 which can have various background, e.g., as a simultaneously acquired second language or a foreign language, etc. (Jordà 2005, 11).

For instance, some researchers (Jessner 2008; Herdina and Jessner 2002) insist on distinguishing the bilingual and multilingual speakers because of the difference in the second and the third language acquisition and the consequences of the language learning. Such a definition of a multilingualism refers to "a varied phenomenon involving bilingualism and monolingualism as possible forms, but addressing mainly those languages learned after a second one" (Jordà 2005, 12).

Similar distinction is made by Meisel (2001, 12) who defines multilingualism as "the fact that more than one language is acquired and used by the same individual" and claims (2005, 136) that bilingualism "is a special case of multilingualism" when children are exposed to two languages in the childhood and the conditions and ways for acquiring both of them are the same as the conditions for monolinguals. Moreover, he (Meisel 2005, 136) argues that bilingual acquisition equals simultaneous acquisition of two 'first' languages, although he admits that this comparison between monolinguals and bilinguals has been a topic of discussion.

However, Smith (2005, 601) raises a question of how well a person has to master two languages to be considered a bilingual and argues that individuals who use two languages with equal ease in all situations are rare. Similarly, Baker (2004, 65) does not make the distinction between a second language learner and a bilingual person either, since "any language learner is an incipient bilingual [and] any bilingual is/was a language learner", but uses the term bilingual to encompass also people with varying proficiency degrees in three or more languages.

Cruz-Ferreira's understanding (2010b) is in line with Baker, since multilinguals are people who use several languages everyday. Blommaert et al. (2005, 197) point out that "multilingualism is not what individuals have and don't have, but what the environment, as structured determinations and interactional emergence, enables and disables". In this view, everyone is multilingual "wherever and whenever the need for communication arises" (Cruz-Ferreira 2010a, 5).

Reflecting the previous arguments, Jordà (2005, 11) concludes that "bilingualism, trilingualism or multilingualism [...] refer to the same phenomenon". Meuter (2009a, 27) goes even further and defines a multilingual speaker to be "a speaker of more than one language". On account of this proposition, the diploma thesis follows the Meuter's (2009a) understanding of the term *multilingual* (used interchangeably with *bilingual* or *bi/multilingual*) and it will be used to define the participants as multilinguals.

2.3.5. Mother Tongue

The definition of the mother tongue is ambiguous since it can mean a language learned at home, the first language learned, the language most used, the stronger language (Baker 2004, 68), the national language, the language of education (Průcha, Walterová, and Mareš 2001, 118), etc. It is apparent that the definition depends on the point of view and the discipline involved, and the individual's language background and sociolinguistic information are needed to determine his/her mother tongue.

In a very broad sense, the mother tongue is the language a mother or a caretaker talks to a child from its birth; the one people use to communicate with the family and close friends; and the one that helps people to identify with the ethnic community and culture (Průcha, Walterová, and Mareš 2001, 118). This general definition of the mother tongue was also used in the 2011 Czech population census (Neustupný and Nekvapil 2003, 348).

Crystal (2003, 462) defines the mother tongue to be the language first acquired as a child, or preferred when a multilingual situation occurs. Mother tongue is often used as a synonym for the first language (L1). The second language (L2) is then a language learned after acquiring the mother tongue, or learned and used in the specific environment (Skutnabb-Kangas, T. 2008).

Skutnabb-Kangas (2000, 32) also distinguishes several criteria according to which she defines a mother tongue. From the sociological point of view, the mother tongue is the language an individual learns as the first one, from the linguistic point of view, it is the

language one knows the best, whereas from the sociolinguistic point of view, the mother tongue is the language "one identifies with" or "the language one is identified as a native speaker of by others" (2008).

2.3.5.1 Mother Tongue of Minority Groups

It is an ethnic identity that binds individuals and minorities together as a distinct, self-identified group (Skutnabb-Kangas and McCarty 2008). Following the terminology of Grosjean (1982a, 198), minorities (also *ethnic groups, ethnic minorities*) usually have a desire to maintain characteristics that distinguish them from the majority and that unite them, one of the characteristics is the mother tongue. Grosjean defines (1982a, 198) defines a minority as a group "having less power than some other group (i.e., being minoritised), a relationship rather than a characteristic which presupposes that another group has been majoritised". This is a reason for the assimilation process by which "minoritised peoples are brought into conformity with the dominant language and culture, often through coercive practices to replace heritage languages and cultures with those of the majority" (Skutnabb-Kangas and McCarty 2008). Linguistic minorities usually use the majority language in the formal domain, they get education through it and they in fact do not choose to use it freely so they can not identify their mother tongue; this means that the linguistic and sociolinguistic criteria (discussed above) do not help with an identification of the mother tongue (Skutnabb-Kangas, T. 2008).

In other words, the definition of the mother tongue in the linguistic minority might be the combination of the criterion of origin (the language learned as first) and the criterion of self-identification (the language treated as the mother tongue) (Skutnabb-Kangas 2000). This may lead to the fact that one person may have two or more mother tongues and what is important, the mother tongue(s) may change during a person's life depending on the factors such as exposure and language maintenance, an influence of the "home language" and the use of the language for official purposes (Skutnabb-Kangas and McCarty 2008). Samuel and Larraza (2015) stress that when attempting to provide characteristics of an individual's language use, information of "the personal path of language acquisition" should be provided.

2.4. Multilingualism in the Czech Republic

The Czech Republic is sometimes seen (Rawling 2014) to be a monolingual country which means that the language for official matters, politics, education, TV, newspapers, radio, etc. is Czech. The Czech Statistical Office ("Národnostní struktura obyvatel" 2014, 5) claims that the Czech Republic is "rather a homogeneous" country. In opposition to this statement, Neustupný and Nekvapil (2003, 300) argue in their report that this country is a multicultural and multilingual, providing several reasons. Firstly, there has always been language contact with the neighbouring countries and inhabitants living in borders areas, namely with Slovakia, Austria, Germany, and Poland, speak these border languages or language codes. Secondly, it is important to remember the ethnic and linguistic minorities that reside in the Czech Republic. As Alladina and Edwards (1991, 19) generally state, nobody lives in "a social vacuum" and minority communities and their culture play an important role in the language maintenance and management in a given state.

As the figures from the 1991-2011 Czech census in Table 2 show, the core of the Czech nation (Neustupný and Nekvapil 2003, 183) consists of Czech, Moravian, and Silesian ethnic groups. Needless to say that the respondents could opt for dual ethnic identity and that other ethnic groups declared Czech as their mother tongue as well ("Národnostní struktura obyvatel" 2014). Czech is here understood to be the majority language, the language of the dominant group in terms of number of speakers and power (Skutnabb-Kangas and McCarty 2008). Neustupný and Kvapil (2003, 189–192) point out, that the ethnic identity and membership is based on linguistic, socio-economic and cultural interests and power and the respondents categorize themselves according their individual choice. Table 2 also portrays historically relevant and long-term resident communities (Úřad vlády ČR 2015), nowadays classified as minorities in the Czech Republic, that played an important historical role, namely German, Slovak, and Polish.

To sum up, ethnic minorities in the Czech Republic are defined in terms of ethnic origin, language, culture, and the size. They are granted rights[2] to assemblage; to participation in decision making about their minority; to use of personal name in the minority language form; to multilingual names of companies, institutions, streets and other signs; to use the minority language in contact with authorities, courts, and at elections; to

2 ("Zákon O Právech Příslušníků Národnostních Menšin - č. 273/2001 Sb. - Aktuální Znění [Law on the Rights of Ethnic Minorities and Amendment of Some Laws Made on 10th July 2001, No. 273/2001]" 2016).

education in the minority language; to development of their own culture, and last but not least, the right to diffusion as well as reception of information in their own language.

Table 2. Responses to Ethnicity from 1991, 2001, and 2011 Census

Ethnicity (Národnost)	1991		2001		2011	
	Number	(%)	Number	(%)	Number	(%)
Czech	8,363,768	81.2	9,249,777	90.4	6,711,624	64.3
Moravian	1,362,313	13.2	380,474	3.7	521,801	5.0
Slovak	314,877	3.1	193,190	1.9	147,152	1.4
Polish	59,383	0.6	51,968	0.5	39,096	0.4
German	48,556	0.5	39,106	0.4	18,658	0.2
Silesian	44,446	0.4	10,878	0.1	12,214	0.1
Romany	32,903	0.3	11,746	0.1	5,135	0.0
Hungarian	19,932	0.2	14,672	0.1	8,920	0.1
Ukrainian	8,220	0.1	22,112	0.2	53,253	0.5
Russian	5,062	0.1	12,369	0.1	17,872	0.2
...						
Other	9,860	0.1	39,477	0.4	58,289	0.6
Undeclared	22,017	0.2	172,827	1.7	2,642,666	25.3
Total	**10,302,215**	100.0	**10,230,060**	100.0	**10,436,560**	100.0

Table 2. *Responses to nationality/ethnicity from 1991, 2001, and 2011 census is based on the official information provided by the Czech Statistical Office* ("Národnostní struktura obyvatel" 2014, 1).

2.4.1. Stratification of the Czech National Language Model

The stratification of the Czech national language has been one of the most discussed topics in the Czech linguistics. Krčmová (2005, 1) criticizes the widely accepted stratification model for being artificial, because it contrasts the Standard language and its codified norm to dialects which are actually used in everyday speech and for the everyday communication and there is a danger of a negative attitude towards them.

An alternative to the stratification model could be a sociolinguistic approach praised by Makoni and Pennycook (2007, 27), since in their view, the languages have fuzzy boundaries, and so the division between language and dialect is arbitrary. Krčmová (2005) also suggests the use of the sociolinguistic approach and advocates the term "prestigious variety" (instead of Standard Czech) for a language used in formal situations, by media, at

Czech schools, in official communication; and the term "territorial dialect" for less prestigious variety used in everyday spontaneous semi-formal communication[3]. There is, however, another language variety on the scale between the prestigious variety and the territorial dialects, namely the Common Czech (Neustupný and Nekvapil 2003, 235), also labelled as substandard (Hronek 1992) or supra-regional (Mattheier and Radtke 1997).

Language varieties are usually associated with "ethnicity, gender, and social group identity" and speakers choose from the language varieties according to the situation, formality, regional background, function and purpose of the communication, etc. (Bryant 2013, 169).

In the Czech Republic, Moravia and Silesia occupy special positions since these regions are linguistically rich in territorial dialects. In contrast, the Common Czech which is typical for Bohemia is used very scarcely there, and in semi-formal situations, the prestigious Czech is used instead (Neustupný and Nekvapil 2003, 192). In particular, it is a region of Silesia and its language communities that attract the attention of linguistic research (Bogoczová 2006) and that are in focus in this thesis as well.

It is beyond the scope of this thesis to cover the complex topic of the stratification of the Czech language. It is however necessary to outline the position of Polish as a language of the ethnic minority and English, as a foreign language.

2.4.2. Polish Language in the Czech Republic

Polish, together with Czech, Slovak and Sorbian are members of the Western Slavic language group within the Indo-European family (Šimáčková, Podlipský, and Chládková 2012). This implies that Czech and Polish are close languages. Though they show a number of structural differences (Lotko 1997), the mutual comprehensibility of speech is high.

2.4.2.1 The Polish Minority in the Czech Republic

The 2001 Czech census showed that 51,968 people reported Polish ethnicity based on their mother tongue, that is 0.5% of the population in the Czech Republic (Neustupný and Nekvapil 2003, 206). The census in 2011 showed a decrease to 39,096 Poles (Kubala 2011). The Polish community[4] resides in the north-east corner of the Czech Republic

3 Translated from *prestižnost útvaru* and *teritoriální dialekt* (Krčmová 2005).This terminology, *prestigious variety* for Standard Czech and Polish and *territorial dialect* will be used in the thesis.
4 Following terms are used as synonyms in the thesis: *the Polish community*, *the Polish minority* or *the Polish ethnic group in the Czech Republic* (Polská národnostní menšina v České republice) (Lotko 1994, 19.

bordering on Poland, in the Moravian-Silesian Region, historically and geographically called Silesia. The region consists of two districts, Karviná and Frýdek-Místek. According to Zeman (1994), Poles are dispersed among the other parts of the Czech Republic as well, but the highest concentration is formed by so called Těšín community, in the vicinity of the town Český Těšín/Cieszyn, the historical capital of the Cieszyn/Těšín Silesia Region. They are the only territorially bound historical ethnic minority in the Czech Republic (Neustupný and Nekvapil 2003, 208) and they have attracted the attention of a number of researchers.

Historically, Silesia has always been an ethnically varied territory (Lotko 1994, 9). People living there have described themselves ethnically as Silesians, but also Poles, Germans, Czechs, Slovaks or Romas (Neustupný and Nekvapil 2003, 191). It is apparent, that the state border between the Czech Republic and Poland does not correspond to the border between the languages. This fact is also reflected in the Czech language stratification and this region is called *[the] mixed Polish-Czech dialect area*[5] (Bělič 1972). The regional territorial dialects spread across the border and Bělič (1975) argues that linguistic features typical for the Polish language are more frequent towards the borders of Poland and the dialects are parts of both national language stratification models, in the Czech Republic as well as in Poland (Bělič 1975). The concept of the *mixed Polish-Czech dialect area* in the Czech classification (Janda 2008, 276) is in Polish very often referred to as *Śląsk Zaolziański* or *Zaolzie*, based on the river Olše (Olza in Polish) (Lotko 1994, 9).

Bogoczová (1994) comments that the bilingual situation in this region is given mainly by the usage of Czech and Polish languages in the official oral or written communication, however, the fact that there are more language codes used, namely territorial dialects (such as *po naszymu* or *Gwara Cieszyńska,* also called *Těšín dialect*), makes the Polish speakers *autochthons* (Bogoczová 2006, 1). Autochthonous people are native and indigenous settlers of the territory (Bogoczová 1994; Grygar 2003; "Autochthon" 2016). It is important to note, that it is a *diglossic* language situation at the same time. Diglossia is defined as a usage of languages or the language varieties in different conditions and situations (A. Wong 2005). In Bogoczová's terminology (2006), the "high variety" (Polish or Czech) used in prestigious domains or situations such as administration, education, and government; and the "low variety" (territorial dialects) restricted to informal domains, such

5 Translated from *nářečí polsko-českého smíšeného pruhu* (see Bělič 1972, 307).

as family or neighbourhood play an important role (A. Wong 2005, 268; I. R. Smith 2005, 601). The Polish language is thus both a community language (the Polish minority) and a foreign language (see Neustupný and Nekvapil 2003, 290).

2.4.2.2 Historical Milestones in the Cieszyn/Těšín Silesia Region

As was stated above, the Polish community is the only territorially bound historical ethnic minority in the Czech Republic. Several historically relevant milestones should be mentioned. The first one was the year 1920, when the former Cieszyn/Těšín Silesia Region was by force allotted to Czechoslovakia (Neustupný and Nekvapil 2003). The town of Teschen/Cieszyn/Těšín was eventually split into Cieszyn (Poland) and Český Těšín (Czech), and the Cieszyn/Těšín Silesia Region was divided as well. This caused that many Poles found themselves living outside of Poland and formed a community. The separation by a force caused antagonistic feelings that marked the cohabitation of Poles and Czechs in this region ever since (Borák and Gabal 1999).

In 1938, the Cieszyn/Těšín Silesia Region was briefly annexed by Poland and during the WW2 it was occupied by the Nazi Germany, to return to pre-war borders afterwards (Neustupný and Nekvapil 2003).

The Cieszyn/Těšín Silesia Region in the post WW2 period remained a nationally *mixed* community in the Czech-Polish border area which saw reestablishment of Polish schools and expansion of Polish cultural institutions and organizations that promote and preserve the language and culture, such as Polskie Towarzystwo Pedagogiczne (Macura 1998, 55). Another important milestone was in 1955, when the principle of bilingualism was accepted for school education and public life (bilingual signs, official notices, etc.) (Neustupný and Nekvapil 2003, 207).

Since the 1960s on, the number of schools and the number of members claiming the Polish ethnicity has been decreasing (Kadłubiec 1997, 200). There are various reasons and factors, such as assimilation, intermarriages, emergence of the Silesian ethnic category in the national census, lack of schools with Polish teaching language, population decline, etc.

2.4.2.3 Language Codes Used by the Polish Minority

As previously outlined, Czech, Polish and territorial dialects are not used equally in the Cieszyn/Těšín Silesia Region. Neustupný and Nekvapil (2003, 302) argue, that Czech as a majority language is a symbol of ethnic identity and of social stability, culture and

prosperity. It is usually argued (Grosjean 1984, 27–29) that the dominant language is more complete and more grammatically correct, which explains its national role. In contrast, the Polish language and the territorial dialect are sometimes perceived by Czechs in an antagonistic way, as a 'mere' minority language and speaking Polish or the territorial dialect in public can also make an individual the object of public derogation (Neustupný and Nekvapil 2003).

On the other hand, the Czech Government recognizes Polish as a language of the minority group with the implementation of the corresponding rights and regulations, i.e., the right to education in Polish, Polish organizations, media (press, radio) in Polish, bilingual names and bilingual road signs etc. (Úřad vlády ČR 2015). Educational Policy and cultivation of the Polish are also in the hands of the Czech state, namely the Ministry of Education which guarantees the courses of Polish language ethnic group if there are at least 3-4 children interested (Neustupný and Nekvapil 2003, 302). The Polish language is used as a language of instruction at the basic and grammar schools with the Polish teaching language.[6]

Although the common language usually unifies the ethnic group (Bogoczová 2006, 1), the situation is more complex, since the sociolinguistic research in the 1990s (Bogoczová 1994) has shown that the Polish minority speakers have problems to identify themselves in terms of the ethnicity and in terms of their mother tongue. They speak three different varieties of language in daily communication: their Těšín territorial dialect(s), a locally influenced variety of Standard Czech and an equally locally affected variety of Standard Polish (Bogoczová 1994). Up to 20% of respondents declared their mother tongue to be the territorial dialect and 62% of respondents considered this dialect to be a mix of Czech and Polish with German features (Dokoupil, Myška, and Svoboda 2005, 25). The respondents were also asked about their official minority mother tongue and more then 40% replied that they do not have very good Polish language skills and they do not consider it to be their mother tongue.

The Těšín territorial dialects (Bogoczová 2006, 2–3) are language codes for all autochthons. They are felt to be home languages (Lust 2008), for more intimate domains such as conversations with family, friends, neighbours, and blue-collar worker-colleagues (miners), in informal everyday situations. The diglossic speakers are able to switch

6 *polské školy na území Těšínského Slezska = školy s polským vyučovacím jazykem na území Těšínského Slezska.*

between different varieties of a language, the standard variety is usually reserved for formal domains such as education and literacy (Alladina and Edwards 1991, 15). The young generation uses the colloquial territorial dialect as commonly spoken code (Bogoczová 2006, 1). This language phenomenon occurred because there is no conversational prestigious Polish developed, since the minority was isolated from the spoken Polish in Poland. Importantly, the territorial dialect is also used by people of Czech ethnicity who acquired it and autochthons who do not identify themselves with the Polish minority.

Nevertheless, it is Standard Czech that has the highest prestige in the Polish community, since it is a language of the majority and power (Neustupný and Nekvapil 2003, 270). Czech language occurs in the written texts and official communication, at schools and at work (Bogoczová 2006, 2–5). At the same time, prestigious Polish language is spoken by the population that claims to be of Polish nationality, and/or goes to Polish schools, it is also a language of instruction at Polish schools, last but not least, in the written official communication.

2.4.2.4 Sociolinguistic Aspects of Language Use in the Cieszyn/Těšín Silesia

Previous sociolinguistic research (Bogoczová 1993) defined official (i.e., school, work) and unofficial (i.e., home, friends etc.) situations and social roles in which the language codes are preferred. Multilingual Polish minority speakers become conscious of the language, they have to deal with the language choice according to the purpose, situation, to whom they speak and where they speak. In terms of the social context, they learn what is appropriate. Crystal (2003, 364) calls this a "social language variation" when "people acquire several identities as they adopt a social role". For example, Czech is usually the language offered by the Polish minority member in the communication during the first encounters with a stranger (Neustupný and Nekvapil 2003, 270). In the work domain, the selection of varieties is normally determined by the variety preferred by the superior (Bogoczová 2006, 21), i.e., when the superior is oriented towards the Czech language, Czech is used, if the code preferred by the superior is the Těšín dialect, subordinate employees use the dialect or Czech (Neustupný and Nekvapil 2003, 270–271). Bogoczová (2006, 5) also reports that the young Polish minority respondents from high schools tend to start a conversation with an unknown person in Czech; they react in the language code of

the person who starts the conversation; and they do not use Polish in everyday communication, but they are satisfied to attend a Polish school.

To sum up, Polish minority members differ in an inclination towards Poland or the Czech Republic and it is difficult for them to define themselves in terms of culture, belonging to a nation, language preference and nationality, since it is not a language but a national consciousness and awareness that form the key factors to define their nationality (Balhar 1984). The sense of community is supported mainly by the fact that this speech community is concentrated into a small geographical area (Alladina and Edwards 1991, 17). Nationalistic feelings and a desire for an identification with a cultural and social groups are the factors that contribute to bi/multilingualism and biculturalism in the researched region. People living on the Czech-Polish border naturally speak Czech and Polish, and one of the Silesian/Těšín dialects. An important is also the fact that they usually switch not only the codes but also their identity depending on the situation (Neustupný and Nekvapil 2003, 191).

Nowadays, there is a wide array of organisations to support the education, national awareness, the Polish language, and the culture of the Polish minority, for instance, *Kongres Polaków*, *Polski Związek Kulturalno-Oświatowy*, *Stowarzyszenie Cieszyńskiej Młodzieży Twórczej* and many others[7].

2.4.3. English Language in the Czech Republic

A foreign language (FL), in this specific case English in the Czech Republic, is understood in the more restricted sense as a "non-native language taught in school that has no status as a routine medium of communication in a country" (Crystal 2010, 388); in other words, it is a language not used by a community living in the Czech Republic (Neustupný and Nekvapil 2003, 290), usually learned at schools at different levels of the mandatory education process. It is sometimes labelled as an L2 due to its use as "a non-native language […] for purposes of communication, as a medium of education, government, or business" (Crystal 2010, 389).

Needless to say that a lot of English educational programs for children are offered in the public and private English kindergartens for Czech native speakers, however,

7 A list of the organisations supporting the Polish minority is offered by Komůrková (2015): *Kongres Polaków* (www.polonica.cz); *Sdružení polské mládeže v České republice*; *Stowarzyszenie Cieszyńskiej Młodzieży Twórczej* (www.scmt.cieszyn.pl); *Polský institut v Praze* (www.polskyinstitut.cz); *Polski Związek Kulturalno-Oświatowy* (Zarząd główny) (www.pzko.cz); *Velvyslanectví Polské republiky v Praze* (www.ambpol.cz); *Velvyslanectví České republiky v Polsku* (www.mzv.cz/katowice); etc.

a compulsory foreign language education based on the Czech Legislative and on the Common European Framework of Reference (CEFR) for Languages starts at Primary and Secondary Schools:

> […] the educational field of Foreign Language has a weekly time allotment of 3 hours and is mandatory for grades 3 to 9; if there is pupil interest and parental consent, Foreign Language instruction may be commenced at lower grade levels; pupils must be offered English before other languages; if pupils (their statutory representatives) choose a language other than English, the school must provably inform the pupil's statutory representative of the fact that the educational system cannot guarantee continuity in the education of the chosen foreign language in case of the pupil's transfer to another basic school or to secondary school […] the educational content of the educational field of Second Foreign Language is elective; the school is obligated to offer it to all pupils no later than by grade 8; the available time allotment for Second Foreign Language is at least 6 hours; pupils who do not select Second Foreign Language shall select from other subjects which better reflect their interest. Second Foreign Language may be German, French, Spanish, Italian, Russian, Slovak, Polish or another language; schools must offer English as Second Foreign Language for pupils who did not select English as their Foreign Language (Jeřábek and Tupý 2009, 118).

Foreign languages are mandatory at the level of the Higher Education as well. Although English is still felt to be a foreign language in the Czech Republic, the system of education supports it and requires it. The entry of the Czech Republic to the European Union in 2004 opened not only the border-economy-market gates, but also the language gates. The importance and demand for foreign languages has increased and learning English has became a necessity. Foreign languages taught at Czech schools

> "contribute to understanding and discovering facts that go beyond the experience facilitated by the mother tongue, […] provide a vivid language basis and the prerequisites for the pupils' ability to communicate within an integrated Europe and the rest of the world, […] help reduce language barriers and increase the individual's mobility in their personal lives and during their future educational and career paths, […] moreover, they promote an awareness of the importance of mutual international understanding and tolerance and create the conditions for schools' participation in international projects" (Jeřábek and Tupý 2009, 19).

For the purposes of this thesis, the English language is understood to be an additional, learned, foreign, usually third language, that can be a subject of the natural language attrition or decay process if not maintained and practised (Jordà 2005, 13).

2.5. Mechanisms of Bi/multilingual Speech Perception and Production

The far-reaching social impacts of bi/multilingualism have been in contrast for centuries with our limited understanding of how the languages are represented in the brain, with many aspects unresolved even nowadays (Kovelman, Baker, and Petitto 2008; Crystal 2011). The question of how bi/multilinguals maintain and control their languages during language processing has attracted a lot of attention in the past decades. The advent of non-invasive imaging methods, such as functional magnetic resonance imaging (fMRI), allowed for investigation of neurobiological basis of linguistic concepts.

Neurolinguistics thus searches for evidence of the nature of language-related structures and processes involved in language use, speech perception, motor control, linguistic information processing and storage (Baker 2004, 309). Although new brain imaging methods empower new more precise models for the language processing in the brain's organisation (Lust 2006, 92), the research still could not propose neural theories that would encompass all linguistic principles (Lust 2006, 99).

Therefore, in the following section, the classical models of bilingualism stemming from behavioural studies are synthesised with the latest findings of neurolinguistics to provide a ground for the research questions postulated in this thesis.

2.5.1. Neurobiological Basis of Language and Speech

2.5.1.1 Current Methodology in Neurolinguistics

Technical advances in electrophysiological and brain-imaging techniques not only led to a new empirical basis for the investigation of cognition (Müller and Strazny 2005, 1024) but also enabled non-invasive measurements of brain activity during the engagement at various stages of language perception, processing, lexical storage, retrieval, and speech production. A brief introduction of the imaging methods and current popular methodologies is provided in the Appendix 1.

2.5.1.2 Localisation of Language Representation in the Brain

Before moving to bi/multilingualism, several basic neurobiological aspects of language representation in general will be clarified in this section.

Language, including speech perception and production, is an inherent cognitive function of the cerebral cortex (also called cerebrum in a narrow sense). Cerebrum consists of the left and right cerebral hemispheres, which can be further divided into several lobes

(Crystal 2007a, 171). Language areas are mostly found in the left hemisphere, since according to the consensus in the research on the cerebral dominance, the left hemisphere is dominant for language in 95% of right-handers, but also in more than 60% left-handers (Crystal 2007b, 173).

According to the theory of the cerebral localisation (Caplan 1981; Phillips, Zeki, and Barlow 1984; York and Steinberg 1994; Marshall and Fink 2003), certain behavioural abilities (functions) such as speech are maintained by specific brain areas (Crystal 2007b, 174). This theory was based on seminal findings of P. B. Broca (1861) and C. Wernicke (1874) who observed that a damage in the particular brain area led to the loss of a relevant linguistic ability.

Since then, Broca's area (mainly Brodmann's area 44 and 45) has been recognised as a region in the frontal lobe operculum (i.e., the lateralmost inferior portion) important for language production. Broca's area exhibits strong functional asymmetry since the left (dominant) opercular region usually has more important language role than the right one (Orrison 2008, 6). An acute damage in the Broca's area leads to inability or reduced ability to speak, with grammatical and phonematic errors (so called non-fluent, or expressive, or Broca aphasia, (Baehr and Frotscher 2012, 249–253)) but the comprehension of the language stays mostly normal (Crystal 2007b, 174), however, it has been also shown that it is possible to speak even without Broca's area, because the compensatory mechanisms of the brain can make up for the lost language functions, especially in young individuals and with slow developing lesions (Plaza et al. 2009). On the other hand, Broca's area may also participate in speech comprehension, e.g., of complex passive sentences (Mack et al. 2013).

Wernicke's area is a region located bilaterally, in the upper back part of the temporal lobe and is essential for understanding of written and spoken languages (Orrison 2008, 32); its damage leads to an inability to comprehend the language (Crystal 2007b, 174).

Current evidence based on the various types of aphasia has shown that the left hemisphere is dominant for speech comprehension and production in almost 99 % of right-handers and up to 63 % of left-handers and ambidextrous people, whereas the right hemisphere is dominant only in 13% of left-handed and ambidextrous adults, and in 24 % both hemispheres contribute more or less equally (I. R. Smith 2005, 607).

This is, however, a simplified view, as both Broca's and Wernicke's areas can be further divided into several subregions with distinct functions, (Boeckx, Martinez-Alvarez, and Leivada 2014).

2.5.1.3 Current Models of Speech Production and Comprehension

Although the classical Wernicke's model (1874) with two major language centres (one for speech comprehension and one for production) is compelling, contemporary research revealed far more complex language networks (Hickok 2012).

An ability to comprehend written, spoken or signed language seems automatic and effortless but it consists of numerous (unconscious) analytic and synthetic multi-layered operations starting with the sensory-perceptual stimuli through neural transmission towards the encoding, allocation, retrieval, comparing, mapping, inhibiting, and integrating of the information (see Kutas and Federmeier 2007, 385–386, and 400). Each of the stages has a neural representation (Crystal 2007b, 176). Warren (2012, 5) describes several unconscious steps in speech production: first, the underlying intention, second, planning of the sentence structure followed by the word selection, and last, the articulation. Recently, several models attempting to include these processes have been proposed, out of which, three will be summarised briefly.

Hickok and Poeppel (2007; Hickok 2012) proposed a dual-stream model of speech perception in which speech is processed in two main parallel pipelines: a bilateral ventral stream mapping phonological representations onto lexical representations in the inferior temporal lobe, and a strongly left-lateralised dorsal stream mapping the phonological input onto articulatory representations in the left frontal lobe. Both streams receive the input through a common phonological network in the superior temporal lobes (in the superior temporal sulcus). The model therefore assumes that both cerebral hemispheres contribute to speech comprehension, but only the dominant hemisphere is crucial for speech production. The model also involves other structures outside the classical speech areas, for instance, the inferior parietal cortex serving as a sensorimotor interface that translates auditory speech signals from the temporal lobe into articulatory representations of the frontal cortex. Hickok and Poeppel (2007) also discuss evidence (Liberman and Mattingly 1989; Price, Thierry, and Griffiths 2005) that linguistic units, such as distinctive features, phonemes and syllables, have biological representation and therefore suggest that they may provide infrastructure for the phonological analysis occurring in the brain. Also

morphemes, i.e., the smallest meaningful units, seem to have “an active role in word recognition” (Hickok and Poeppel 2007) and are not a purely abstract concept (Whalen et al. 2006).

Rauschecker and Scott (2009) proposed a modified dual stream model, in which the ventral stream contributes to semantic analysis by recognising abstract linguistic features, whereas the structures of the dorsal stream maintain the 'internal models' linking multisensory and domain-general information, providing feedback for articulatory network in the Broca's area.

The existence of a dual stream system has been supported by Saur et al. (2010), who noted, however, that cognitive processes emerge as a result of the interaction in a distributed network rather than computational processes occurring in each area (so called node). For instance, speech comprehension has been shown to involve interaction between the temporal and frontal areas, suggesting that it is achieved through the simulation of the speech production (see Liberman's “Motor theory of speech perception” (Liberman and Mattingly 1985; Liberman and Whalen 2000; Galantucci, Fowler, and Turvey 2006)). But still, richly interconnected central nodes, such as the superior temporal gyrus in the phonological network (see above), or middle temporal gyrus in the ventral stream, are still essential since their loss may disrupt the function of the whole network for speech comprehension (Saur et al. 2010).

2.5.2. Competing Concepts of Language Representation in Bi/multilinguals

Although the current models of language representation in the brain are highly advanced, they do not specifically address bi/multilingualism. In this section, several theoretical concepts of bi/multilingualism are introduced that are mainly based on behavioural studies, whereas neuroimaging evidence will be confronted in the following section.

One of the earliest studies on bilingualism, yet still in the focus of scholarly debates, was proposed in late 1960s by Weinreich (for more information see Grosjean 1982b, 240; Cantone 2007a, 5) who introduced three types of individual bilingualism based on the acquisition, representation, and the storage of the language in a brain (Cantone 2007a, 5): First, *the coordinative type* that has two separate lexicons for languages and each word has its own specific meaning (two sets of meaning units, two modes of expression). The second type of bilinguals is *the compound type* in whom each word conjures up the same

reality (one set of meaning units, two modes of expression), and the third is *the subcoordinative type* (the meaning units of the first language, two modes of expression) in whom the word of a weaker language is interpreted through the stronger one, in other words, one language is stronger and faster than the other language.

Grosjean (1989; 2001) researched the monolingual-bilingual comparison issues and first presented psycho-linguistic *monolingual* (or *fractional* (Grosjean 1985)) and later *bilingual* (*holistic* (Grosjean 1994)) views. The former presupposes that the bilingual speaker is two monolinguals in one person, and the latter states that the coexistence of two languages in one bilingual produces a unique speaker-hearer, and bilingual speaker is seen as a complete linguistic entity.

The fractional view is nowadays regarded as simplistic since the monolingual-bilingual comparison is criticized (Baker 2004, 68), however, the concepts of monolingual and bilingual modes are relevant for the code switching phenomenon, (see below).

The interest in bi/multilinguals derives from the question of the degree of separation of bilinguals' dual-language representation (Kovelman, Baker, and Petitto 2008). Bi/multilingual speakers control their language production so that they do not mix the languages in an inappropriate way in the communication (Costa and Sebastián-Gallés 2014). Still, it is equally important to stress that mixing languages is natural since it illustrates that speakers can use all the linguistic resources available to them when need arises (Crystal 2011). Moreover, although language mixing has been shown in polyglots and polyglot aphasics (Grosjean 1985), monolinguals mix languages as well, e.g., in the form of loan words (Crystal 2011). This phenomenon is dealt with in a special section below.

The research concerning the relationship between the linguistic systems in bi/multilinguals distinguishes between *dependent* and *independent* concepts (Jordà 2005, 11). There are two cognitive developmental theories of simultaneous bilingual acquisition, *Unitary Language System Hypothesis* (one system common for both languages) (Volterra and Taeschner 1978), and *Independent Development Hypothesis* (Bergmann 1976). According to Hoffman (2014), the former one has been criticised (Meisel 2005) since there is insufficient evidence for an initial undifferentiated language system.

Using similar concepts, two contradictory hypotheses for storage and mental representation of linguistic knowledge are distinguished: *Separate/Independence*

Hypothesis (two languages in two storage systems), and *Shared Storage/Interdependence Hypothesis* (single storage) (Jordà 2005, 29–30). However, Jordà (2005, 30) also argues that both hypotheses are needed in the description of bilingual cognitive processing.

Similar concerns were raised also in terms of grammatical differentiation in bilinguals, and two concepts emerged: *Differentiation Hypothesis* (differentiated grammatical systems) and *Fusion Hypothesis* (one grammatical system), with the former being now widely accepted (Meisel 2001, 14).

An analogous dichotomy is also apparent in concepts of lexical access in bi/multilinguals. The *selective* approach, postulating that language systems work independently of each other (one is "on" while the other is "off") was in recent years outweighed by *non-selective* theories (i.e., both languages active at the same time, even those "irrelevant") of multilingual language processing and code-switching (Altarriba and Basnight-Brown 2009, 13; Wu and Thierry 2010).

The *non-selective* view was first introduced in the single word processing context and it was later applied to bilingual sentence processing (Altarriba and Basnight-Brown 2009) and to research concerning third language acquisition. For instance, Jordà (2005, 14) claims that languages already known by the multilingual speaker play an important role in the learning process of another language and this "whole linguistic system" is commanded by the user simultaneously.

Williams (2006) showed *non-selective* processing in non-native non-fluent speakers of English as an L2 activating[8] their L1 while using L2. Moreover, Duyck et al. (2007) reported faster reaction times to cognates in Dutch-English bilinguals in a word recognition task and this facilitation occurred even though the task did not require access of the first language lexicon. Simultaneous non-selective activation of both languages in bilinguals was also ascertained in other studies employing visual and auditory word recognition tasks (e.g., Sánchez-Casas and García-Albea 2005; Marian and Spivey 2003).

The *non-selective* view is also endorsed by Crystal (2011) who states that languages in a brain do not occupy individual spaces "like bricks in a box", and what is more, there is no proof for the claim that one language can somehow block the other. In a balanced bi/multilingulism, "multilingual's languages are '*always on*', equally available to access

8 In linguistic terminology, *activation* means availability or engagement of a language or language resources in a bi/multilingual person. This term should not be interchanged with the term *activation* used in functional neuroimaging to indicate a regional blood oxygenation level-dependent (BOLD) signal increase correlated with the *a priori* model of haemodynamic response.

[… and] multilingual people often don't know which of their languages they used on a particular occasion" (Crystal 2011). Altarriba and Basnigh-Brown (2009) suggested that, the *non-selective* processing mentioned above seems to be "in line with the assumptions posited by Bilingual Interactive Model" by Dijkstra and van Heuven (see below).

Depending on the prevailing concept of separate (independent) or shared (interdependent) resources for bi/multilingual speech production, several bi/multilingualism models were proposed which are discussed in the next section.

2.5.3. Selected Models for Bi/Multilingual Speech Processing Mechanisms

Behavioural, mainly psycholinguistic studies introduced a great number of models of bilingual language representation and processing, such as the IC model or BIA+ models (see below), dealing with questions of how bilingual speakers maintain their languages, how the language system in bilinguals functions, whether the speech production and processing in L1 influences L2 and vice versa, and last but not least, how and when the languages are activated (van Heuven and Dijkstra 2010).

De Bot (1992) adapted Levelt's (1989) model of speech production and processing in monolinguals and presented the Bilingual Production Model. Several levels during the language activation/non-activation in the bilinguals are distinguished, namely *active*, *non-active*, *selected,* and *dormant* (1992). Bilingual speakers who want to express a thought in their "mother tongue" (Jordà 2005, 33) activate grammatical and phonological systems in both of their languages, however, only the phonetic plan involving the targeted language is converted into speech (de Bot 1992). This model of a parallel activation of two speech plans provides a good platform for a description of cross linguistic phenomena and intentional language switching (not for the unintentional switches) specifically tailored for bilingual experiments (Jordà 2005, 35).

Poulisse and Bongaerts (1994) proposed another bilingual speech production model. In this model, a lexical item from all the bi/multilingual's languages is in the "common conceptual core" and language choice information is added to the pre-verbal message as a "language component" responsible for an activation of the lemmas of the chosen language which prevents the other language(s) from being activated (Poulisse and Bongaerts 1994).

Grosjean (1989; 2001) introduced a concept of two modes of language production depending on the receiver, namely *a monolingual mode* and *a bilingual mode*.

The former represents the mode in which bilingual speakers use *one language (A)* in a conversation with monolinguals with whom they cannot use their *other language (B)*; in neural modelling terminology, they deactivate this other (B) language so that it is not produced. However, bilingual speakers can be at an "intermediate position" (Grosjean 2001), i.e., when the receiver speaks the other language (B) in a limited extent and this may lead to mixing of the languages (Baker 2004, 69). In the intermediate position, the other language (B) is according to Grosjean partially activated.

The latter, the bilingual mode, applies to situations when a bilingual speaker speaks with another bilingual and they share their languages and can code-switch, that is, they change a language in the course of the conversation (Baker 2004, 68). Both languages are activated and available but one slightly less since it is not currently the main language of processing (Grosjean 2001).

Bilinguals decide which language to use, how much they need it and an activation of languages reflects this decision. In short, the language mode is "the state of activation of the bilingual's languages and language processing mechanisms at a given point in time" (Grosjean 2001, 2). It is argued that language modes can to some extent account for findings related to language representation and language processing, interference, code-switching, language mixing, etc. (Grosjean 2001, 3).

In contrast to Grosjean's (1989) hypothesis that specifies mechanisms of language activation during speech production, Green (1998) proposed a model involving an inhibitory mechanism as well, so called Inhibitory Control (IC) Model. He based this model on the Revised Hierarchical Model by Kroll and Stewart (1994) which accounted for asymmetries observed in translation performance in late bilinguals with dominant L1, suggesting that L1 has privileged access to meaning and the less proficient L2 has to be mediated via L1 translation equivalent (Kroll et al. 2010).

The Green's (1998) IC Model proposes that to select a target language during speech production, unbalanced bi/multilinguals exert inhibitory control to suppress the interfering non-target language, limiting attention to the intended one. Thus, the interplay between the activation and inhibition seems to form the basis of regulation in bilingual phenomena (Green 1998). Green also suggests that the inhibitory mechanism underlying lexico-semantic control is a general cognitive mechanism and not one specific to language processes. This seems to be supported by recent neuroimaging evidence, indicating that

language switching recruits brain areas related to domain-general inhibition (de Bruin et al. 2014a). Furthermore, it has been reported that the language switching comes at a cost (Bobb and Wodniecka 2013), because it requires a change of a language and time to overcome inhibition of the previously activated language (Valenti and Scheutz 2013). Moreover, the IC Model suggests that the source of language switching costs can not be found in the lexico-semantic system but in the system of a task/decision (Valenti and Scheutz 2013). This can be illustrated with an experimental study of language switching by Meuter and Allport (1999) in which the bilingual participants unpredictably named numerals in their languages. The authors reported that bilinguals took longer to name a number in the L1 directly following an L2 trial than to name a number in the L2 following an L1 trial. It was therefore suggested that bilinguals suppress the more dominant L1 during L2 production (Meuter and Allport 1999).

Dijkstra and van Heuven (2002) extended the Green's IC Model by incorporating a new model of the lexico-semantic system and proposed Bilingual Interactive Activation Model (BIA+) of non-selective access in bilingual word recognition. This model offers a framework for bilingual memory, cross-lingual interference and it also deals with semantic *priming effect*, i.e., the non-conscious memory effect during the semantic activation of the bilingual's languages in which the previous stimulus influences a response to a later stimulus (Martin et al. 2009; M. Ford 2013).

This model is also an extension of the previous BIA Model of a word recognition in bilingual memory, according to which the two languages of the bilingual speaker form an integrated lexicon in which an activated word in one language activates entries that are similar in the other language so that both lexical entries are activated, even those not relevant and not needed (Dijkstra and van Heuven 2002). The Model BIA+ was reported to account not only for lexical representation in which it distinguishes two directions of the activation, *top-down* (contextual) and *bottom-up* (feature-based) (Altarriba and Basnight-Brown 2009, 21), but according to Valenti and Scheutz (2013), it also accounts for empirically observed phenomena, such as “orthographic neighbourhood effects, cross-linguistic effects, non-linguistic context effects, and stimulus-response binding”.

A different perspective is offered by Paradis (2004) who integrated several his previous hypotheses, such as *the Three-store Hypothesis*, *the Direct-access Hypothesis*, *the*

Activation Threshold Hypothesis, and *the Subsystem Hypothesis*, into a Neurofunctional Model.

The Three-Store Hypothesis suggests that bilinguals posses two language-specific systems and one separate non-linguistic cognitive store (system) (Paradis 2004, 195). In the Subsystem Hypothesis, Paradis (2004) further proposed that encoding processes and representations are not shared across languages and are organised into collaborating independent modular systems, including "implicit linguistic competence, explicit metalinguistic knowledge, and linguistic pragmatics" for each language, and at the common store, a conceptual system and motivation/affect (Paradis 2009). According to Paradis' (2004, 206) Direct-access Hypothesis, speakers have immediate access to the language of their choice when encoding a message. The acoustic signal representing a word is also suggested to automatically activate its lexical representation, which then activates a representation in the conceptual system (Paradis 2004, 223). Irrespective of the system, the Activation Threshold Hypothesis postulates that all representations or items require a certain amount of positive impulses to be activated. The threshold is lowered after each activation, but increases when the stimulation is absent (Paradis 2004, 28). The interference with competing items (and/or language systems) is avoided by increasing their activation threshold, which corresponds to Green's inhibitory control (Paradis 2004, 28; cf. Green 1998).

Recently, Green and Abutalebi (2013) proposed the Adaptive Control Hypothesis with a special focus on speech production of bilingual speakers. Research has shown that speech comprehension and production require a top-down cognitive control (Boudewyn, Carter, and Swaab 2012; Erb and Obleser 2013), an internal process that involves interference suppression and conflict monitoring, necessary for the bilinguals to maintain a goal of speaking the target language (Green and Abutalebi 2013). From the evolutionary perspective, these control processes are the same as those generally involved in action control, and as such, they are recruited also by monolinguals (Green and Abutalebi 2013).

The model presented by Green and Abutalebi (2013) introduces a framework of speech pipeline (speech-related processes) governed by and providing feedback to control and meta-control processes. The control processes may engage over the whole speech pipeline, from the formulation of the message, to the selection of the target sequence of lemmas, word forms and phonemes. However, the cognitive control is not only responsible for

selection of target representations stored in the working memory, but also for conflict monitoring and error correction (Green and Abutalebi 2013). The control processes can be therefore decomposed into several classes, such as "goal maintenance, conflict monitoring, interference suppression, salient cue detection, selective response inhibition, task disengagement, task engagement, opportunistic planning". These processes require that also brain structures outside the classical speech network exerting the top-down control (see above) are involved, such as the pre-supplementary motor area (pre-SMA), anterior cingulate cortex (ACC), and prefrontal cortex.

The demands on individual control processes vary in different interactional contexts (i.e., single-language or dual-language context) and their sum results in a context-specific interaction cost (joint effort needed to carry out a conversation in a given interactional context) (Green and Abutalebi 2013). These demands (interaction costs) placed on the control network lead to adaptive changes via the meta-control processes (Green and Abutalebi 2013).

This model has been used as a feasible framework for neurobiological interpretation of phenomena such as language switching (Abutalebi et al. 2013) and has been supported by recent functional neuroimaging studies (García-Pentón et al. 2016b).

2.5.4. Features of Bi/multilingual Speech

An interaction between languages in the bi/multilingual speakers brings about certain features, such as language/code switching, mixing, transfer, and interference (Jordà 2005, 36). These will be briefly introduced with a focus on the language/code switching.

2.5.4.1 Language/Code Switching (CS)

In the past, *language switching* (LS) used to be seen as a proof of the internal mental confusion (Lipski 1982, 191). Nowadays, it is regarded as efficient, valuable, rational, usually unconscious linguistic strategy and a defining feature of spontaneous bi/multilingual speech (Jordà 2005, 11). The ability to switch, however, is a very complex fast, efficient and flexible process and a fundamental aspect of bi/multilingual communication (Sierpowska et al. 2013). Although bi/multilingual speakers produce and perceive a switch from one language to another without any apparent difficulty (Abutalebi et al. 2007), they have to control the interaction between their languages during the communication; they have to choose the language currently needed, maintain the

functional and pragmatic clarity in terms of politeness, directness, and the possible outcome or the goal of the communication, and at the same time, they need to avoid interferences from the language that is currently not in use (Altarriba and Basnight-Brown 2009, 3).

CS typically occurs when bi/multilinguals change a language in the course of the conversation with other bi/multilingual (Grosjean 2001). When bilinguals code-switch, they select a *base language* (also called *recipient* or *matrix*) and the other language is the *donor* (*embedded*); CS can happen at a word/phrase/ or a sentence level (Baker 2004, 68; Grosjean 2001).

This phenomenon is also known as *code mixing*, *language mixing*, *language switching*, or *code shifting* (Crystal 1987, 362); the variety of the terminological apparatus reflects different discipline approaches (e.g., linguistics, pragmatics, sociolinguistics) and the switch at different language levels, for example, *code mixing* sometimes describes changes at the lexical level, however, it is nowadays universally used for any switch at all language levels (Baker 2004, 68).

There are various reasons for a bi/multilinguals to code-switch depending on the situation, discourse, and language choice. Firstly, CS very often takes place in order to facilitate communication or to express concepts that can be language-specific (Altarriba 2005, 140), i.e., when the bilinguals want to convey a precise semantic content of the message and/or when the expression does not exist in an active language (Grosjean 1982a). Among other reasons, CS is used to clarify, to stress, to emphasize, to substitute, and to offer an equivalent, loan or borrowing; last but not least, CS takes place because of the lack of knowledge of the correct word (Altarriba and Basnight-Brown 2009; Grosjean 1982b; Heredia and Altarriba 2001). Heredia and Brown (2005, 214–215) stress the importance of CS when the lack of knowledge occurs and CS is then a strategy to compensate for diminished language proficiency, this situation is known as *semilingualism*.

Another reasons for CS to take place is situational, such as to mark transitions from one domain to another, to mark a change in topic, or it is used to create a special effect and to signal the attitude towards the listener etc. Very important are sociolinguistic circumstances, when the switch can be a tool to serve social reasons (I. R. Smith 2005, 601), such as to signal a particular identity, to express status of the relationship, solidarity with and belonging to a social group, showing friendship or creating distance, intimacy,

solidarity, an attitude of defence; it can also be used as a 'secret language' with the purpose to exclude the listener who does not belong to the certain group (Crystal 1987, 363; Baker 2004, 71; Bermel 2001).

LS is indeed a characteristic social marker of an identity or belonging to a particular group or minority (Baker 2004, 70); since in-group languages used within the community are a sign of community solidarity, usually not understood by outsiders (Papen 2005, 138).

From the neurolinguistic point of view, it is suggested that areas in the prefrontal cortex, the parietal lobe and/or the basal ganglia are involved in the LS (Grosjean 2014; Green and Abutalebi 2013). Therefore, the LS has been one of the most used paradigms in the field to study multilingual language control/language selection (Altarriba and Basnight-Brown 2009; Hernandez, Martinez, and Kohnert 2000b; Jackson et al. 2001; Costa and Santesteban 2004; Christoffels, Firk, and Schiller 2007; Verhoef, Roelofs, and Chwilla 2009; Abutalebi et al. 2013).

2.5.4.2 Language Mixing

The term *language mixing* in adults has to be differentiated from the phenomenon of *early mixing* (Cantone 2007b) in bilingual children. The former is systematic and follows linguistic rules, whereas the latter occurs when bilingual children do not distinguish the two language systems (Meisel 2001, 15). There were attempts to explain children's mixing as a lack of grammatical knowledge but the “frequency of mixing does not generally decrease with grammatical development” (Meisel 2005, 137).

The early mixing phenomenon is related to the language separation hypotheses and language acquisition in children. In contrast to original beliefs, it has been observed that children acquiring two or more languages simultaneously eventually reach the same grammatical knowledge as their monolingual peers (Meisel 2001, 12). Researchers have thus proved that the language separation in bi/multilingual children works from the very early on and without much effort (Meisel 2005, 137).

2.5.4.3 Language Transfer

Language transfer is a natural situation in which features from one language code influence another or the mechanisms or organization are transferred from one language code to another (Bogoczová 2006, 3). It can appear at all language levels (Muryc 2013)

and it may involve any linguistic feature, such as pronunciation, word structure, grammar, vocabulary, or semantics (I. R. Smith 2005, 601).

Smith (2005, 601) argued that the characteristics and the definition of the phenomenon known as *transfer* depend on the context, since transfer could be also referred to as *structural borrowing*, *interference*, *imposition*, or *convergence* (Bullock, Hinrichs, and Toribio 2014). Bi/multilinguals may incorporate features of one of their languages while speaking the other; the reasons are various, e.g., incomplete mastery of one of the languages (I. R. Smith 2005, 601).

Research on second and third language acquisition has revealed much about the role of language transfer from L1 and/or L2 in learning an L3 (Fouser 1995, 400). Recent studies have found that transfer in L3 acquisition is generally productive, especially in the lexicon (Ringbom 2007), and that it facilitates learning the most when the target L3 is closely related to one of the two languages already acquired (Hufeisen and Neuner 2004; S. Williams and Hammarberg 1998; Ringbom 2007).

2.5.4.4 Interference

When a dominant language influences the less dominant in the monolingual mode and occasional language mixing happens, it is called *interference* (Baker 2004, 69), however, it is sometimes interchangeable with *transfer*. The most evident interference is language dominance, meaning that one language is stronger and has a bigger lexicon than the other one. Interference is not only on the lexical level, it applies to all language levels. Grosjean (2001) distinguishes *static* and *dynamic* interference, the former one is a rather permanent influence of one language on the other in terms of accent, pronunciation or intonation. The latter, dynamic interference, is a temporal influence of one language in terms of syntax, phonology, or lexicon (Baker 2004, 69).

2.5.4.5 Positive and Negative Impact of Bi/multilingualism

Although the positive aspects of bi/multilingualism are complex and difficult to generalize as the research data always depend on many factors such as age, socio-economic background, education, etc., there are several advantages of bi/multilingualism to be emphasised. Previous research stressed the positive impact of bi/multilingualism on the cognitive skills, i.e., metalinguistic awareness and executive control. Bi/multilingual

speakers are said to possess cognitive and mental flexibility and these are very beneficial in cognitive processing (Altarriba 2005, 140).

Metalinguistic awareness is an explicit knowledge of the language system and the capacity to speak about its properties; it is also essential for literacy and it develops mainly in pre-school years when children grow cognitively and acquire better control of languages (Melzi and Schick 2013, 338; Buchweitz and Prat 2013). Bi/multilingualism fosters children's ability to think about the language and it indisputably leads to greater metalinguistic skills, nevertheless, the relation between bilingualism and other forms of metalinguistic knowledge depends on a level of competency in both languages, literacy instruction and other factors (Melzi and Schick 2013, 342). Bi/multilingual children have more ways to label the world around them and they have an early awareness of multiple ways in which concepts and systems can be described and named across languages (Altarriba 2005, 141). The previous research has shown that bi/multilingual children outperform monolingual in tasks that include role-playing, object classification, creativity, concept formation, memory, metalinguistic awareness, perceptual disembedding, problem-solving, role-taking, social sensitivity, and complex instruction comprehension (Altarriba 2005, 140). Bi/multilinguals are better at multitasking and prioritizing (Jha 2011). Crystal (2011) argues that the more languages people acquire, the more they have an insight into other language systems and how they work.

Some of these effects may be related to higher language-processing demands in bilinguals in comparison to monolinguals, which probably reflect the need for cognitive or executive control to resolve lexical competition (Costa and Sebastián-Gallés 2014). *Executive control* (or *executive function EF*) is an umbrella term for more complex cognitive processes, mainly for inhibitory control, working memory, and cognitive flexibility; among other cognitive processes rank also attention, inhibition, monitoring, selection, planning, working, problem solving, and others (Buchweitz and Prat 2013). Executive control system is also responsible for multitasking (Myler 1998) and since the language systems of bi/multilinguals are constantly active and competing (Marian and Shook 2012), bi/multilingual speakers “need to manage attention to the target language and avoid interference from the non-target language by recruiting the EF system” (Poarch and Bialystok 2014). Through the reorganization and strengthening of the involved neural networks, bi/multilingualism has been suggested (Freedman et al. 2014) to increase the so

called cognitive reserve (associated with factors, i.e., higher levels of education, occupational status, social networks, or physical exercise), providing a significant positive impact on the executive control (Grosjean 2015).

Bialystok et al. (2011) argue that the attentional control that bilinguals used to govern their languages during lifetime brings an advantage in EF that are responsible for managing attention and that are similar to complex mental activities known to protect against dementia. Indeed, Freedman et al. (2014) reported that speaking two or more languages has a protective effect in delaying the onset of dementia. Current research aims at examining the bilingual advantage in terms of EF in patients with Parkinson's disease (Hindle et al. 2015).

Previous research confirmed that the formation of synapses is activity-dependent and that new synapses can emerge and change throughout the life depending on memory and learning (Baehr and Frotscher 2012, 9). This ability is called brain plasticity or neuroplasticity.

Plasticity in children during language acquisition is a natural developmental process of "changes in the configuration of language-related brain systems [...], with differential sensitivity of different language subsystems to age and experience" (Kutas and Federmeier 2007, 400). There has been evidence for a cognitive advantage, also called a bilingual advantage (H. Yang, Hartanto, and Yang 2016), i.e., improved cognitive skills in terms of working memory and switching attention, an influence of executive control system on multitasking and sustained attention etc. in bilingual children (S. Yang, Yang, and Lust 2011; Myler 1998) and there are studies providing solid evidence for the view that learning a second language leads to long-term adult plasticity (compensatory mechanisms of the brain) (Kutas and Federmeier 2007, 400).

Despite numerous evidence for positive effects of bilingualism on EF, it is still a matter of scientific debate. Some authors (Paap et al. 2014) even question whether the bilingual advantage exists. Previous studies concerning the bi/multilingual disadvantage show an evidence that language switching comes at a cost (Meuter and Allport 1999; Valenti and Scheutz 2013; Bobb and Wodniecka 2013) since it takes time to overcome inhibition (Green 1998). It has also been reported that "bilinguals take longer to read and comprehend sentences containing code-switch words as compared to monolingual sentences" (Heredia and Brown 2005, 215).

Drawbacks in healthy bi/multilinguals have been recently reported by Ouzia and Folke (2016). They tested whether there are advantages in cognitive abilities and focused on metacognitive processing, namely on ability for decision making. Monolingual and bilingual groups were tested in accuracy of the self-report performance in the tasks and they were asked to evaluate their confidence in the decision. A disadvantage in metacognitive processing was reported in the bilingual group showing, that the "bilinguals had less insight into their performance than monolinguals" (Ouzia and Folke 2016). New direction of the bilingual metacognition research needs to be explored to provide more information about the bilingual dis/advantage.

2.5.5. Neurobiological Correlates of Language Switching

2.5.5.1 Language Switching Network

There are several cerebral structures involved in language switching in multilinguals, among others the complex of (pre-)supplementary motor area and anterior cingulate cortex (pre-SMA/ACC), left prefrontal cortex (middle frontal gyrus), and the left caudate nucleus (Abutalebi and Green 2007; 2008; Green and Abutalebi 2013; García-Pentón et al. 2016b; B. Wong, Yin, and O'Brien 2016). As discussed in greater detail below, these structures do not belong to the classical speech network as they share more general cognitive functions (Abutalebi and Green 2007).

First, Hernandez et al. (2001; 2000a) observed frequent switching during mixed language picture naming was accompanied by an increased activation in the right dorsolateral prefrontal cortex. This lateral prefrontral region is implicated in various generic functions, such as executive control, decision-making, response selection and inhibition, and working memory, while in the context of language switching, the DLPFC has been suggested to exert top-down control (Abutalebi and Green 2007).

Another key component of the language control network in multilinguals has been identified in the head of the left caudate nucleus (Crinion et al. 2006). The left caudate is an elongated subcortical grey matter structure which constitutes the lateral wall of the lateral ventricle in both cerebral hemispheres. The caudate and other similar structures in the deep grey matter of the forebrain are also called "basal ganglia". In classical anatomical descriptions, these structures receive vast input from the cerebral cortex, and together with the thalamus, another deep grey matter structure, they form complex control

circuits involved in motor, cognitive and emotional processes (Baehr and Frotscher 2012, 214–219).

Specifically, the left caudate nucleus has been shown in neuroimaging studies to engage whenever there is a change of meaning or change of the language, suggesting that it is responsible for lexical-semantic control and for monitoring and controlling the language in use in bilinguals (Crinion et al. 2006). This was also supported by the finding that the grey matter volume in the left caudate was increased in bilinguals compared to monolinguals (Zou et al. 2012). It was also demonstrated that patients with the isolated damage of the left caudate may present with spontaneous involuntary language switching (e.g., Abutalebi, Miozzo, and Cappa 2000). This specific role of the left caudate could be determined by its connections with the DLPFC which mediates goal-directed behavior (Grahn, Parkinson, and Owen 2008) and is also involved in language switching (Hernandez, Martinez, and Kohnert 2000a; Hernandez et al. 2001; Abutalebi and Green 2007). However, more recent imaging studies have shown inconsistent or variable degree of activation in the left caudate (Garbin et al. 2011; Wang et al. 2007; Abutalebi et al. 2013; Hernandez 2009; Wang et al. 2009; Hernandez et al. 2001), possibly reflecting the relative language proficiency (Abutalebi et al. 2013).

The third structure which has been repeatedly reported in language switching, i.e., the anterior cingulate cortex (ACC), is also involved in general cognitive functions, such as attention, conflict monitoring and error detection (Abutalebi and Green 2007). These skills are so essential to maintain a multilingual system, such that the ACC of bilinguals becomes more effective than in monolinguals also in detecting conflicts in non-linguistic tasks (Abutalebi et al. 2012).

As discussed in the previous sections, there have been several attempts to integrate the evidence from individual structures into a new comprehensive model of speech control, e.g., the so called “Adaptive Control Hypothesis” (Abutalebi and Green 2007; 2008; Green and Abutalebi 2013). But still, as further outlined below, many inconsistencies and controversies remain and the debate about the most accurate model is still open (García-Pentón et al. 2016b; Green and Abutalebi 2016; de Bruin and Sala 2016; Bialystok 2016; García-Pentón et al. 2016a; Luk and Pliatsikas 2016; Paap 2016).

2.5.5.2 Factors Modulating Language Switching

As indicated above, it has been suggested that proficiency in a language influences the way the brain regions are involved in language control during language switching (Abutalebi et al. 2013) since the previous findings in the switching-related regions, especially in the pre-SMA/ACC responsible for language monitoring, and the left caudate nucleus responsible for language selection, have been largely inconsistent (Abutalebi et al. 2013; Wang et al. 2007; Garbin et al. 2011; Wang et al. 2009; Hernandez 2009; Hernandez et al. 2001; Crinion et al. 2006; Hosoda et al. 2012; Guo et al. 2011).

In order to overcome the limitations of previous bilingual studies which could introduce a group bias, Abutalebi and colleagues (2013) were the first to carry out an fMRI study employing an overt picture naming task in trilingual participants with different degree of proficiency in their languages (English, German, and Italian), so that the difference between a high-proficient and a low-proficient language could be assessed within subjects, without any potential group bias (e.g., different education or socio-economic background).

A new result was reported: differential responses in the pre-SMA/ACC and left caudate to language proficiency were observed. First, Abutalebi et al. (2013) noted that the pre-SMA/ACC was activated during language switching regardless of the language context and proficiency. In other words, the response in the pre-SMA/ACC was independent of differences in relative proficiency. The authors also argued against the notion that the pre-SMA/ACC activation reflects general task difficulty since there they did not observe any activation increase in a control group of monolinguals who exhibited higher error rate during a stimulus-matched word category switching task.

Second, Abutalebi et al. (2013) observed that the response in the left caudate nucleus peaked during switching from the most (L1) to the least proficient language (L3), confirming the results of previous studies in bilinguals (Crinion et al. 2006). Abutalebi at al. (2013) thus suggested a crucial role of the left caudate in the selection of the less proficient language during language switching. However, these conclusions were based upon a comparison with monolinguals who performed a different task, while the regional activation differences between language contexts in the left cuadate in multilinguals did not reach statistical significance at all. Furthermore, the regional brain activation was not correlated with any behavioural measures.

Abutalebi et al. (2013) further rejected that higher left caudate Blood Oxygenation Level-Dependent (BOLD) response during switching from German (L1) into English (L3) in comparison to switching from German (L1) into Italian (L2) could reflect the increased difficulty when switching between languages in the same language family. The authors argued that if that was the case, naming in German (L1) would be also more demanding when switching from English (L3) than from Italian (L2) which would lead to an activation increase, but their data did not support that. This led the authors to the conclusion that the linguistic distance or the task difficulty do not affect the neural response to language switching. On the other hand, they admitted that such modulation could be possibly apparent when comparing more distinct language families, e.g., European and non-European (Abutalebi et al. 2013).

However, the findings of Abutalebi et al. (2013) have not been fully replicated. For instance, several previous and more recent studies failed to show any activation in the left caudate (de Baene et al. 2015; Hernandez 2009; Hernandez et al. 2001; Wang et al. 2009; Guo et al. 2011). Others showed a language switching effect in the right cuadate rather than the left caudate (de Bruin et al. 2014b). A possible bias could be also introduced by the inconsistent definition of the baseline throughout the studies (Ma et al. 2014). On the other hand, a variable degree of activation in the (pre-)SMA/ACC related to language proficiency has been also shown (de Bruin et al. 2014b; Hosoda et al. 2012).

Thus, although much has been already learned, some questions remain still unanswered. Moreover, as pointed out by a recent review (García-Pentón et al. 2016b), current neuroimaging evidence in the research of bilingualism is based on samples with varying language background and inconsistent methodology, which hinders the generalization of the results. Therefore, there is a pressing need for studies with well-described sample population and comparable methodology to ensure that results could be integrated into a bigger picture.

3. Research Questions and Hypotheses

In the previous section, the role of the left caudate nucleus in language control and switching was discussed (Crinion et al. 2006; Abutalebi et al. 2013). However, methodological concerns regarding the previous studies have been raised. Therefore, this thesis primarily aims to assess the reproducibility of the discussed study (Abutalebi et al. 2013) in an independent sample of multilinguals with a different language background, but a similar bilingual environment. Thus, an overt picture naming task with language switching was carried out in Polish-Czech-English multilinguals to address the following questions:

1. Is the left caudate more engaged when multilinguals switch into a less proficient language than into a more proficient language?
2. Similarly, is the activation of the medial frontal cortex in the (pre-)SMA/ACC greater when switching into a less proficient language than into a more proficient one?

Based on the aforementioned findings of Abutalebi et al. (2013), an increased activation in the left caudate is expected when multilinguals switch into less proficient language and it is assumed that the activation of (pre-)SMA/ACC will not be modulated by language proficiency, as measured by fMRI in an overt picture naming task.

Furthermore, the influence of the linguistic distance between languages during language switching is still a matter of debate, as the previous studies could not reliably address this issue (Abutalebi et al. 2013). Here, a novel approach is suggested to compare the neural responses to switching between two languages (English and Polish) that belong to two different language families and two much more closely related languages, namely Czech and Polish, members of the West Slavic language group (Nordhoff et al. 2013). The suggested two language families (Slavic and Germanic) are also less closely related than those studied by Abutalebi et al. (2013) (Romance and Germanic), as measured by "relative cognate frequency" introduced by Schepens et al. (2013), providing a bigger contrast between the tested languages. The related research question is:

3. Does the switching between closely related languages influence neural response in comparison to switching between less related languages?

The hypothesis is that if switching to a closely related language is indeed a more cognitively demanding task, an activation increase in executive control areas will be observed, compared to switching into a more distant language. In the current fMRI overt picture naming paradigm, such an activation increase should be observed in the switching from Czech into Polish compared to the switching from English into Polish.

4. Methods

4.1. Participants

The study participants were recruited based on a two-step selection procedure involving an on-line screening questionnaire disseminated among the target population.

4.1.1. Language History Questionnaire

The screening questionnaire (i.e., the Language History Questionnaire) gathered sociolinguistic data and was inspired by Li and colleagues (2006). Additional data were obtained using Extended Language Background Questionnaire which was based on the previous research undertaken in the year 1991 by Bogoczová (1993) in the area of Český Těšín and it was also inspired by Wartenburger et al. (2003). The Language History Questionnaire provided the sociolinguistic information and self-reported language learning history, current language proficiency and health condition relevant to the fMRI screening. Example questions are provided in the Appendix 1. Other background language information, such as how often do the multilingual participants use their languages, in which situations, if they recently learned or acquired new languages etc. were covered by the Extended Language Background Questionnaire.

The Language History Questionnaire was in Polish to test if the respondents are able to interact in the language. It was distributed among university students and their relatives, members of the Polish ethnic minority in the Czech Republic living on the Czech-Polish borders and who attended the Czech Secondary School with the Polish teaching language (*Gimnazjum z Polskim Językiem Nauczania*) in Český Těšín and Karviná. The contacts were retrieved from the PZKO[9] and SAJ[10], the Polish minority associations. In total, 61 students were asked to fill out the online Language History Questionnaire and 20 responses[11] were received (response rate 32.8%) out of which potential participants were selected, based on the inclusion criteria.

9 PZKO, *Polski Związek Kulturalno-Oświatowy w Republice Czeskiej (Polský kulturně-osvětový svaz v České republice*, *Polish Cultural and Educational Union in the Czech Republic*). For more information about the organization, see http://pzko.cz/pzko/o-pzko.html.
10 SAJ, *Sekcja Akademickiej „Jedność" (Akademická sekce PZKO "Jednota", Polish Cultural and Educational Union "Jednota"*). More informtion on http://www.sajweb.org/
11 There were 20 respondents who took part in the Language History Questionnaire out of which 8 participants were selected and these replied to the Extended Language Background Questionnaire.

4.1.2. Inclusion and Exclusion Criteria for fMRI study

The inclusion criteria were age above 18 and below 30, past education at a high school with the Polish teaching language, relevant language background (Czech and Polish as mother tongues, with a sound competency in English as a foreign language), right-handedness, and willingness to participate. Among the exclusion criteria were MRI contraindications, such as presence of metallic or electronic implants, tattoos or permanent make-up containing ferromagnetic particles, claustrophobia, refusal to sign the informed consent, non-compliance, a history of any neurological or psychiatric condition and/or risk factors.

Eight healthy Czech-Polish-English multilingual participants over 18 years of age (2 women and 5 men, mean age 25.43, standard deviation 1.72) met the inclusion criteria. Their right-hand dominance was confirmed by the Edinburgh Handedness Inventory (Oldfield 1971). Ethical principles were followed as all participants expressed their will to participate in the study by signing the Informed Consent prior any study procedures. The study was conducted under the Act No. 101/2000 Coll., on the Protection of Personal Data[12].

4.1.3. Extended Language Background Questionnaire

In the Extended Language Background Questionnaire, the 8 participants were asked to provide details about the assessment of the level of exposure to Czech and Polish. The focus of the questionnaire was to investigate the present use of the languages. Participants estimated how many hours a day they were exposed to CZ, PL, which language they preferred for media (TV, PC, radio), what was the home language, which language they speak with friends, classmates and which language dominates in their hobbies.

Although eight participants were included in the questionnaire results and underwent the MRI scanning, only seven of them were included in the group imaging data analysis, since the first participant completed a pilot task set different from the task set in the remaining seven participants. Despite the fact he is not in the group for fMRI analysis, the socio-linguistic data are taken into account.

12 Zákon č. 101/2000 Sb., o ochraně osobních údajů a o změně některých zákonů.

4.2. Tasks

4.2.1. Prior Scanning

4.2.1.1 Word Translation Test

Although the participants have self-evaluated their language proficiency in the Language History Questionnaire, prior the scanning, they also completed a written Word Translation Test to obtain their objective language proficiency. This task was inspired by Abutalebi et al. (2007). The participants were assigned to translate two lists of words in two language contexts. The first language context, Polish-Czech and Czech-Polish, consisted of the translation of 60 low, middle, and high frequency words. The second language context was Polish-English and English-Polish combination and it consisted of 60 words translation at all frequency levels as well. The pre-selected words were matched for word length and there were in total 120 items translated. Corpus of Contemporary American English (Davies 2008) and Celex database (Max Planck Institute for Psycholinguistics 2001) were used for English, Czech list of words was based on the Český národní korpus – SYN2010 (Ústav Českého národního korpusu FF UK 2010; Těšitelová 1972) and Korpus Języka Polskiego PWN (Wydawnictwo Naukowe PWN 2014) was used for Polish.

4.2.1.2 Training Picture Set

Before entering the scanner room, the task procedure was explained and trained thoroughly to assure a stable performance throughout the experiment. The complete experimental picture set was presented to the participants who were asked to name pictures in each of the three languages, depending on the colour and the language combination. The volunteers therefore become familiar with the pictures and the learning effect during scanning could be alleviated. The errors were noted, however, they were not corrected to avoid any potential bias.

4.2.2. fMRI Task

A set of 32 different pictures (8.5×8.5 cm) was selected from the Snodgrass and Vanderwart (1980) set, so that picture labels were matched for frequency and number of syllables in Czech, Polish and English language (Davies 2008; Max Planck Institute for Psycholinguistics 2001; Ústav Českého národního korpusu FF UK 2010; Wydawnictwo Naukowe PWN 2014). Cognates were excluded from the selected picture set.

All participants completed four 8-minute experimental runs of the overt picture naming task according to a modified fMRI paradigm introduced by Abutalebi et al. (2012; 2013), previously used in behavioural studies (Costa and Santesteban 2004). Two language contexts, i.e. language combinations, were tested with two experimental runs per each context: Polish and Czech (PL/CZ), Polish and English (PL/EN).

During each run, visual stimuli (pictures from the selected set) were presented repeatedly using E-Prime 1.1 software (Psychology Software Tools, Inc., Sharpsburg, PA, USA[13]). Each stimulus was presented for 2 s and was followed by a blank screen with fixation cross with an inter-stimulus interval (ISI) of 1880, 3550, or 4950 ms according to pre-defined pseudo-randomized order (Abutalebi et al. 2012). Each run consisted of 96 stimuli so that there were 192 stimuli per language context in total. Therefore, each picture was repeated six times in each language context, that is three times in each language. The language was indicated by the picture foreground colour (either blue or red), as instructed before each run. The order of the contexts and the colours was shuffled and balanced across the participants.

Participants were asked to name each picture overtly immediately after the stimulus appeared on the screen. They were also told to minimize head movements during the scanning in order to reduce the artefacts. In case the picture was not recognized or the participant could not recall the picture name, (s)he was instructed to say "(I) don't know" in the required language (i.e., "nevím" in Czech, or "nie wiem" in Polish) in order to minimize the impact on the sensitivity of the analysis. These trials were therefore not discarded. The naming responses could not be recorded due to equipment limitations and the acoustic noise in the scanner room.

Each trial (i.e., visual stimulus and the corresponding response) was either switch or non-switch trial, based on the language required in the previous trial. The switch trials were those preceded by pictures named in different language, while the non-switch trials were preceded by pictures named in the same language. In each context, there were 48 switch and 48 non-switch trials per language. The order of switch and non-switch trials was pseudo-randomized. There were maximum two consecutive non-switch trials allowed, in order to minimize a potential bias of stimulus summation, since no consecutive switch trials in the same language are possible.

13 For more information, see https://www.pstnet.com/eprime.cfm.

After each run, participants were asked to verbally rate the task difficulty on a scale ranging from 1 (the easiest) to 10 (the most difficult) and their responses were recorded.

4.3. Imaging Data Acquisition

The collection of brain imaging data was performed in cooperation with the Functional Magnetic Resonance Imaging Laboratory at the Department of Neurology, the Faculty of Medicine and Dentistry, Palacky University in Olomouc. The study did not involve any drug administration and any invasive procedures. In all cases, a radiologist was present to reassure safety and all participants have given their written informed consent prior entering the MR scanner.

Magnetic resonance imaging (MRI) data were acquired on a 1.5-Tesla scanner (Siemens Avanto, Erlangen, Germany) with a standard head coil. The participants' head was immobilized with cushions to assure maximum comfort and minimize head motion. The instructions were given using fMRI compatible headphones and the stimuli were presented using rear-projection screen and an angled mirror positioned in the head coil. The imaging protocol included functional T_2-weighted BOLD images during task performance. BOLD images were acquired with gradient-echo echo-planar imaging (29 axial slices parallel to the AC-PC line, 5-mm thick, repetition time (TR) 2400 ms, echo time (TE) 41 ms, flip angle 50°, field of view = 220 mm, matrix 64×64) to provide 3.4mm×3.4mm×5.0mm resolution.

In total, 200 images were acquired per each 8-min functional run. Anatomical high-resolution 3-dimensional T_1-weighted images (magnetization-prepared rapid acquisition gradient echo, MPRAGE) were acquired to provide anatomical reference.

4.4. Statistical Analysis

4.4.1. Behavioural Data

The difficulty ratings and correct response rates in the Word Translation Test were compared across languages using the Wilcoxon signed-rank test (paired comparison to test for significant shift) and Wilcoxon rank-sum test (unpaired comparison to test for significant difference in medians). Where applicable, the resulting *p* values were corrected for multiple comparisons using Holm-Bonferroni correction (Holm 1979).

4.4.2. Imaging Data

A General Linear Model (GLM) analysis of the fMRI data was performed at the single subject level specifying eight regressors coding switch and non-switch trials. Four within-subject contrasts coded the difference between switch and non-switch trials for each language in both contexts (switching into CZ from PL, switching into PL from CZ, switching into EN from PL, switching into PL from EN).

The analysis was carried out using FEAT (FMRI Expert Analysis Tool) Version 6.00, part of FSL (FMRIB's Software Library, www.fmrib.ox.ac.uk/fsl), (S. M. Smith et al. 2004; Woolrich et al. 2009; Jenkinson et al. 2012). The following pre-statistics processing was applied; motion correction using MCFLIRT (Jenkinson et al. 2002); non-brain removal using BET (S. M. Smith 2002); spatial smoothing using a Gaussian kernel of FWHM 8.0 mm; grand-mean intensity normalization of the entire 4D dataset by a single multiplicative factor; highpass temporal filtering (Gaussian-weighted least- squares straight line fitting, with sigma = 25.0 s). Time- series statistical analysis was carried out using FILM with local autocorrelation correction (Woolrich et al. 2001). Registration to high-resolution structural and standard space images was carried out using FLIRT (Jenkinson and Smith 2001; Jenkinson et al. 2002) and FNIRT (Jenkinson et al. 2012).

After the first-level processing, the repeated measures were averaged within subjects using a fixed effects analysis. At the group level, one-way between-subject analysis of variance (ANOVA) has yielded an average positive effect across all four contrasts. The whole-brain F-test was performed to detect any area significantly differing across the contrasts.

The between-subject higher-level analysis was carried out using FLAME (FMRIB's Local Analysis of Mixed Effects) stage 1 and 2 with automatic outlier de-weighting (Beckmann, Jenkinson, and Smith 2003; Woolrich et al. 2004; Woolrich 2008). Z (Gaussianised T/F) statistic images were thresholded using clusters determined by $Z>2.3$ and a corrected cluster significance threshold of $P = 0.05$ (Worsley 2001). Before thresholding, data were zeroed outside the mask based on the labels for the cerebral cortex and subcortical grey matter in the Harvard-Oxford subcortical atlas (Desikan et al. 2006) to decrease the number of unnecessary multiple comparisons in the white matter, brainstem and cerebellum.

The resulting clusters of activation were superimposed on T_1-weighted Montreal Neurological Institute (MNI) standard brain (Grabner et al. 2006) and their anatomical locations were derived from the Harvard-Oxford brain atlas (Desikan et al. 2006) incorporated in FSL.

The significant voxels (determined by $p < 0.001$ uncorrected) within the clusters from the group analysis were further analysed as regions of interest (ROI). Each ROI was transformed into each individual's functional space and the single-subject mean percent signal change (%SC) values were extracted, as implemented by Featquery tool in FSL. The values were statistically compared across the conditions using the Wilcoxon signed-rank test and correlated with the Word Translation Test scores using Spearman's correlation coefficient.

5. Results

5.1. Questionnaires

The results from the online Language History Questionnaire are based on the 20 responses (10 women and 10 men). The Extended Language Background Questionnaire provided the information only on the 8 enrolled participants (including 1 pilot participant).

5.1.1. Language History Questionnaire

As was stated above, the purpose of this questionnaire was to find eligible participants. Out of 61 respondents addressed, there were 20 multilingual responses obtained. These respondents were members of the Polish minority PZKO organisation. Here is a summary of the most significant findings. Personal information, health condition information and other personal details are not presented.

Firstly, the respondents were asked about the home language. It turned out that the territorial dialect *po naszymu* is the home language for 16 (80%) of them. Only 1 respondent (5%) uses two language codes at home, the territorial dialect and the Polish language, and 3 respondents (15%) reported the use of three language codes at home: the dialect, Polish, and Czech (Fig. 1).

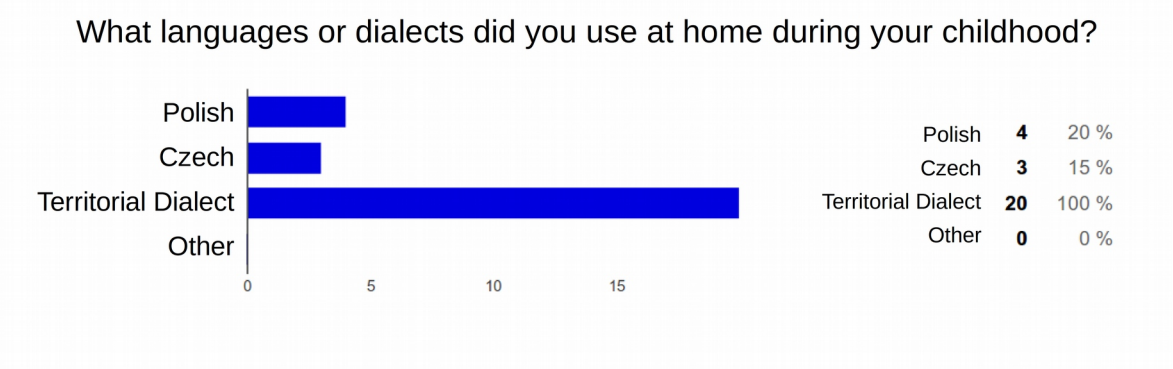


Figure 1. Language History Questionnaire – Home language

The bar plot shows responses to the question: "What languages or dialects did you use at home during your childhood?". The possible responses were (in order of appearance): 1) Polish; 2) Czech; 3) Dialect "po naszymu"; 4) Other.

The information collected shows that all respondents (100%) attended kindergarten with the Polish teaching language. Two respondents (10%) spent in the kindergarten one year, 1 (5%) reported two years, 13 (65%) stated that they attended the Polish kindergarten

for three years, 3 respondents (15%) spent there four years, and 1 (5%) replied five years (Fig. 2).

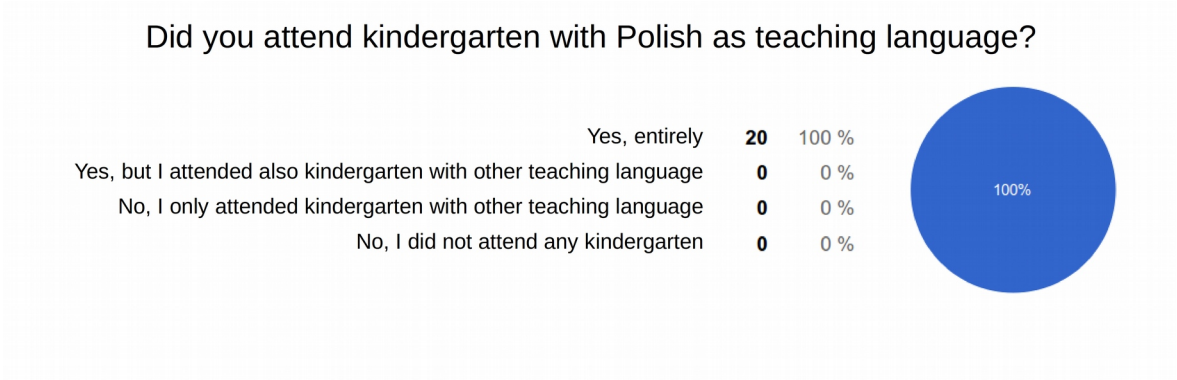


Figure 2. Language History Questionnaire – Kindergarten

The pie chart shows responses to the question: "Did you attend kindergarten with Polish as teaching language?". The possible responses were (in order of appearance): 1) Yes, entirely; 2) Yes, but I attended also kindergarten with other teaching language; 3) No, I only attended kindergarten with other teaching language; 4) No, I did not attend any kindergarten.

The data recorded indicate that all respondents (100%) attended the basic school with the Polish teaching language as well. However, there was 1 respondent who claimed that he also attended an elementary school with other than Polish teaching language. Details are unknown (Fig. 3).

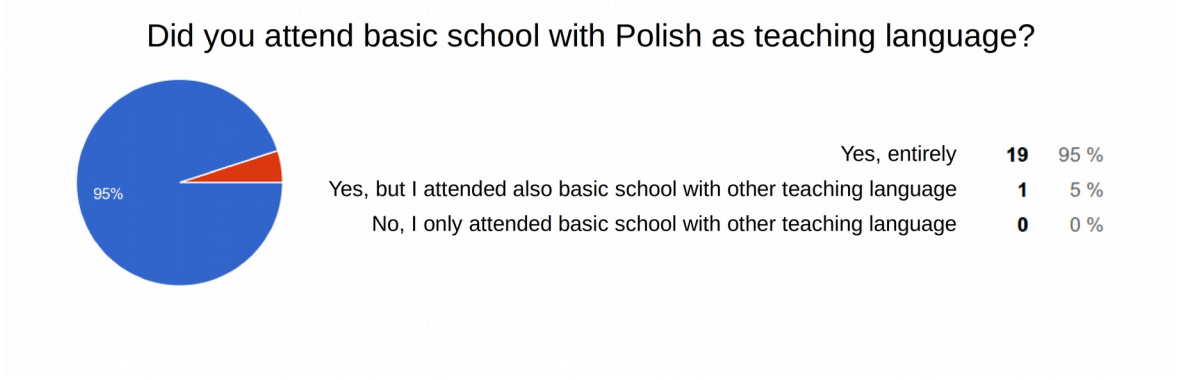


Figure 3. Language History Questionnaire – Basic School

The pie chart shows responses to the question: "Did you attend basic school with Polish as teaching language?". The possible responses were (in order of appearance): 1) Yes, entirely; 2) Yes, but I attended also basic school with other teaching language; 3) No, I only attended basic school with other teaching language.

Furthermore, 19 respondents (95%) received their high school education at high schools with the Polish teaching language. All of them (95%) studied 4 years at the high

schools and passed the high school leaving examination (*"Maturita Exam"*)[14] in the Polish language. One respondent (5%) attended a high school with different language than Polish as a teaching language and (s)he consequently did not pass the high school leaving examination in the Polish language (Fig. 4)[15].

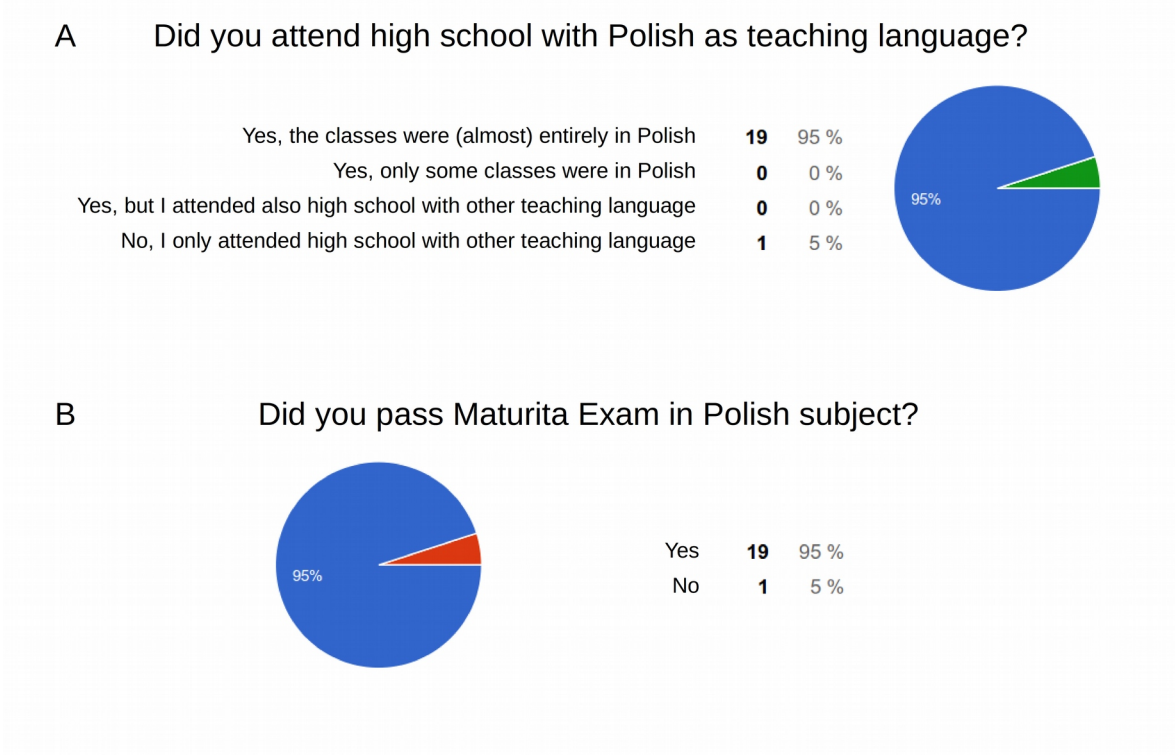


Figure 4. Language History Questionnaire – High School

*In **Panel A**, the pie chart shows responses to the question: "Did you attend high school with Polish as teaching language?". The possible responses were (in order of appearance): 1) Yes, the classes were (almost) entirely in Polish; 2) Yes, only some classes were in Polish; 3) Yes, but I attended also high school with other teaching language; 4) No, I only attended high school with other teaching language. In **Panel B**, the pie chart shows responses to the question: "Did you pass Maturita Exam in Polish subject?". The possible responses were Yes or No.*

The respondents were also asked whether they use and how often they use oral or written Polish language, on the scale: 1) not at all; 2) rather not (i.e., less frequently than once a month); 3) not regularly; 4) more often than once a week; 5) every day; 6) other.

14 *Maturitní zkouška ("Maturita Exam")* is a final state examination at the end of the secondary education at high schools in the Czech Republic.
15 This does not mean (s)he did not receive high school education at all since (s)he could study at the high school with the Czech teaching language and passed the high school examination (*Maturita Exam*) in other subjects.

None of the respondents reported daily usage of the Polish language. There were 6 respondents (30%) who claimed to use Polish more often than once a week. Not regularly opted 9 respondents (45%), and 5 (25%) claimed that they use Polish less frequently than once a month (the option rather not), see Fig. 5A.

Figure 5. Language History Questionnaire – Language Usage

*In **Panel A**, the pie chart shows responses to the question: "Do you actively use Polish (in oral or written form)?". The possible responses were (in order of appearance): 1) Yes, every day; 2) Yes, more often than once a week; 3) Yes, not regularly; 4) Rather not (i.e., less frequently than once a month); 5) Not at all; 6) Other. In **Panel B**, the pie chart shows responses to the question: "Do you actively use Silesian dialect?". The possible responses were: 1) Yes, every day; 2) Yes, more often than once a week; 3) Yes, not regularly; 4) Rather not (i.e., less frequently than once a month); 5) Not at all; 6) Other.*

The very same scale was used for the territorial dialect, *po naszymu*. It was revealed that 5 respondents (25%) speak the dialect more often than once a week, 14 (70%) reported that they use the dialect every day and 1 (5%) respondent speaks the dialect not regularly (Fig. 5B).

Since the questionnaire was distributed among people living in the Czech Republic who studied at the Czech universities or worked in the Czech environment, it was assumed that they come into contact with the Czech language on a daily basis and there were no

questions regarding the usage of Czech language. This was further investigated in the Extended Language Background Questionnaire.

The 20 respondents were also instructed to self-evaluate their foreign languages according to the *Common European Framework of Reference for Languages* (CEFR)[16], the European standard rating scale for establishing language proficiency. For English as a foreign language, 1 respondent (5%) evaluated himself as A1 level, 4 respondents (20%) A2 level, 5 (25%) confirmed the B1 level, 6 (30%) opted for B2 level, 3 (15%) consider themselves to be on the C1 proficiency level, and 1 respondent (5%) declared C2 proficiency in English (Fig. 6).

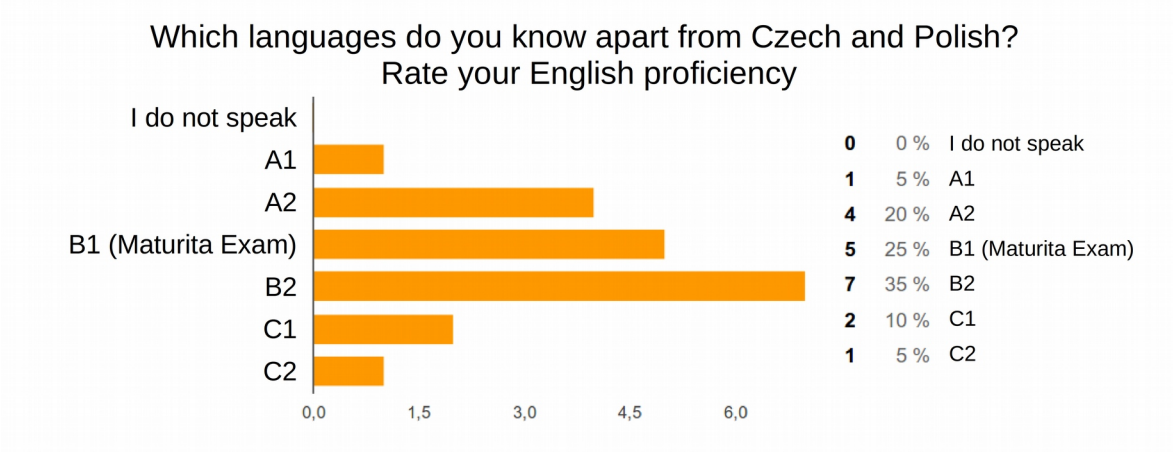


Figure 6. Language History Questionnaire – Foreign Languages: English

The bar plot shows responses to a sub-question regarding English knowledge in the question "Which languages do you know apart from Czech and Polish?". The possible responses were (in order of appearance): 1) I do not speak (English); 2) A1; 3) A2; 4) B1 (Maturita Exam); 5) B2; 6) C1; 7) C2.

Age of acquisition of English (AoAE) as a foreign language differed considerably, since 2 respondents (10%) started to learn English at the age of three, 1 respondent (5%) at the age of five, 1 respondent (5%) at the age of six, 1 (5%) at the age of seven, 2 (10%) at the age of eight, 3 (15%) responded to start with English at the age of nine, 7 (35%) stated the AoAE at the age of ten, 1 (5%) at the age of eleven, and 2 (10%) at the age of 12. Additionally, 3 (15%) out of the 20 respondents stated a different first foreign language

16 For more information see: http://www.coe.int/t/dg4/linguistic/cadre1_en.asp

than English, namely German. In those cases English was a second foreign language with AoAE seven years for one participant and twelve years for 2 participants.

A question inquiring the information about other foreign languages that respondents have learned or acquired and to which they were frequently exposed was also included, the results are reported only for the 8 shortlisted participants (see Table 1 below).

In connection to the previous question, the respondents were asked about the time recently spent abroad. One respondent spent more than one year in the USA, one claimed a year study internship in three countries, namely Hungary, Austria, and Denmark. Another respondent reported a semester stage in Finland, and one spent half a year in Belgium (Fig. 7).

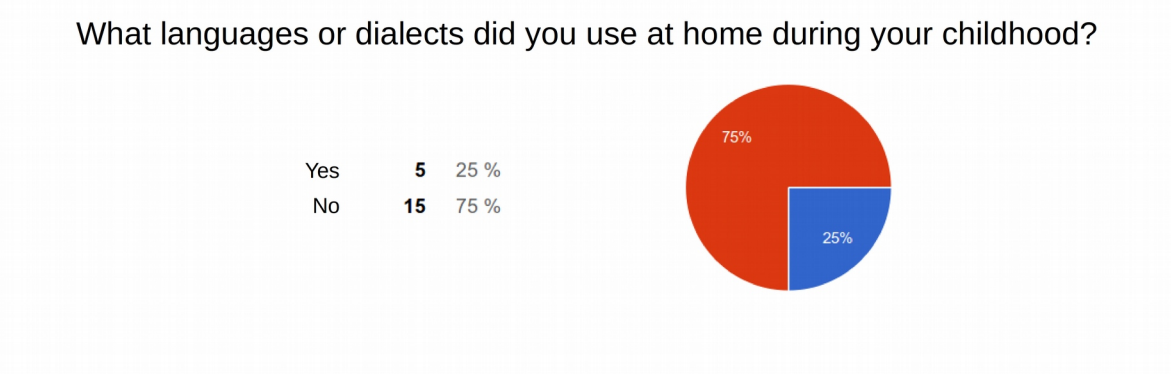


Figure 7. Language History Questionnaire – Living Abroad.

The pie chart shows responses to the question "Have you stayed abroad (outside the Czech Republic) for a longer time?". The possible responses were Yes or No.

5.1.2. Extended Language Background Questionnaire

The Extended Language Background Questionnaire provided additional information on the 8 enrolled participants[17]. The language information obtained in the Language History Questionnaire was mostly reflected in the Extended Language Background Questionnaire, as the territorial dialect was a home language for all of the participants but one, who reported to speak Czech and Polish at home as well. All of the short-listed participants (100%) attended a kindergarten with the Polish language, 6 (75%) participants for three years, 1 (12.5%) for four years, and 1 for one year. All of them attended basic and subsequently high schools with the Polish teaching language where they studied for four

17 As stated in the Methods, eight participants completed the Extended Language Background Questionnaire, but only seven of them were included in the imaging analysis since one (P8) completed a different task set than other participants.

years and passed the high school leaving examination in Polish. However, they differed in the usage frequency of the Polish language at the time of the study enrolment, since 3 (37.5%) reported they did not use Polish actively (i.e., less frequently than once a month), 4 (50%) declared they speak Polish not regularly, and only 1 (12.5%) claimed to speak Polish more often than once a week.

On the other hand, the participants were quite consistent in responses in terms of the usage of the territorial dialect, since 7 (87.5%) claimed they speak *po naszymu* every day and 1 (12.5%) uses it more often than once a week.

The questions concerning the usage of the Czech language were covered as well. All in all, it was confirmed that the participants speak Czech every day (more in the section 5.1.3. below).

In terms of foreign languages, the participants provided information about their proficiency based on self-evaluation according to the CEFR and Age of Acquisition (AoA). According to the Age of Acquisition for the English language (AoAE), all but two (75%) had English as the first foreign language, since participants P3 and P4 started to learn German as their first foreign language at the age of nine. However, they confirmed that they use English more than German.

In terms of the CEFR and AoAE, 1 participant (12.5%) evaluated himself to be at A1 level with AoAE twelve years (English as the second foreign language), 2 participants (25%) self-evaluated themselves at A2 level with AoAE five and eleven years, 1 (12.5%) claimed B1 proficiency with AoAE twelve years, 2 (12.5%) reported CEFR B2 both with AoAE ten years (English as the second foreign language for one of them), and 2 (12.5%) opted for CEFR C1, both with AoAE ten years.

Due to a complexity of the results, CEFR proficiency and AoAE are illustrated in the Table 3 together with other foreign languages and corresponding Age of Acquisition, if stated. Overall, according to the language acquisition, the 8 participants started to learn English as their foreign language at an average age of 10.0 years, at the basic school. The participant P6 has been learning English longer than others.

Table 3. Language Background of the Participants

	CEFR and AoA							
Participant	**English**	**German**	**French**	**Russian**	**Spanish**	**Italian**	**Other**	
P1	B2, 10	A1, 15	A1, 20	-	A2, 20	A1, 20	Arabic	A1, 21
							Japanese	A1, 21
P2	A2, 11	A1, 13	-	-	-	-	-	
P3	B1, 12	B1, 9	-	-	-	-	-	
P4	A1, 12	A1, 9	-	-	-	-	-	
P5	C1, 10	A1, 15	A1, 13	-	-	-		
P6	A2, 5	-	-	B2, 15	-	-	-	
P7	B2, 10	A1, 14	-	-	-	-	-	
P8*	C1, 10	B1, 15	-	-	-	-	Portuguese	A2, 22

Table shows the self-evaluated proficiency levels in foreign languages of participants (CEFR) and Age of Acquisition (AoA) in these foreign languages [CEFR, AoA]. The participant marked with asterisk was not included in the final analysis of imaging data.

5.1.3. Sociolinguistic and Cultural Background of Participants

All 8 participants were asked about their active usage of languages and examples of situations in which they use them. The questionnaire consisted of open questions and its reason was to provide the participants with space to explain in detail the previous answers from the Language History Questionnaire. It was also found out that the language situation has changed for almost all of them since they have left the high school with the teaching Polish language and there have been other languages than Czech and Polish they have been being exposed on a daily basis, namely Slovak.

Since none of the participants at the time of the research lived in the Těšín area, they were also asked to provide examples of specific situations in which they used only Czech/Polish/the dialect.

All of the participants reported to use Czech "every day" for several reasons, 5 of them (62.5%) were at that point students at the Czech universities, 3 participants (37.5%) were graduates of the universities in the Czech Republic and they worked in the Czech language environment and lived in the cities of Brno and Olomouc, outside the Těšín area.

The replies demonstrated that the Czech language was naturally used in "the Czech environment", "for the official communication", "at the university", "in Czech shops", with "Czech friends", "classmates", and "colleagues at work". Three participants

responded that they spoke Czech “because of (and to) their partners”, however, two of these partners were Slovaks. It was also reported that when starting a communication with unknown person outside the Polish community, the Czech language was primarily being used.

Participants were also asked in open questions to once again rate their Polish language frequency usage. It was found out that it was “minimal”, “infrequent” and “limited”. The participants spoke Polish “with the extended family relatives” or “family members who speak Polish very occasionally”, with “Poles in the Czech Republic”, with “people who speak Polish” or “when someone starts conversation in Polish”. The participants chose Polish “when they go to Poland (for example for shopping)”, or “when they meet Poles abroad”. One participant specifically stated that (s)he “speaks Polish with teachers from the basic and high schools”. It is also important to note that one participant at that time studied Polish Philology at the Czech university, so (s)he “used the Polish language on the daily basis orally and in the written form” or “with the international students from Poland”.

In contrast to the limited use of the Polish language, all of the participants firmly confirmed to “speak *po naszymu* every day” or “at least several times a week”, namely “on the phone with parents and grandparents”, “during the family weekends”, “when going home”, “with friends who speak the territorial dialect (also outside the community)”, “during the meetings of the SAJ organization” or “in the choir”. They also reported to speak the dialect in “the local (Těšín area) shops”. One participant said that (s)he speaks the dialect “with the partner who is Slovak”. There were other two participants with Slovak partners, however, in those cases participants claimed to speak Czech, whereas their partners spoke Slovak. One respondent replied that (s)he speaks the dialect “every time (s)he finds out the other person speaks the dialect as well”, since it “feels more natural” and it “shows the bond with the Polish minority”. One participant mentioned that (s)he used the dialect “with the room-mate” and it developed into their “secret language” since the other room-mates did not understand.

Participants stated that English is felt to be a foreign language since it was limited to the usage “at the university”, “language courses”, “travelling” or “vacation”; they also spoke English with foreigners” and “with people who start the conversation in English”. One respondent worked for the international company and spoke English “infrequently with the boss and the colleagues”.

The participants “watch films and series” in English to improve their language skills, they preferred to “watch TV and news in Czech”, but two participants mentioned they “prefer to listen to the Polish radio when driving” or “at home”. Three participants reported to read books in Czech, one participant stated Polish (probably because of the studies), and four participants replied they “read books in all three languages”.

5.2. Word Translation Test

The individual results and the distribution of the test scores are shown in Fig. 8A and 8B and Table 4. Participants achieved the best performance when translating from Polish into Czech (median 96.7%), followed by translation from Czech into Polish (median 90.0%). These distributions were rather narrow, as the inter-quartile range (IQR) was 95.0% – 98.3%, and 86.7% – 93.3%, respectively. Although the medians did not differed by more than 6.7%, the pair-wise difference reached the uncorrected significance level (p = 0.03, Wilcoxon signed-rank test [WSRT] uncorrected).

Table 4. Word Translation Test Scores

Translation direction	Range [%]	IQR [%]	Median [%]
PL → CZ	86.67 – 100.00	95.00 – 98.33	96.67
CZ → PL	60.00 – 96.67	86.67 – 93.33	90.00
PL / CZ averaged	**76.67 – 98.33**	**89.17 – 95.83**	**93.33**
PL → EN	10.74 – 83.33	50.00 – 62.96	55.93
EN → PL	36.67 – 80.00	61.67 – 73.33	66.67
PL / EN averaged	**35.37 – 81.67**	**50.65 – 68.15**	**60.00**

Table shows basic descriptive statistics of the Word Translation Test scores. Each row represents a single translation direction (indicated by arrow) or averaged score for the language context (indicated by slash). Abbreviations: CZ = Czech; EN = English; IQR = inter-quartile range; Max. = maximum; Min. = Minimum; PL = Polish.

In contrast, the overall Word Translation Test performance between Polish and English was considerably lower, as the median performance from Polish into English was 55.9%, whereas the translation performance from English into Polish reached 66.7%. Additionally, these results were less homogeneous, as the distributions were rather broad (IQR was 50.0% – 63.0%, and 61.7% – 73.3%, respectively), but the two opposite directions (from Polish into English, and from English into Polish) did not differ significantly (p = 0.30, WSRT), see Fig. 8A-B.

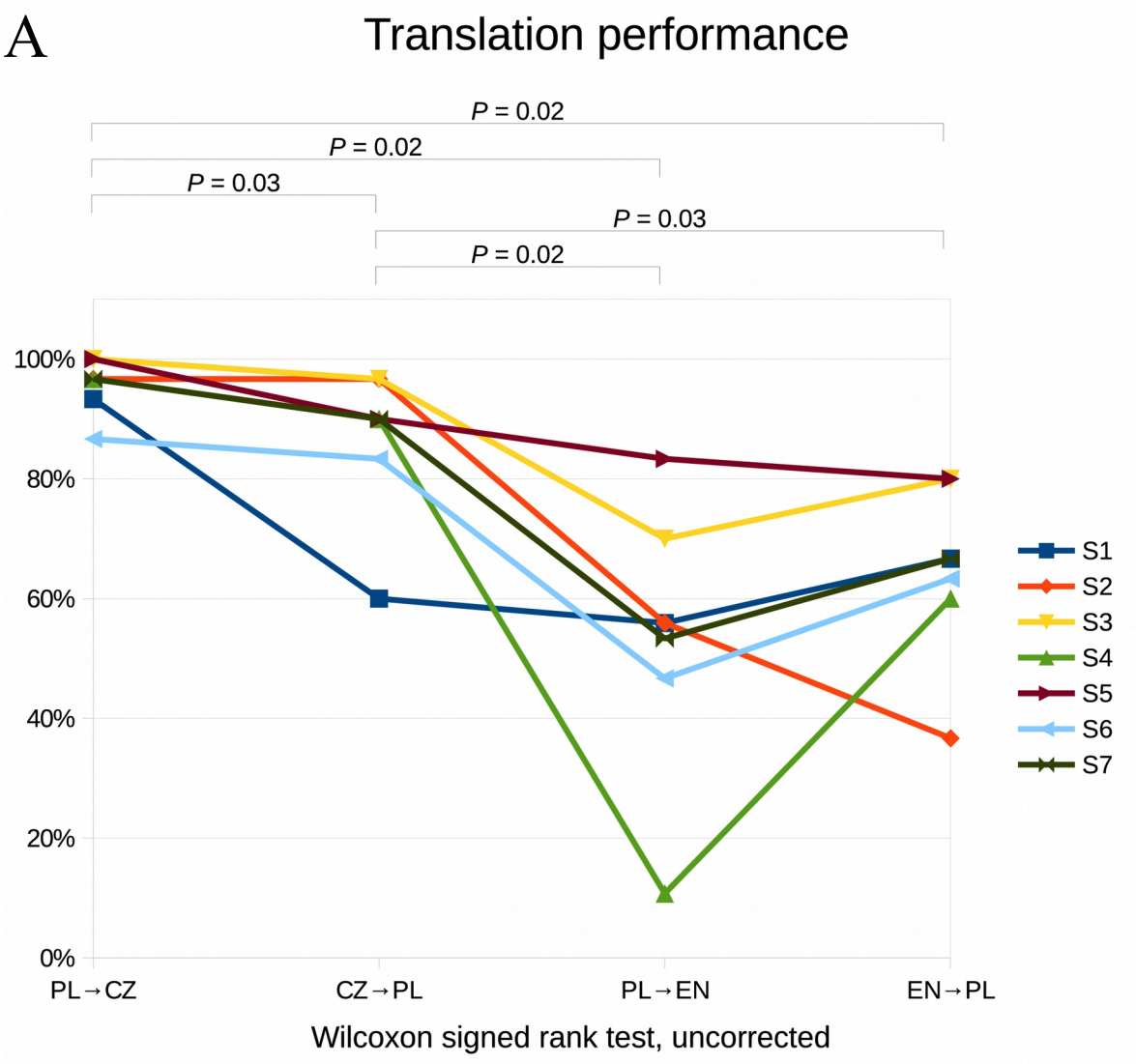
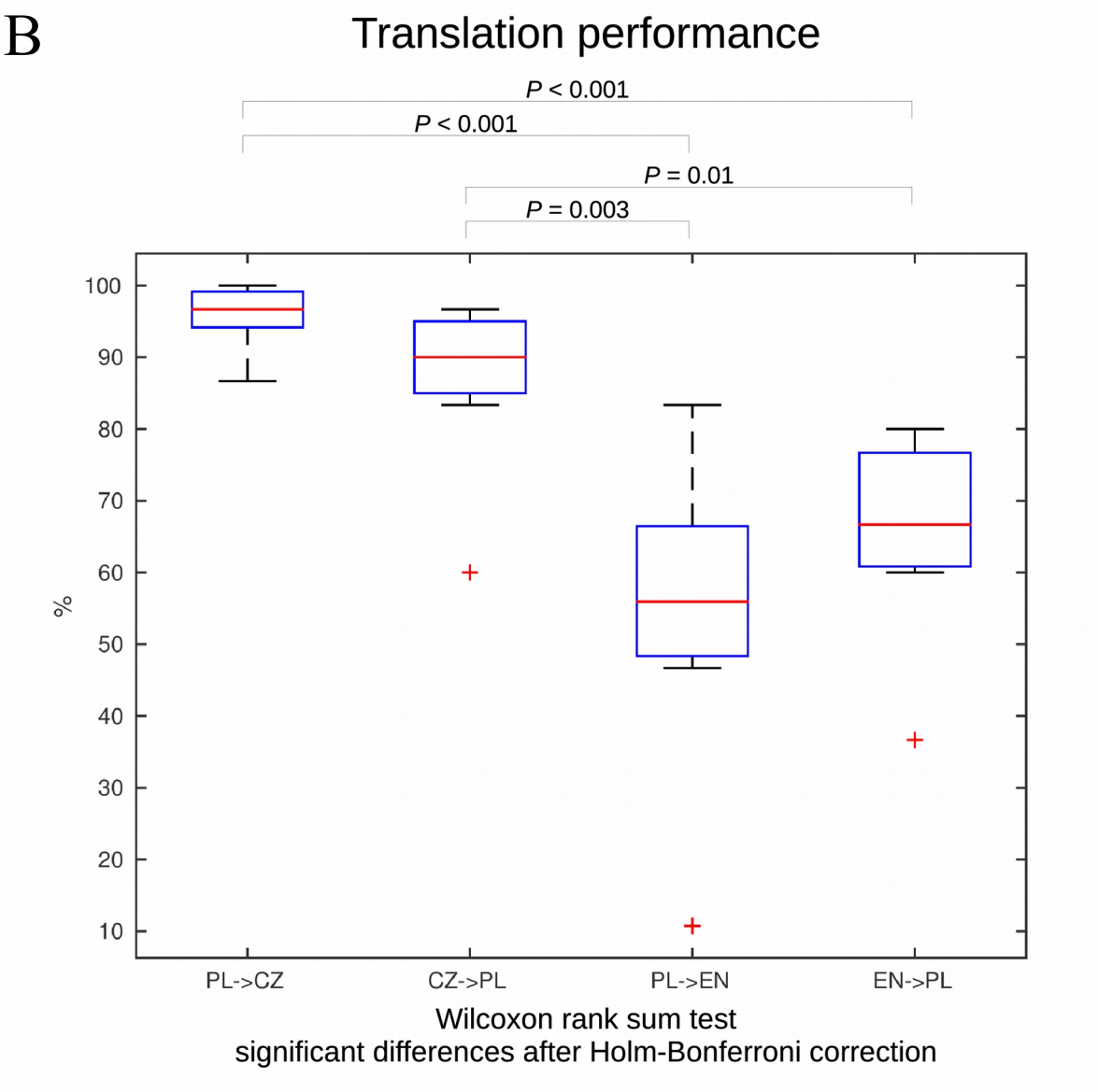


Figure 8. Word Translation Test Performance

Panel A *shows plot of individual scores for each language context and direction in the Word Translation Test. Each column represents a single direction, as indicated by the abscissa label. Ordinate represents the performance score in %. Each participant is represented by a separate color and a unique symbol. On top, significant pair-wise differences are marked along with the respective p values (Wilcoxon signed-rank test, uncorrected).* ***Panel B*** *shows boxplot of individual scores in each of the language contexts. Median (red line), inter-quartile range (box), extreme values (whiskers), and outliers (red crosses) are indicated. On top, significant unpaired differences are marked along with the respective p values (Wilcoxon rank-sum test, Holm-Bonferroni-corrected). Remaining conventions see Panel A. Abbreviations: CZ = Czech; EN = English; PL = Polish.*



Overall, the participants performed significantly better when translating between Polish and Czech than between Polish and English, which was irrespective of the translation direction, i.e., after averaging both directions within each language context (p = 0.02, WSRT). The pair-wise differences between unidirectional (unaveraged) scores also reached uncorrected significance levels, but none of the differences was significant after Holm-Bonferroni correction (Fig. 8A, Table 5). However, when considered as independent samples, significant (corrected) differences between Polish/Czech and Polish/English contexts were observed in all cases (Fig. 8B, Table 5), but not between the translation from Polish into Czech and from Czech into Polish (p = 0.07, WRST).

Table 5. Word Translation Test Statistical Comparisons

Translation direction	CZ → PL *p* WSRT; *p* WRST	PL → EN *p*, WSRT; *p*, WRST	EN → PL *p*, WSRT; *p*, WRST	PL / CZ *p*, WSRT; *p*, WRST
PL → CZ	**0.031;** *0.066*	**0.016; <0.001**	**0.016; <0.001**	
CZ → PL		**0.016; 0.003**	**0.031; 0.010**	
PL → EN			0.297; 0.299	
PL / EN				**0.016; 0.001**

Table shows p values of statistical comparisons between Word Translation Test scores. Each cell represents comparison between the respective column and row. The first p value represents WSRT and the second WRST. Note that each comparison is listed only once and that the empty rows and columns have been removed. Bold type indicates significant differences. Abbreviations: CZ = Czech; EN = English; PL = Polish; WRST = Wilcoxon rank-sum test; WSRT = Wilcoxon signed-rank test.

5.3. Difficulty Rating

The median difficulty rating of the overt picture naming task was 3.5 out of 10 (IQR 3.0 – 6.0; range 2.5 – 7.0) for the Polish/Czech context, and 4.0 out of 10 (IQR 3.5 – 5.8; range 2.0 – 7.5) for the Polish/English context (Fig. 9). Repeated measures were averaged within-subject. The medians did not differ significantly ($p = 0.95$, WSRT).

Figure 9. Task Difficulty

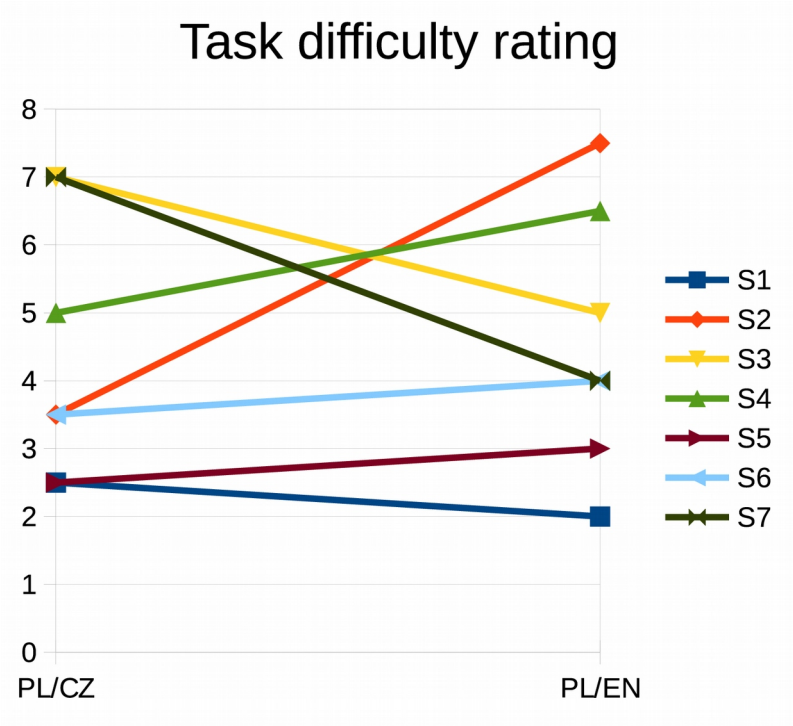


Figure shows plot of individual task difficulty ratings for both language contexts during over picture naming task, as indicated by the abscissa label. Ordinate represents the difficulty rating on the scale 0–10 (least difficult – most difficult). Each participant is represented by a separate color and a unique symbol. The respective p value indicates Wilcoxon signed-rank test. Abbreviations: CZ = Czech; EN = English; PL = Polish.

5.4. Imaging Data

5.4.1. Group ANOVA

All seven participants completed the whole task set and reported that they could easily recognize all the pictures presented. The single-subject analysis yielded reproducible results and no excessive motion levels were detected.

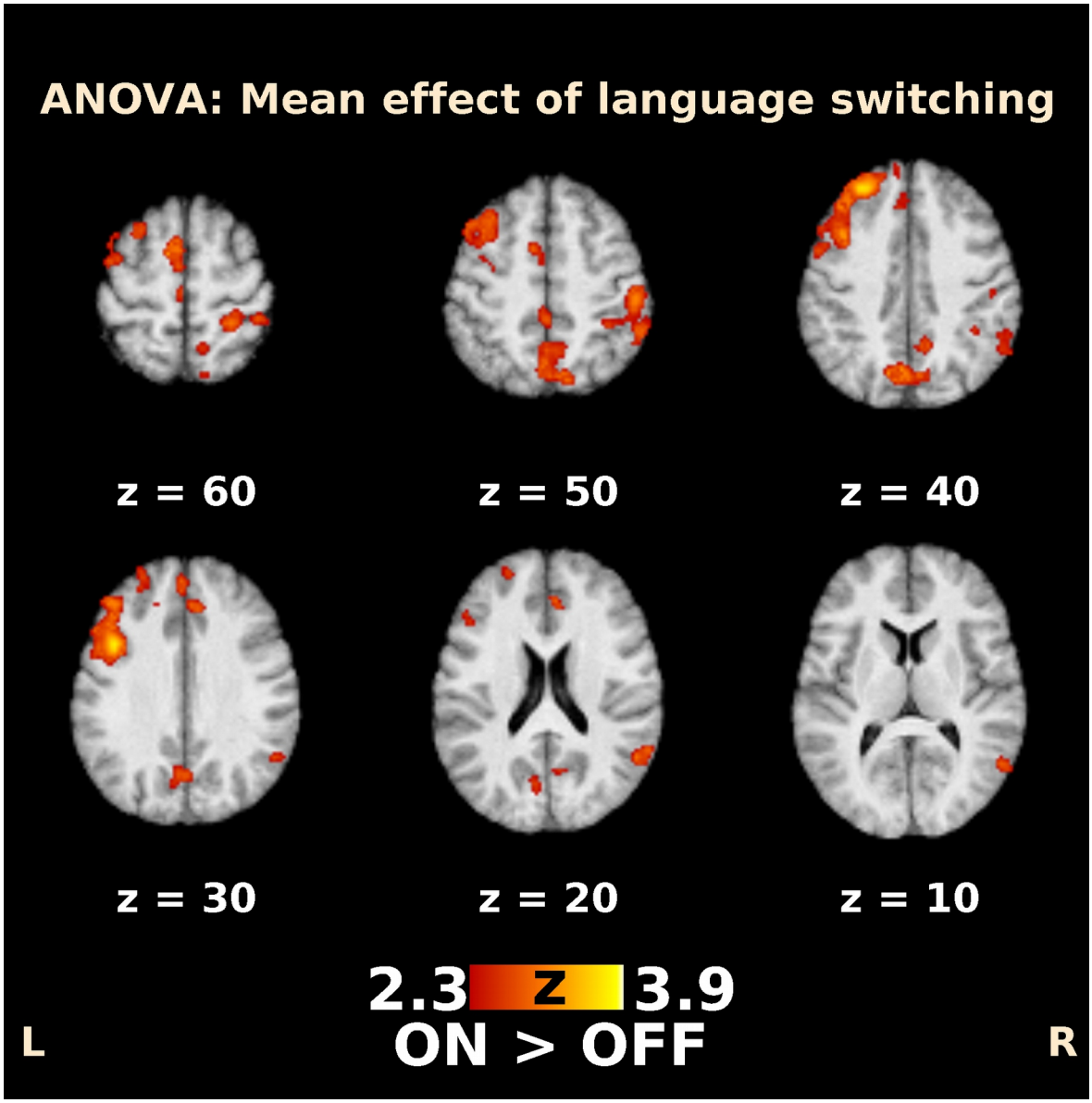


Figure 10. ANOVA: Mean Effect of Language Switching – Transversal Slices

Figure shows selected axial (transversal) slices depicting significant clusters of the mean effect in the group ANOVA for the switching ON>OFF contrast. The grey-scale background represents the averaged group-wise T_1-weighted structural image. The red-yellow overlay represents the Z statistical score of the mean effect as indicated by the scale. Left is left, according to the neurological convention.

The group-wise analysis of variance (ANOVA) of the within-subject switching contrast (switching > non-switching) yielded several significant clusters of mean effect (or intercept), as indicated in the Fig. 10 and 11, and Table 6. The most significant cluster was located in the left prefrontal cortex, predominantly in the left middle frontal gyrus (MFG) and the frontal pole (FP), but extended also to the left precentral gyrus. The second cluster was located more posteriorly in the bilateral precuneous cortex (PCUN), but extended also rostrally along the mesial wall of the left hemisphere to the left supplementary motor area (SMA). The last cluster was located in the right parietal cortex, spreading across the superior parietal lobule (SPL), angular (AG), supramarginal (SMG), and postcentral gyrus (Fig 10 and 11).

In contrast, the F-test looking for differences among the conditions (i.e., pair-wise comparisons between each of the contrasts: from Polish into Czech [PL→CZ], from Czech into Polish [CZ→PL], from Polish into English [PL→EN], and from English into Polish [EN→PL]) did not yield any significant clusters at the whole-brain level.

Table 6. ANOVA Switching ON>OFF: Significant Clusters of Mean Effect

Cluster	Volume [mm^3]	*p*	Z_{max}	Z_{max} MNI coordinate (x, y, z) [mm]	Atlas label [%]
1	25,136	$<10^{-6}$	3.88	-30, 38, 44	Left: 54% Middle Frontal Gyrus; 17% Frontal Pole; 8% Precentral Gyrus
2	14,048	$<10^{-4}$	3.41	-4, -70, 4	Right: 34% Precuneous Cortex; Left: 32% Precuneous Cortex; 18% Supplementary Motor Area
3	10,240	0.001	3.29	54, -24, 48	Right: 29% Angular Gyrus; 27% Supramarginal Gyrus, 21% Postcentral Gyrus; 14% Superior Parietal Lobule

Table lists significant clusters of the mean effect in the group ANOVA for the switching ON>OFF contrast. Clusters are sorted by significance, in descending order. Cluster volume in mm, cluster p value, maximum Z score (Z_{max}), MNI coordinates of Z_{max} in mm, and labels from Harvard-Oxford cortical probabilistic anatomical atlas. Only labels uniquely assigned to more than 5% of voxels are listed. Abbreviations: MNI = Montreal Neurological Institute; Z_{max} = maximum Z score.

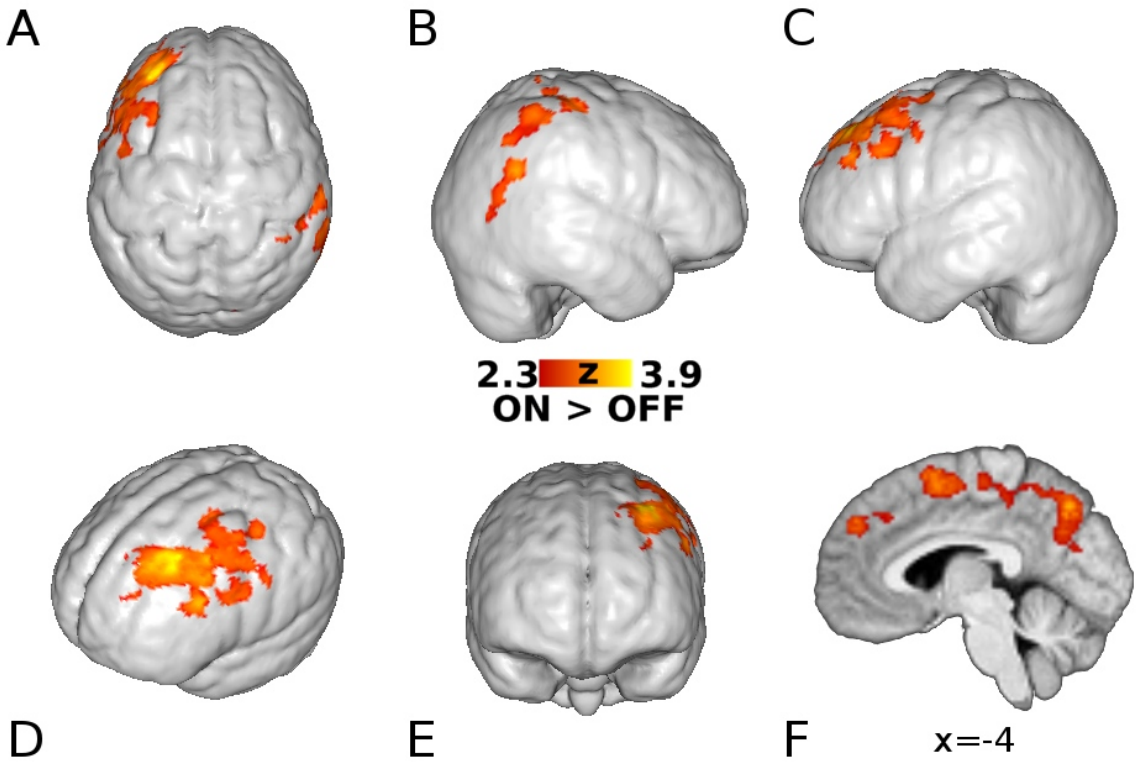


Figure 11. ANOVA: Mean Effect of Language Switching – Cortical projection

Figure depicts significant clusters of the mean effect in the group ANOVA for the switching ON>OFF contrast. The red-yellow overlay represents the Z statistical score of the mean effect as indicated by the scale. ***Panels A-E*** *show selected views of the reconstructed three-dimensional cortical surface: A – superior view; B – right lateral view; C – left lateral view; D – left anterior oblique view; E – anterior view. In* ***Panel F****, a single sagittal slice at x = -4 mm depicts midline structures on a grey-scale background representing the averaged group-wise* T_1*-weighted structural image. Left is left, according to the neurological convention.*

5.4.2. *Post-hoc* Analysis

The mean effect of Switching vs. Non-switching trials in the group ANOVA yielded 9 regions of interest (ROI) thresholded at the uncorrected $p < 0.001$ which exceeded 20 voxels and overlapped with the cluster-based mean effect map.

According to the research question, another ROI in the head of left caudate nucleus (LC) was additionally based on the Harvard-Oxford subcortical probabilistic atlas (Desikan et al. 2006), with 50% probability cut-off and MNI coordinates $y > 4$ mm, and $z < 8$ mm, since no mean effect was observed in that region. All ROIs, including the LC, are summarized in Table 7.

5.4.2.1 Average Local %SC

As expected, there was a significant or close to significant BOLD signal increase during language switching (Wilcoxon signed-rank test, uncorrected) at least in one contrast in most ROIs, which was the most prominent in the switching contrast PL→EN. On the other hand, the overall %SC in the switching vs. non-switching contrast in the LC was not significantly increased in any of conditions (Table 8, Fig. 12A-D).

Table 7. Regions of Interest

Cluster	Volume [mm^3]	COG coordinate (x, y, z) [mm]	Atlas label	ROI
1	3,344	-31.9, 36.4, 40.2	47% Left Middle Frontal Gyrus (anterior division); 47% Left Frontal Pole	aMFG/FP
2	2,512	-43, 13.4, 32.7	77% Left Middle Frontal Gyrus (posterior division); 14% Left Inferior Frontal Gyrus, pars opercularis; 9% Left Precentral Gyrus	pMFG
3	888	-4, -70.4, 44.1	88% Left Precuneous Cortex; 12% Right Precuneous Cortex	PCUN
4	680	-6.0, 2.9, 57.1	100% Supplementary Motor Area	SMA
5	488	58.3, -54.7, 24	100% Right Angular Gyrus	AG
6	376	53.3, -25.1, 49.1	66% Right Postcentral Gyrus; 34% Right Supramarginal Gyrus, anterior division	aSMG
7	192	7.75, 34.9, 26.6	88% Right Paracingulate Gyrus; 12% Right Cingulate Gyrus, anterior division	ACC
8	184	28.4, -39.4, 61.2	61% Right Superior Parietal Lobule; 39% Right Postcentral Gyrus	SPL
9	184	56.9, -44.2, 47.3	83% Right Supramarginal Gyrus, posterior division; 17% Right Angular Gyrus	pSMG
10	1,376	-11.8, 15.7, 1.9	100% Left Caudate Nucleus	LC

Table lists regions of interest (ROIs) defined by the Harvard-Oxford subcortical probabilistic atlas (ROI 1) or based on the mean effect in the group ANOVA for the switching ON>OFF contrast (ROIs 2-9). ROIs are sorted by size, in descending order (except for the LC). ROI volume in mm^3, MNI coordinates of the Centre of Gravity (COG) in mm, labels from Harvard-Oxford cortical probabilistic anatomical atlas, and simplified abbreviation. Only labels uniquely assigned to more than 5% of voxels are listed. Abbreviations: ACC = Anterior Cingulate Cortex; AG = Angular Gyrus; aMFG/FP = Anterior Middle Frontal Gyrus / Frontal Pole; aSMG = Anterior Supramarginal Gyrus; COG = Centre of Gravity; LC = Left Caudate nucleus; MNI = Montreal Neurological Institute; PCUN = Precuneous Cortex; pMFG = Posterior Middle Frontal Gyrus; pSMG = Posterior Supramarginal Gyrus; ROI = Region of Interest; SMA = Supplementary Motor Area; SPL = Superior Parietal Lobule.

5.4.2.2 Differences in Local %SC between Language Contexts

Although some divergent tendencies in the median %SC could be observed (Table 8), there was no significant pair-wise difference between any of language switching conditions in any of the ROIs (Wilcoxon signed-rank test, numerical data not shown).

With respect to our research questions, there was a tendency in the ACC towards higher %SC in the Polish/English language context (median PL→EN was 0.08% and median EN→PL was 0.09%) than in the Polish/Czech context (median PL→CZ was 0.05% and median CZ→PL was 0.01%, see Table 8 for *p* values), but still, no differences were significant (PL→CZ vs. CZ→PL: $p = 1.00$; PL→EN vs. EN→PL: $p = 0.94$; PL→CZ vs. PL→EN: $p = 0.94$; CZ→PL vs. EN→PL: $p = 0.69$, Wilcoxon signed-rank test).

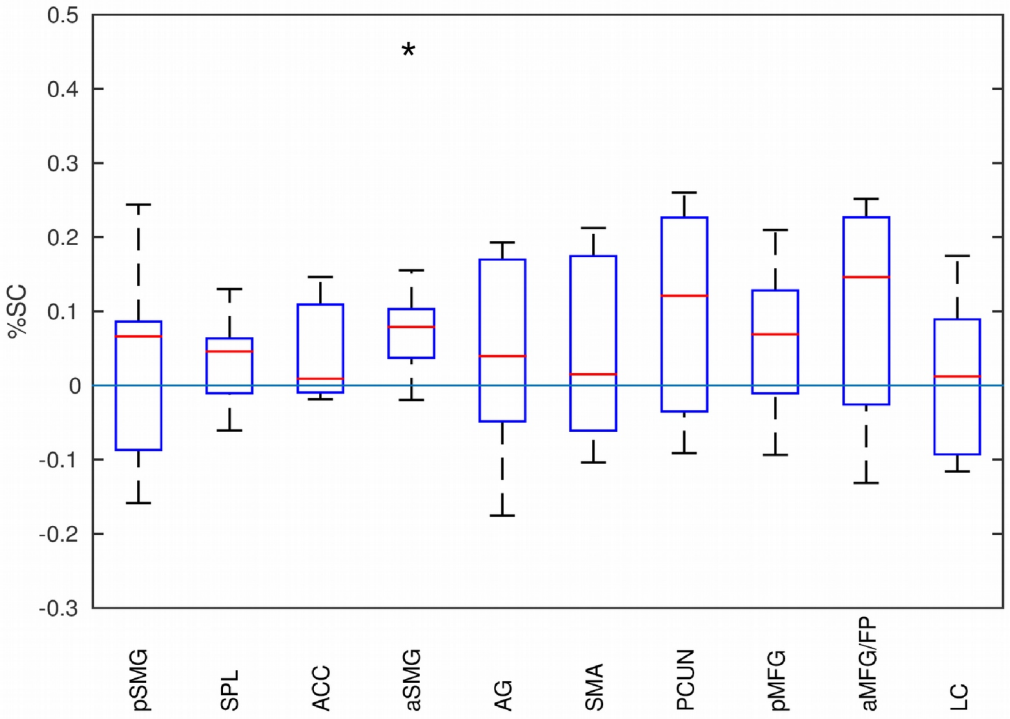
In contrast, the %SC in the SMA was increased when the switching into Czech (median PL→CZ was 0.07%) and switching into English (median PL→EN was 0.09%), but not when the switching into Polish (median CZ→PL was 0.02%; EN→PL was 0.03%, see Table 8 for *p* values). Again, none of the differences were significant (PL→CZ vs. CZ→PL: $p = 0.58$; PL→EN vs. EN→PL: $p = 0.30$; PL→CZ vs. PL→EN: $p = 0.81$; CZ→PL vs. EN→PL: $p = 0.81$, Wilcoxon signed-rank test).

In the LC, the median %SC was not significantly different from zero in any of the switching vs. non-switching contrast: median CZ→PL was 0.01%, PL→CZ was -0.02%, EN→PL was 0.01%, and PL→EN was -0.04% (see Table 8 for *p* values). The differences were insignificant as well (PL→CZ vs. CZ→PL: $p = 1.00$; PL→EN vs. EN→PL: $p = 0.30$; PL→CZ vs. PL→EN: $p = 0.69$; CZ→PL vs. EN→PL: $p = 0.81$, Wilcoxon signed-rank test).

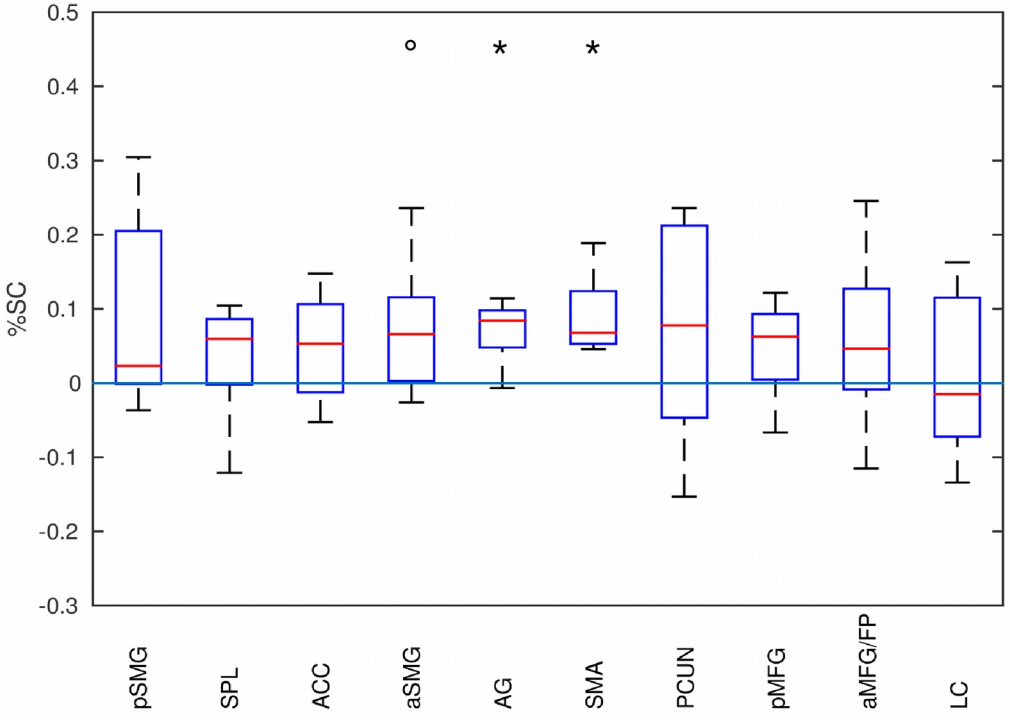
Figure 12. Percent Signal Change in Regions of Interest

*Figure shows boxplots of percent signal change (%SC) in the regions of interest (ROI) for the switching ON>OFF contrast. Median (red line), inter-quartile range (box), extreme values (whiskers), and outliers (red crosses) are indicated. On top, medians significantly different from zero are indicated with asterisk ($p < 0.05$), close to significant values are marked with circle ($p < 0.1$). **Panel A** shows switching from Czech into Polish; **Panel B** switching from Polish into Czech; **Panel C** switching from English into Polish; and **Panel D** switching from Polish into English. Abbreviations: ACC = Anterior Cingulate Cortex; AG = Angular Gyrus; aMFG/FP = Anterior Middle Frontal Gyrus / Frontal Pole; aSMG = Anterior Supramarginal Gyrus; CZ = Czech; EN = English; LC = Left Caudate nucleus; PCUN = Precuneous Cortex; PL = Polish; pMFG = Posterior Middle Frontal Gyrus; pSMG = Posterior Supramarginal Gyrus; SMA = Supplementary Motor Area; SPL = Superior Parietal Lobule.*

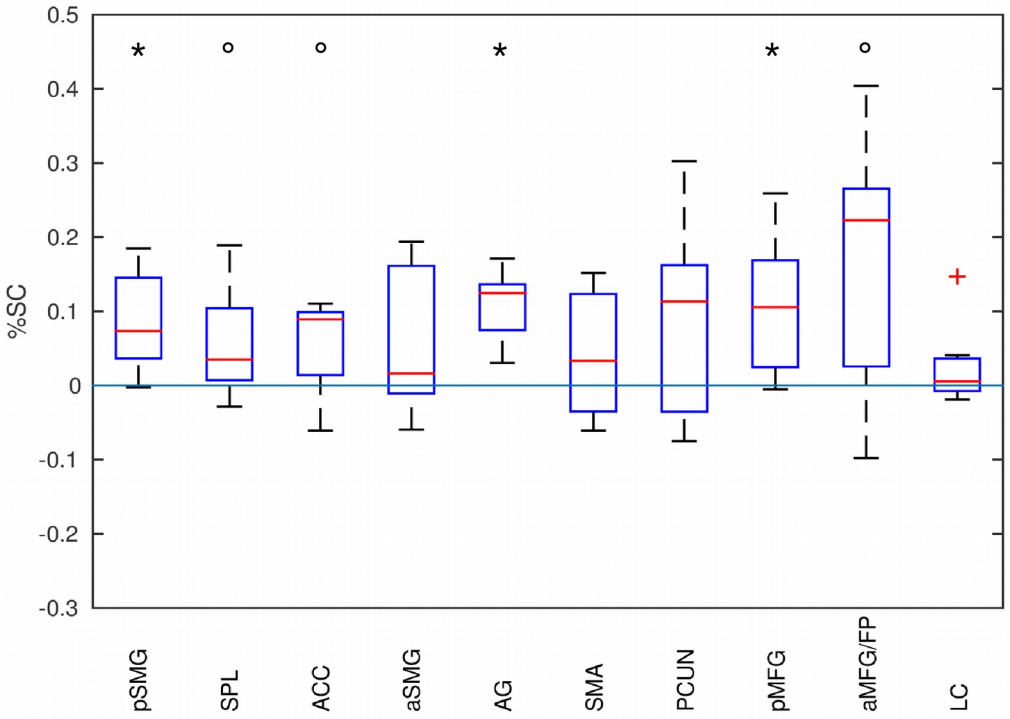
A. Regions of interest: Switching from Czech into Polish



B. Regions of interest: Switching from Polish into Czech



C. Regions of interest: Switching from English into Polish



D. Regions of interest: Switching from Polish into English

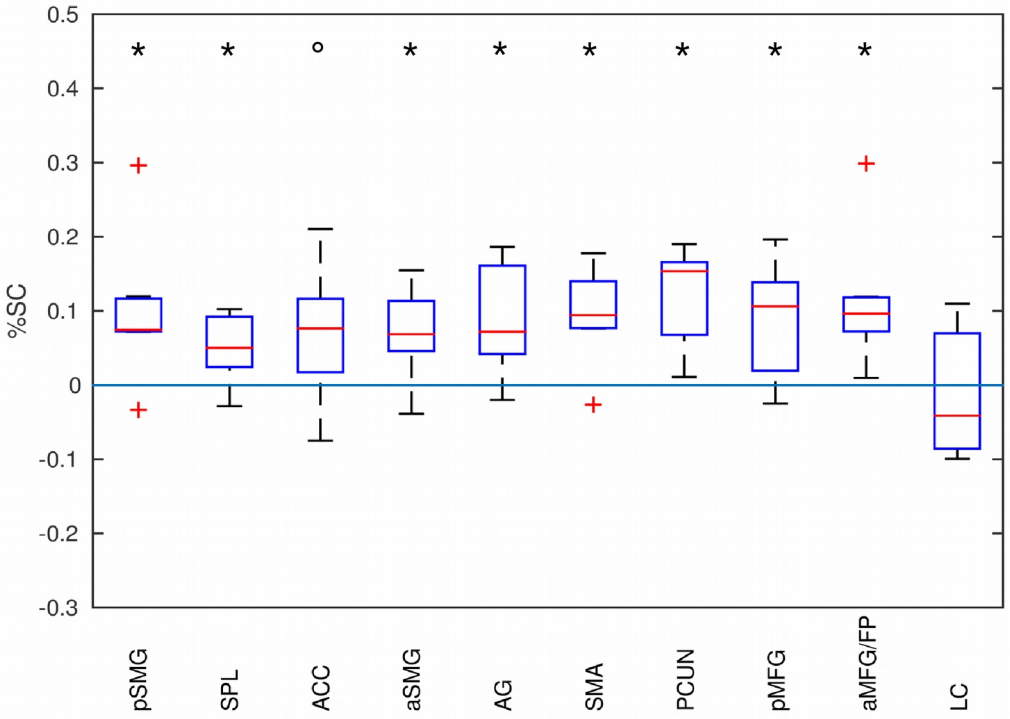


Table 8. Regions of Interest: Median Percent Signal Change

ROI	CZ→PL %SC median; IQR *p*	PL→CZ %SC median; IQR *p*	EN→PL %SC median; IQR *p*	PL→EN %SC median; IQR *p*
aMFG/FP	0.15; -0.03–0.23 0.11	0.05; -0.01–0.13 0.22	*0.22*; 0.03–0.27 *0.08*	**0.10**; 0.07–0.12 **0.02**
pMFG	0.07; -0.01–0.13 0.16	0.06; 0.00–0.09 0.16	**0.11**; 0.02–0.17 **0.03**	**0.11**; 0.02–0.14 **0.05**
PCUN	0.12; -0.03–0.23 0.11	0.08; -0.05–0.21 0.30	0.11; -0.04–0.16 0.22	**0.15**; 0.07–0.17 **0.02**
SMA	0.02; -0.06–0.17 0.30	**0.07**; 0.05–0.12 **0.02**	0.03; -0.03–0.12 0.38	**0.09**; 0.08–0.14 **0.03**
AG	0.04; -0.05–0.17 0.58	**0.08**; 0.05–0.10 **0.03**	**0.12**; 0.07–0.14 **0.02**	**0.07**; 0.04–0.16 **0.03**
aSMG	**0.08**; 0.04–0.10 **0.03**	*0.07*; 0.00–0.12 *0.08*	0.02; -0.01–0.16 0.30	**0.07**; 0.05–0.11 **0.03**
ACC	0.01; -0.01–0.11 0.38	0.05; -0.01–0.11 0.11	*0.09*; 0.01–0.10 *0.08*	*0.08*; 0.02–0.12 *0.08*
SPL	0.05; -0.01–0.06 0.22	0.06; -0.00–0.09 0.38	*0.03*; 0.01–0.10 *0.08*	**0.05**; 0.02–0.09 **0.05**
pSMG	0.07; -0.09–0.09 0.69	0.02; -0.00–0.20 0.30	**0.07**; 0.04–0.15 **0.03**	**0.07**; 0.07–0.12 **0.03**
LC	0.01; -0.09–0.09 0.94	-0.02; -0.07–0.12 0.94	0.01; -0.01–0.04 0.47	-0.04; -0.09–0.07 0.81

Table shows percent signal change (%SC) within the regions of interest (ROIs) in the switching ON>OFF contrast. ROIs are sorted by size, in descending order (except for the LC). The median %SC, interquartile range (IQR) and the uncorrected p value of the Wilcoxon signed-rank test against the zero median are provided. Bold type indicates significant median difference from zero, whereas italic type indicates a trend towards significance, both marked by grey background. Abbreviations: ACC = Anterior Cingulate Cortex; AG = Angular Gyrus; aMFG/FP = Anterior Middle Frontal Gyrus / Frontal Pole; aSMG = Anterior Supramarginal Gyrus; CZ = Czech; EN = English; IQR = Interquartile Range; LC = Left Caudate nucleus; PCUN = Precuneous Cortex; PL = Polish; pMFG = Posterior Middle Frontal Gyrus; pSMG = Posterior Supramarginal Gyrus; ROI = Region of Interest; SMA = Supplementary Motor Area; SPL = Superior Parietal Lobule.

5.4.2.3 Correlation between %SC and Word Translation Test Performance

The Spearman's ρ (rho) showed significant (uncorrected) positive correlation between the Word Translation Test score when translating from Polish into English and the %SC in

the PCUN (ρ = 0.79; *p* = 0.04) and left SMA (ρ = 0.81; *p* = 0.04) in the contrast EN→PL (Table 9, Fig 13A-B). The mean %SC in the LC negatively correlated with translation performance from Czech into Polish during switching from PL→CZ (ρ = -0.86; *p* = 0.02), see Table 9, Fig 13C. In contrast, there was no significant correlation of the %SC (switching vs. non-switching trials) with the translation performance in the ACC (Table 9).

Table 9. Correlation between Percent Signal Change and Translation Performance

Translation	**PL→CZ**	**CZ→PL**	**PL→EN**	**EN→PL**
ROI	ρ(%SC CZ→PL); *p* ρ(%SC PL→CZ); *p*	ρ(%SC CZ→PL); *p* ρ(%SC PL→CZ); *p*	ρ(%SC EN→PL); *p* ρ(%SC PL→EN); *p*	ρ(%SC EN→PL); *p* ρ(%SC PL→EN); *p*
aMFG/FP	-0.49; 0.29 -0.39; 0.40	-0.54; 0.23 -0.36; 0.44	0.58; 0.19 -0.58; 0.19	0.45; 0.30 -0.25; 0.57
pMFG	-0.06; 0.91 -0.07; 0.88	-0.13; 0.76 -0.21; 0.67	0.29; 0.53 -0.04; 0.95	0.16; 0.73 -0.02; 0.98
PCUN	0.36; 0.44 -0.52; 0.24	-0.07; 0.88 -0.22; 0.63	**0.79; 0.04** -0.13; 0.80	0.24; 0.60 -0.20; 0.67
SMA	-0.26; 0.56 -0.26; 0.56	-0.21; 0.67 0.07; 0.88	**0.81; 0.04** -0.25; 0.58	0.56; 0.20 -0.02; 0.98
AG	0.06; 0.91 -0.62; 0.15	-0.43; 0.35 -0.41; 0.37	0.59; 0.17 -0.49; 0.28	0.05; 0.92 -0.09; 0.85
aSMG	-0.11; 0.80 -0.30; 0.52	-0.54; 0.23 -0.07; 0.88	0.20; 0.67 -0.22; 0.64	0.05; 0.92 0.04; 0.96
ACC	-0.15; 0.74 -0.62; 0.15	0.24; 0.59 -0.22; 0.63	0.63; 0.14 -0.45; 0.32	0.56; 0.20 -0.56; 0.20
SPL	-0.58; 0.20 0.21; 0.67	-0.64; 0.13 0.26; 0.56	0.07; 0.88 -0.29; 0.53	-0.11; 0.82 -0.09; 0.85
pSMG	-0.02; 0.99 -0.64; 0.13	-0.26; 0.56 -0.30; 0.52	0.23; 0.62 -0.63; 0.14	-0.40; 0.38 -0.22; 0.64
LC	-0.52; 0.24 -0.64; 0.13	-0.32; 0.50 **-0.86; 0.02**	-0.34; 0.46 0.05; 0.92	-0.58; 0.18 -0.15; 0.76

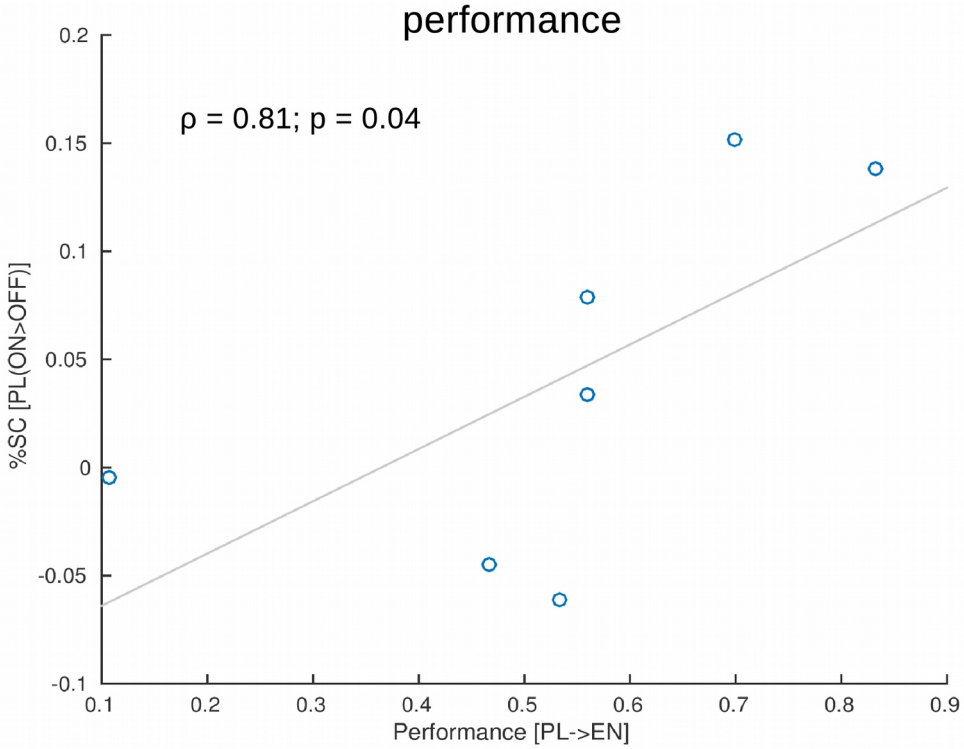
Table shows correlations of the signal change (%SC) within the regions of interest (ROIs) in the switching ON>OFF contrast with the performance in the Word Translation Test. ROIs (rows) are sorted by size, in descending order. Columns represent four translation directions (from left to right): translating from Polish into Czech; from Czech into Polish; from Polish into English; and from English into Polish. In each cell, the upper row represents the correlation with the %SC while switching into Polish, whereas the lower row represents the opposite direction in the respective context. The Spearman's ρ (rho), and the uncorrected p value are provided. Remaining conventions see Table 8.

Additionally, a correlation analysis between the relative Word Translation Test performance (i.e., a difference between the two language contexts) and the relative %SC (i.e., a difference between the %SC in the two language contexts) was carried out to assess whether the LC reflected within-subject differences. In other words, the difference in the translation performance (an average of performance in Polish→Czech and Czech→Polish vs. average of Polish→English and English→Polish) was correlated with the difference between the %SC in both language contexts (switching, non-switching, and switching vs. non-switching trials were tested). In the LC, this revealed a significant positive correlation with the difference between the Czech and English switching trials (PL→CZ > PL→EN, $\rho = 0.79$; $p = 0.05$), and with the difference between the Czech and English non-switching trials (CZ→CZ > EN→EN, $\rho = 0.79$; $p = 0.05$), but no significant correlation with the contrast of the switching vs. non-switching trials ($\rho = -0.50$; $p = 0.27$), see Fig 13D. An analogous comparison of trials in Polish did not yield any significant correlations (data not shown) and no significant correlation of relative scores was found in the ACC or SMA.

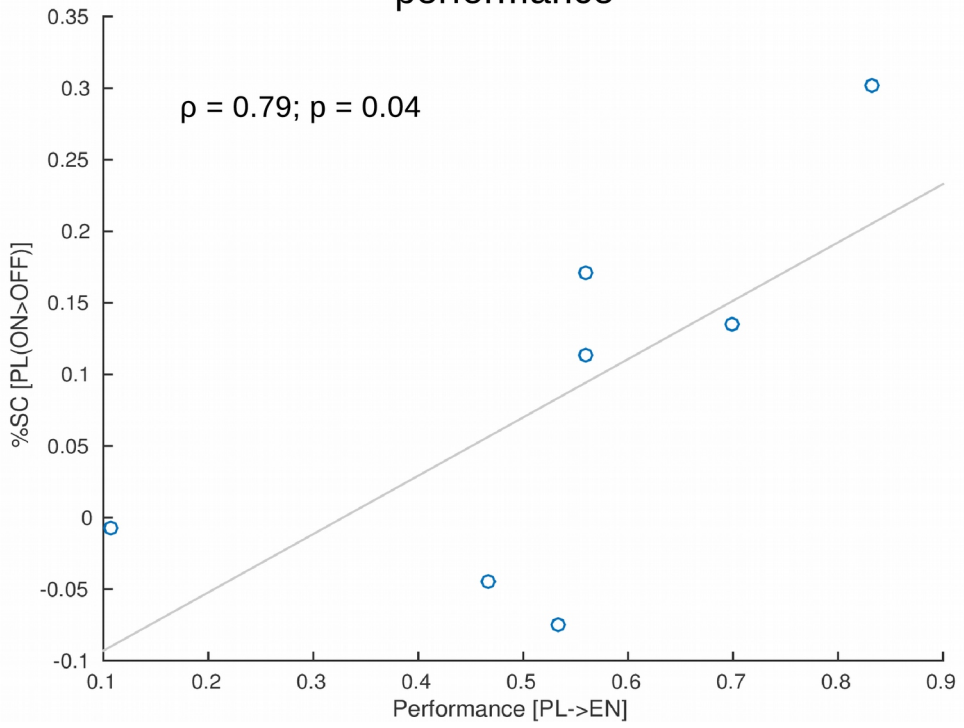
Figure 13. Correlation between Percent Signal Change with Word Translation Test Performance

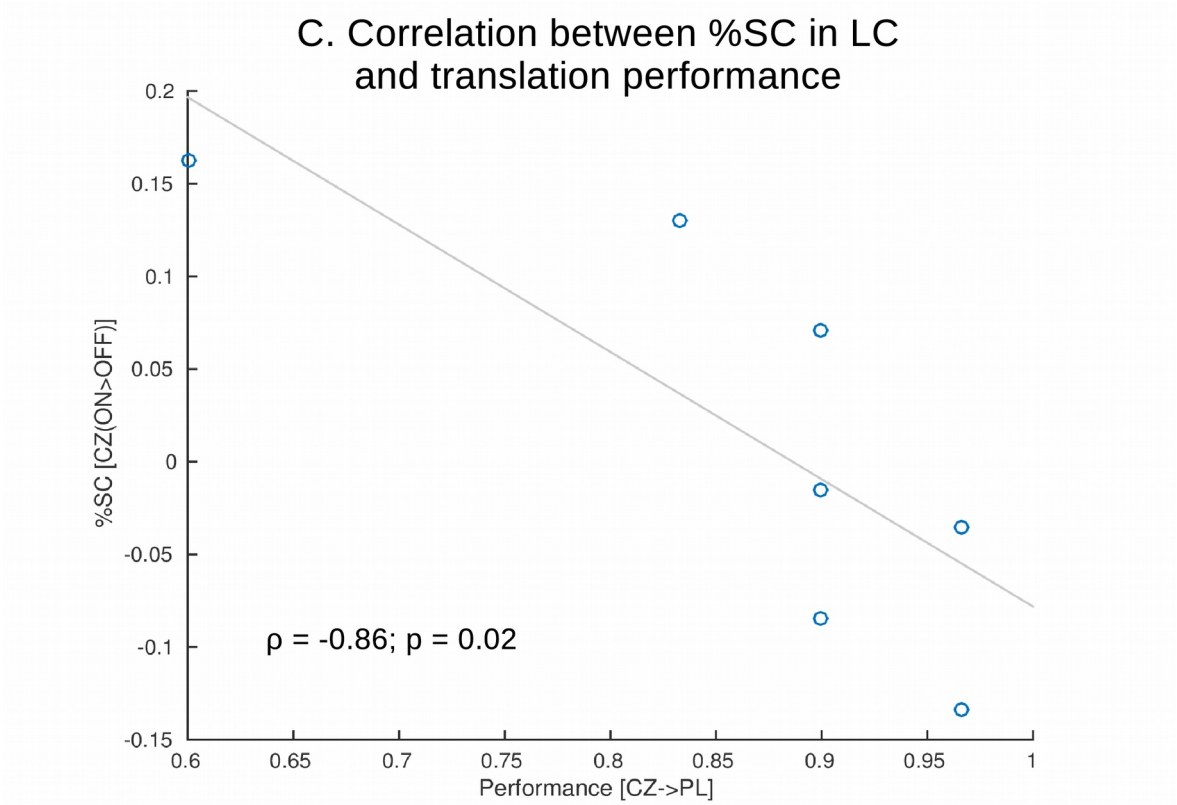
Scatter plots depict percent signal change (%SC) in the regions of interest (ROI) (abscissa) over the performance in the Word Translation Test (ordinate). Each datapoint represents a single participant. Least squares linear fit, Spearman's ρ (rho) and the corresponding p value (uncorrected) are indicated. ***Panel A*** *shows %SC (switching vs. non-switching contrast from English into Polish) in the supplementary motor area (SMA) against the translation performance from Polish into English;* ***Panel B*** *shows %SC (switching vs. non-switching contrast from English into Polish) in the precuneous cortex (PCUN) against the translation performance from Polish into English;* ***Panel C*** *shows %SC (switching vs. non-switching contrast from Polish into Czech) in the left caudate nucleus (LC) against the translation performance from Czech into Polish;* ***Panel D*** *shows the difference in %SC between the switching (blue) and non-switching (red) trials in Czech and English in the LC, plotted against the difference in the averaged translation performance in the two language contexts. Abbreviations: %SC = Percent Signal Change; EN = English; LC = Left Caudate Nucleus; PCUN = Precuneous Cortex; PL = Polish; ROI = Region Of Interest; SMA = Supplementary Motor Area.*

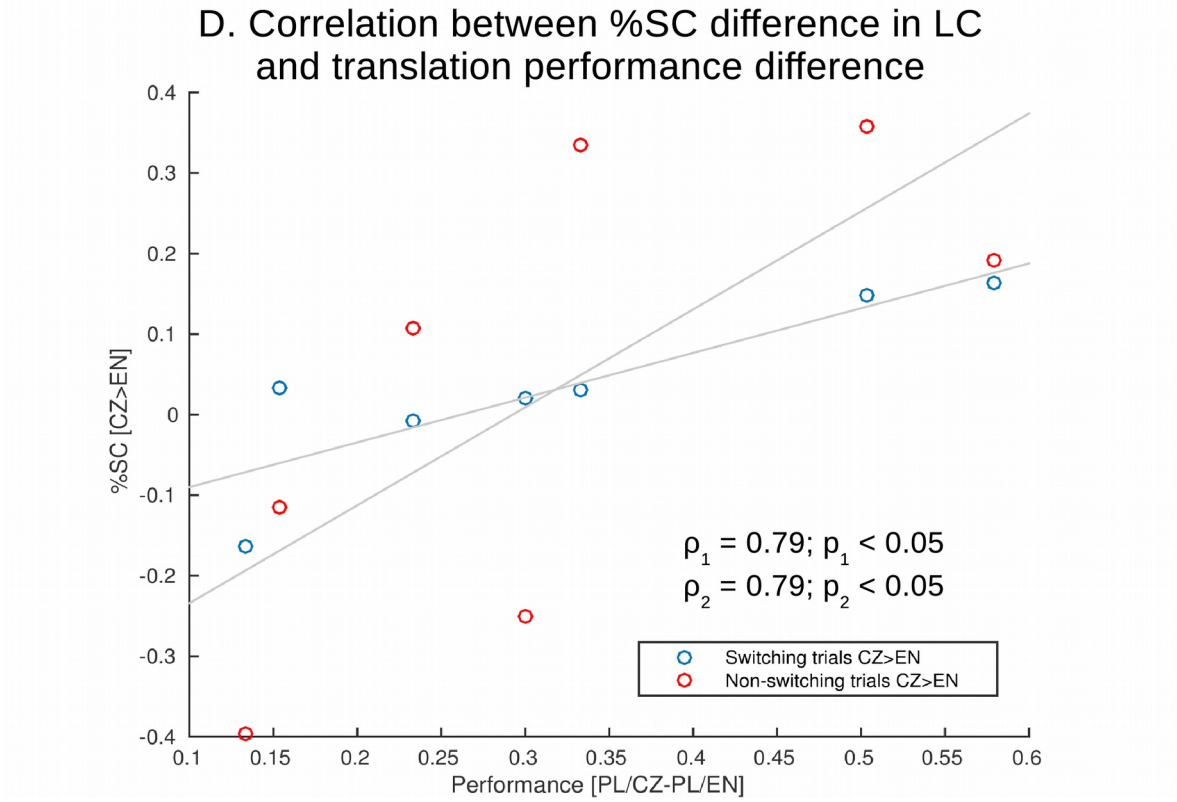
A. Correlation between %SC in SMA and translation performance



B. Correlation between %SC in PCUN and translation performance




C. Correlation between %SC in LC and translation performance
%SC [CZ(ON>OFF)]
Performance [CZ->PL]
ρ = -0.86; p = 0.02
0.2
0.15
0.1
0.05
0
-0.05
-0.1
-0.15
0.6
0.65
0.7
0.75
0.8
0.85
0.9
0.95
1


D. Correlation between %SC difference in LC and translation performance difference
%SC [CZ>EN]
Performance [PL/CZ-PL/EN]
ρ1 = 0.79; p1 < 0.05
ρ2 = 0.79; p2 < 0.05
Switching trials CZ>EN
Non-switching trials CZ>EN
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
0.55
0.6

6. Discussion

This thesis presents several findings and their significance will be discussed in the following section. First, sociolinguistic background of the study participants will be contrasted to previous literature. Next, imaging data will be interpreted in light of the recent developments in neurolinguistics.

6.1. Participants: Questionnaires

6.1.1. Language History Questionnaire

The 20 respondents (10 women and 10 men, mean age 23.6) had several features in common; first, they they were all university students or fresh graduates of the universities in the Czech Republic; second, they had a similar place of origin, the Cieszyn/Těšín Silesia Region. Third, at the time of questionnaire completion, they studied or worked outside the Těšín area. The collected information applied also to the 8 study participants. The main remarks are:

1) Since the mother tongue does not have to be a prestigious variety and it can therefore be a territorial dialect[18] (Bogoczová 1993, 9), the Language History Questionnaire showed that the mother tongue code was for 16 respondents *po naszymu,* for 1 respondent *po naszymu* and Polish, and for 3 respondents all three codes, i.e., Czech, Polish, and *po naszymu*.

2) All respondents attended Polish kindergartens. This proved that the respondents were exposed to the Polish language from very early on.

3) Nineteen respondents attended elementary schools and high schools with Polish as the teaching language and passed the high school final examination in Polish, as well as in Czech. It can be thus assumed that until that point their Czech and Polish were balanced (Bogoczová 1993).

4) When asked about the usage frequency of the Polish language, 6 reported to speak Polish more than once a week, 9 not regularly (less than once a week), and 5 less frequently than once a month. This indicated the exposure to Polish among the respondents was rather variable. In contrast, the questionnaire showed that 14 respondents speak the territorial dialect every day, 5 more than once a week, and only 1 not regularly (less than

18 Bogoczová (1993, 9) introduces *mateřský jazykový kód* ("mother tongue code") for the territorial dialect spoken at home.

once a week). This illustrates that the territorial dialect was actively used by the respondents despite living outside the Těšín Region.

5) Respondents reported various proficiency levels in English, namely from A1 to C2, with the AoA ranging between 3 and 12 yrs. Moreover, English was not the first foreign language for 3 respondents. Proficiency could be also influenced by other reported foreign languages and stages abroad.

6.1.2. Extended Language Background Questionnaire

The 8 shortlisted study participants represented the predominant characteristics all respondents, which was further confirmed by the Extended Language Background Questionnaire.

The participants were classified as multilinguals based on the Meuter's (Meuter 2009b) definition "speakers of more than one language". Since their early childhood, they have been using three language codes, Czech, Polish and the territorial dialect. Secondly, all of them have been learning English as a foreign language since the primary school. Last but not least, they have been studying or have been frequently exposed to other foreign languages such as Slovak or German. All these reasons make the participants in this research multilingual.

Based on the Language Background Questionnaire, there were five major findings that affect the interpretation of the neuroimaging data:

1) According to definition by Pavlenko (2015), the home language of all 8 participants was neither Czech nor Polish, but the territorial dialect *po naszymu*, because they use it at home to speak with their families (except for 1 participant who reported to use also Polish). This concept of home language is similar to the "mother language code" introduced by Bogoczová (1994, 12). However, despite that 7 participants claimed to use the territorial dialect every day and 1 more often than once a week, they reported that the usage is limited and influenced by the situations and with whom they speak. In contrast, they all reported to use Czech every day and more often than the territorial dialect.

2) All 8 participants attended a Polish kindergarten, basic and high schools with the Polish teaching language and all passed the high school leaving examination in Polish, as well as in Czech. Since the high school final examination, the participants have had very diverse exposure to various languages, including Polish. Only one participant reported to speak Polish more often than once a week, 4 speak Polish not regularly and 3 reported they

did not use it actively. In other words, the questionnaire showed that the respondents do not use Polish because they it is not needed on a daily basis, except for one participant studying Polish Philology as his/her major. It can be assumed that the Polish language is going through the process of forgetting and attrition (Jordà 2005). However, the Polish language could be still regarded as one of their mother tongues in the "dormant state" *(Grosjean 2014)*.

3) In contrast to Polish, Czech was reported to be spoken every day by all participants, which made it the most frequently spoken language. It was mostly used at the university or at work.

4) All 8 participants started to learn English as their foreign language at the basic school, at an average age of 10.0 yrs. The self-reported proficiency level was rather inhomogeneous, ranging from A1 to C1. However, 2 participants stated that German was the first acquired foreign language, but they reported to have better language skills in English and to use English more frequently. Other languages, such as Slovak, Japanese, Portuguese were reported as well.

6.1.3. Classification of Participants

Taking into account that the study participants claimed to speak three language codes, Czech, Polish and *po naszymu*, they could be classified according to the Table 1, Classification of Bilingualism (Jordà 2005; Wei 2000), as follows:

Ascendant bi/multilinguals, because the use of Czech language has increased since the high school examination and gained importance and became dominant language that is the most needed on a daily basis.

Coordinate bi/multilinguals, since they acquired their languages in different cultural contexts and they use them in different environments and for different functions (Altarriba 2005; Lust 2008).

Dominant bi/multilinguals, since the Czech language is used substantially more often than Polish or the territorial dialect. The data about proficiency in the three language codes are unavailable.

Dormant bi/multilinguals, since the Polish language is not in an active use.

Early bi/multilinguals, since they acquired their languages early in the childhood. The AoA of all three language codes (Czech, Polish, and the territorial dialect) could be assumed to equal 0, with individual differences in the families. Since all participants went

to the Polish kindergarten and they lived in the Czech Republic, they were exposed to Polish and Czech before the critical period, i.e., before the age of 3 (Costa and Sebastián-Gallés 2014).

Horizontal bi/multilinguals, since Polish and Czech languages are distinct but they have similar status, both of them are national and standard/prestigious languages.

Maximal bi/multilinguals, despite the fact that the respondents confirmed they are forgetting the Polish language, they used to have near native or native control of it.

Natural bi/multilinguals, since they acquired Polish, Czech and the territorial dialect without any special training.

Productive bi/multilinguals, since they can comprehend, speak, and write in Polish as well as in Czech.

Recessive bi/multilinguals, since some of the participants do not use Polish very often, it is speculated that Polish undergoes the process of attrition and forgetting due to the lack of its use.

Simultaneous bi/multilinguals, since from the responses it can be concluded, that Polish, Czech, and the territorial dialect are present from the onset of speech and they are ready to be used (Jordà 2005).

Vertical bi/multilinguals, since they speak two standard related languages and one territorial dialect.

Considering the classifications mentioned above, it may be stated that bi/multilingualism in the Polish minority speakers should be regarded as a complex phenomenon characterised by many features. Importantly, they cannot be classified as *balanced bilinguals* since their mother tongues are not equivalent (Meisel 2005). In line with this complexity is the idea that bi/multilingualism should be studied from a "dynamic perspective" (Jordà 2005, 15), meaning that individual socio-economic differences, current language states, and other foreign language influence should be taken into account. It is apparent that not only the classification but also the attempts to set the individuals into the bi/multilingual frames based on language skills and socio-linguistic backgrounds fail to bring homogeneous categorisation for the 8 participants.

6.1.4. Issues Arising from Socio-linguistic Background Differences

There are several discrepancies to be dealt with that concern the mother tongue, L1/L2, language dominance, various proficiency levels in English among others. All of them stem

from the fact that the group of 8 participant, however small it is, showed variability and heterogeneity in socio-cultural and language background.

Considering the facts stated in the section on Mother tongue, the participants could be classified to have one, two, or three mother tongues, depending on the criterion of origin and self-identification (Skutnabb-Kangas 2000). Keeping in mind that the language dominance can change throughout the life and that the mother tongue can shift as well (Grosjean 1982b), it is complicated to state the mother tongue in the participants.

According to the criteria to define a mother tongue proposed by Skutnabb-Kangass (2000), the language of origin, the "home language" (Pavlenko 2015) of the participants is the language code *po naszymu*, since they identify themselves with it, other speakers outside the minority identify them with it, and they know it best.

It is apparent that it is difficult to determine which language is the L1, L2, and L3 of the participants. Therefore, this classification is not used in the diploma thesis. L1 and L2 are not explicitly labelled, they are referred directly (as CZ, PL) instead, for several reasons:

a) *The territorial dialect as L1*: All the 8 participants firmly stated, that their home language is the territorial dialect. According to the definition of the mother tongue being the language acquired the first and based on the criteria of the mother tongue (Skutnabb-Kangas 2000), L1 would be the territorial dialect. Therefore, for a future research, the territorial dialect as L1 might be used. However, there are issues associated with the proficiency level since there is no common language frame (such as CEFR) against which the dialect could be gauged, secondly, it brings along complications in terms of the language stratification, since it is a dialect, not a standard/prestigious codified code.

b) *Polish as L1*: From the very early on, at home and at school, the 8 participants were daily exposed to the Polish language, they watched Polish TV, read Polish books, listened to Polish songs, and they cling to the Polish culture. One participant reported that Polish (beside the territorial dialect) was actually spoken at home. The language of instruction in the kindergarten was Polish, the basic and secondary education was in Polish as well. All these arguments imply that the L1 could be also Polish. However, daily exposition to the Polish language was over after the high school education. Since the average age of students passing the school leaving examination is 19 years (Český statistický úřad 2011), it can be estimated from the average age of participants (25.4) that it is on average more than

6.4 years since they left the high school. Needless to say, that the participants were also exposed to the Czech language and culture since the birth as well and it has been shown that up to 40% of students hesitate between Polish and Czech as their mother tongue (Bogoczová 1993, 14).

c) *Czech as L1*: It is a well known fact that the language dominance within a bi/multilinguals develops and decays over time, depending on opportunities, need, motivation, exposition, and choice (Baker 2004; Grosjean 1982b; Meisel 2005; Heredia and Brown 2005). In terms of the language dominance, it is generally assumed that more active/dominant language is the one that is more needed and to which bi/multilinguals are more exposed. From this perspective, all 8 participants use currently the Czech language the most frequently and the exposure is the highest. It developed to be their dominant language and it could be labelled as L1 as well.

To sum up, there are several factors causing heterogeneity in the participants. First, the participants were not of the same age which means that they may have been undergoing the attrition process of the Polish language for a differing time span. Second, one participant studies Polish Philology and another one speak Polish (and the territorial dialect) at home. Third, it was found out that there are other languages that should be taken into account and to which the participants are frequently exposed, such as other foreign languages taught at school or Slovak, as it was in the previous research omitted (Bogoczová 1993).

These issues could be avoided in the future research, for instance, by including carefully chosen high school students who share the same language background and home language, since at the high school with the Polish teaching language, Czech and Polish languages are both daily exercised and as Bogoczová (1993, 13) reported, they are more balanced. Moreover, the exposure to other languages, such as Slovak, should be included as well.

However heterogeneous the group of 8 participants was, there were commonalities found: English was the least proficient language than CZ and PL, which are more or less equivalent.

6.2. Word Translation Test

The Word Translation Test was inspired by Abutalebi et al. (2007) and designed to test lexical retrieval which is essential in picture naming. Other skills were not explicitly tested. Notably, the test only assessed the translation proficiency between the languages in the

language contexts PL/CZ and PL/EN, so that following directions were tested: PL→CZ, CZ→PL, PL→EN, and EN→PL. The test thus did not explicitly address each language proficiency since two languages always contributed to the overall result.

Although the overall medians in the PL/CZ context were close to identical, the participants performed slightly, but significantly worse when translating into Polish than into Czech. Taken together with the data from the Extended Language Background Questionnaire, it could be assumed that it was Czech, not Polish which was the most proficient language in most participants (Fig. 8, Table 4-5). These findings are consistent with the existing studies (Bogoczová 1994; Kadłubiec 1997; Bogoczová 2006).

Furthermore, the translation in the PL/EN context yielded significantly worse result than in the PL/CZ context. Since Polish had only moderate influence on the overall score in PL/CZ, it could be assumed that the result in PL/EN was mostly driven by the proficiency in English, which was therefore the least proficient language for all participants. There was, however, no significant difference between translation performance from English into Polish and from Polish into English. This might mean that the participants' competence in English was the limiting factor both in passive and in active use.

Although a global pattern could be well recognised, there were also inter-individual differences marked. Overall, the translation scores showed higher variability (higher value range) in the PL/EN context than in the PL/CZ context, reflecting the substantial differences in self-reported language proficiency in English. Fig. 8b also shows that some participants were outliers and performed worse than the rest of the participants in some translation sets.

In summary, it could be assumed that the language context PL/EN was a low proficiency context, and PL/CZ was high proficiency context. Moreover, the most likely overall language proficiency order was Czech > Polish >> English.

6.3. Difficulty Rating

The self-reported difficulty rating failed to show any consistent trend (Fig. 9). The possible reason is that the subjective difficulty rating could reflect many factors apart from the individual language proficiency, such as picture recognition, distraction due to the acoustic scanner noise, fatigue, self-esteem, etc. One of the precautions taken to equalise the difficulty and assure smooth performance was the training picture naming session in

which participants familiarised themselves with the picture set and had an opportunity to consider the appropriate picture names.

6.4. Imaging Data

In the following section, the main imaging results are discussed in the light of recent literature. It is demonstrated that the results of previous studies could be reproduced and several novel findings are reported as well. Furthermore, the limitations of the imaging analysis are thoroughly commented.

6.4.1. Whole-brain Analysis

First of all, the overall mean contrast of switching vs. non-switching trials yielded activations in an expected set of cortical areas which were reported in previous literature, such as the left dorsolateral and anterior prefrontal cortex (in the middle frontal gyrus [MFG] and frontal pole [FP]) (Hernandez et al. 2001; Zou et al. 2012; Guo et al. 2011; Wang et al. 2007), left supplementary motor area (SMA) and anterior cingulate cortex (ACC) (Abutalebi 2013; de Baene et al. 2015; de Bruin et al. 2014b; Zou et al. 2012; Wang et al. 2009; Guo et al. 2011), right inferior and superior parietal cortex (supramarginal [SMG] and angular gyrus [AG], and superior parietal lobule [SPL]) (Zou et al. 2012) and bilateral precuneous cortex (PCUN) (Guo et al. 2011; de Baene et al. 2015; de Bruin et al. 2014b; Zou et al. 2012; Garbin et al. 2011; Wang et al. 2009) (Fig. 10 and 11, Table 6). The primary speech areas (Broca's and Wernicke's) were not observed which means they were equally activated both in the switching and non-switching conditions. The observed pattern confirms that the paradigm and the statistical analysis were robust enough to detect significant effects, although the number of subjects was smaller than in previous studies (e.g., Abutalebi 2013).

On the other hand, the results did not show the expected significant F-test (significant differences across contrasts) in the left caudate (LC), reported by Abutalebi et al. (2013). Although the activation of LC during language switching has also been observed in several previous studies (Crinion et al. 2006; Zou et al. 2012; Hosoda et al. 2012; Garbin et al. 2011), many authors have not reported any effect in LC either (de Baene et al. 2015; Hernandez 2009; Hernandez et al. 2001; Wang et al. 2009; Guo et al. 2011; Wang et al. 2007). Moreover, Abutalebi et al. (2013) did not observe significant differences in LC during switching in multilinguals, but only when comparing multilinguals and

monolinguals, who actually performed a different task (word category switching). This contrast has probably driven the significant F-test result. Since no monolingual task was performed in this study, the differences between language contexts were less likely to produce a significant F-test.

6.4.2. Regions of Interest

The percent signal change (%SC) extracted from the regions of interest (ROIs) in the significant clusters was consistently increased during switching in the PL/EN context (meaning both directions, PL→EN, EN→PL), especially during switching into English (Fig. 12cd, Table 8). All these consistently activated areas are generally considered to be non-selectively involved in cognitive control (Abutalebi and Green 2007).

Notably, only a few ROIs were significantly activated also in the PL/CZ context, namely the left SMA, and the right AG and aSMG (Fig. 12ab, Table 8). The differences between the %SC in the two language contexts were not statistically significant and this apparent discrepancy could be merely due to a higher between-subject variability in PL/CZ. However, since the Word Translation Test scores were less variable in PL/CZ than in PL/EN (Fig. 8, Table 4), an alternative explanation is also possible. Namely, the switching in the PL/CZ context could be for most participants so effortless that they did not have to engage any extra cognitive resources. The difficulty rating (Fig. 9) is, however, inconclusive and there are no on-line behavioural data, such as error rate, to support or reject either hypothesis.

In contrast to the remaining ROIs, the left caudate (LC) did not show any significant (or even close to significant) activation increase in any condition (Fig. 12, Table 8). By contrast, LC has been reported to specifically engage during so called forward switching (switching from a more proficient into a less proficient language), especially from L1 into L3 (Abutalebi et al. 2013; Garbin et al. 2011). Here, the absence of such an activation could be due to an inconsistent difference between proficiency in Polish and in English (Fig. 8, Table 5). A closer look at individual data (Fig. 8a) shows that there were two participants whose translation performance was similar in the PL/CZ and PL/EN contexts. Therefore, the overall difference may have been too low to yield any group-level effect, especially given the small effect size even in a sample twice as big as the current sample (Abutalebi et al. 2013).

In summary, the absence of significant differences between the contexts hinders drawing any definite conclusions regarding the last research question, namely whether the switching between closely related languages influenced neural response in comparison to switching between less related languages. Still, the trends observed in the data support the hypothesis that switching between the related languages is not generally more cognitively demanding than switching between unrelated languages.

6.4.3. Correlation with Language Proficiency

6.4.3.1 Left Caudate Nucleus

The correlation analysis showed that there was a negative correlation between the Word Translation Test performance from Czech into Polish and the activation in the LC during switching from Polish into Czech (PL→CZ), (Fig. 13c, Table 9). In other words, a higher proficiency in translation from Czech to Polish resulted in lower activation when switching into Czech, whereas lower proficiency led to activation increase. Similar trends (i.e., negative coupling between the proficiency and activation) were observed in all remaining conditions in the PL/CZ context. This would suggest that the LC activation was context-dependent and modulated regardless of the actual switching direction. Although it supports the general idea that activation in the LC increases when switching between two less proficient languages, such an effect was not previously observed between equivalent languages, but between L1 and L3 (Abutalebi et al. 2013).

Surprisingly, no such consistent dependence was found in the PL/EN context. This might be due to the nature of the proficiency test used, which only assessed word translation in which both languages contributed to the overall result. In contrast, monolingual tasks, such as word retrieval, vocabulary size, grammaticality judgements, etc., only reflect proficiency in a single language. In general, the Word Translation Test score should mostly reflect the less proficient language, but if neither of the two languages in a language context were fully proficient (possibly the PL/EN context), the test may have lead to underestimation of language proficiency. In that case, the difference between the scores in the two context (PL/CZ and PL/EN) might be more informative, as it accounts for the proficiency of the reference language (PL).

The correlation of differences in the switch vs. non-switch contrast showed a negative coupling between the proficiency difference (PL/CZ > PL/EN) and activation difference (Czech > English trials). Although this result was not significant ($\rho = -0.50$; $p = 0.27$), it

shows that the bigger was the proficiency gap between the PL/CZ (reference context) and PL/EN (low proficiency context), the higher was the switch vs. non-switch activation in English compared to Czech.

However, the underlying activations in switching and non-switching trials yielded an opposite dependency. Fig. 13d shows that the higher was the proficiency difference between PL/CZ and PL/EN, the more LC engaged in the Czech naming trials compared to English naming trials (and *vice versa*). Notably, this significant positive correlation was shown independently both in the switching and non-switching trials (Fig. 13d). With regard to the first research question, whether the LC was more engaged when multilinguals switch into a less proficient language than into a more proficient one, this demonstrates just the opposite, since the activation was actually higher in the more proficient language context. On the other hand, the contrast between the switch and non-switch trials increased in the less proficient language.

Although this result might be challenging to interpret, it illustrates that the activation in LC is proficiency-dependent, no matter whether switching occurred or not. The apparently opposite correlation of the switching and non-switching contrast seems to be due to different slopes of the correlation in switching and non-switching trials (Fig. 13d). In other words, the activation during switching trials increased with a lower rate (across participants) than the activation during non-switching trials. Thus, differences between switching and non-switching trials can be relatively low, which might be the reason for inconsistent results in the LC throughout the literature (e.g., Abutalebi et al. 2013; de Bruin et al. 2014b; de Baene et al. 2015).

Nevertheless, this potentially important finding is difficult to compare with the previous studies, which have either used a different paradigm (Crinion et al. 2006), or have not reported the BOLD signal parameters separately for the switching and non-switching trials (Abutalebi et al. 2013; Garbin et al. 2011; Zou et al. 2012; Hosoda et al. 2012). It is therefore a task for future studies to finally determine how the LC responds to switching and non-switching conditions.

6.4.3.2 Supplementary Motor Area and Precuneous Cortex

The correlation with the Word Translation Test performance has further shown that both supplementary motor area (SMA) and precuneous cortex (PCUN) exhibited increased

activation (switch vs. non-switch) in the EN→PL contrast in subjects with higher translation performance from Polish into English (Fig. 12a-b, Table 9).

The SMA has been repeatedly reported to be involved in language switching (Abutalebi et al. 2013; Zou et al. 2012; Wang et al. 2009; Guo et al. 2011; de Baene et al. 2015; de Bruin et al. 2014b) and is generally thought to be responsible for the speech initiation (Peck et al. 2009). The involvement of PCUN has also been repeatedly observed in language switching paradigms (Guo et al. 2011; Garbin et al. 2011; de Bruin et al. 2014b), but a recent study (de Baene et al. 2015) has shown that PCUN is generally activated by non-linguistic switching tasks and therefore may represent more general resources required for cognitive skills.

The observed correlation between the switching activation and the Word Translation Test performance could be explained as follows: It could be speculated that for subjects with high English proficiency the switching direction EN→PL is no longer a switching into a more proficient language and the SMA and PCUN have to be activated to control the increasing interference with English. This account corresponds well with the inhibitory model introduced by Green (1998) and supported by de Bruin et al. (2014b).

Contrary to LC, this correlation has not been observed in the PL/CZ context. The reason for this discrepancy might be that LC is involved in higher-order language control (Abutalebi and Green 2007), whereas the (pre-)SMA is also involved in speech initiation, and in lower-order speech processes, such as articulation (A. Ford et al. 2010). These distinct functions may therefore lead to different interactions with behavioural parameters such as language proficiency.

In summary, although the increased activation in the SMA could not be directly confirmed by pairwise statistical comparison (see 6.4.4 Limitations of Neuroimaging Analysis for comments on the possible reasons), the modulation of the activation in the anterior SMA by language proficiency could be confirmed. This answers the second postulated research question, leading to the rejection of the hypothesis based on Abutalebi et al.'s (2013) conclusions.

6.4.4. Limitations of Neuroimaging Analysis

In this thesis, only 7 healthy participants were evaluated, which is considerably less than in previous similar studies (e.g., Abutalebi 2013). This therefore poses the main limitation of the reported results (Abutalebi 2013). This may prevent drawing any

conclusions from negative results, but given the robustness of the employed statistical analysis (Woolrich 2008), positive results can still be extrapolated under certain conditions to the whole sampled population and compared with previous literature.

Moreover, the rather heterogeneous language background of the participants introduced variability which is limiting especially in a study with a small sample size such as this. As shown in the behavioural data, Czech was the most frequently used language in all the participants and, thus, a third language context (Czech and English) could be beneficial. However, increasing the scanning time by one third could negatively influence the compliance of the participants due to fatigue and discomfort. An alternative solution would be an inclusion of participants with more homogeneous language background, such as adult students at Polish minority schools (Bogoczová 1994).

A further limiting factor stems from the Word Translation Test which was specifically designed to reflect only the lexical competence required by the picture naming task. First, other competencies different from the lexical skills, such as pronunciation, were not reflected but may have contributed to neural responses to switching as well. Second, the Word Translation Test was not designed to assess each language separately, limiting the inference especially if a participant did not perform well in the reference language (Polish).

Another limitation is the absence of on-line behavioural measurements, such as error rate and reaction time, which was prevented by technical constraints (acoustic scanner noise). As such, missing or false responses could not be assessed and controlled in the study. These may have especially influenced the neural responses in the less proficient languages. As a precaution, all pictures were presented to the participants and they named each picture from the final set before entering the scanner room, and the participants were instructed to say "(I) don't know" in the required language whenever they could not recall the picture name.

Furthermore, the analysis has shown the involvement of areas generally involved in cognitive control. A control task, such as that introduced by de Baene et al. (2015), might help distinguish areas involved in general cognitive control from those more specifically involved in language tasks. Again, the increased scanning duration could then negatively influence the data quality.

Last but not least, the reported *p* values for significant statistical comparisons and correlations were not corrected for multiple comparisons. This is again a limitation of the

small sample which limits the significance of the results. Therefore, the general conclusions based on these results have to be interpreted with caution.

6.5. Future Research

One direction for future research involves cognates. Abutalebi et al. (2013) excluded cognates from the picture naming task. Schepens et al. (2013) observed that the "cross-language frequency and similarity distributions of cognates vary according to evolutionary change and language contact." The results showed that "relative cognate frequency predicts degree of genetic relatedness between languages" (Schepens et al. 2013). This might indicate, that in the previous research, Abutalebi et al. omitted significant features conveying similarities between two languages, which, in effect, could obscure the contribution of linguistic distance. The research question would be: How are the neural activity and error rate during overt picture naming influenced by the presence of cognates?

One possible scenario is that there would be an increased demand on inhibition of competing representation when switching into a cognate in contrast to a non-cognate switch, leading to activation of executive control areas. Based on that hypothesis, it would be assumed that this effect would be more prominent when switching between closely related languages[19].

However, the previous research of picture naming in bilinguals has shown that cognate naming "is processed faster and with fewer errors than control words that exist in only one language" […] (Costa, Caramazza, and Sebastian-Galles 2000) and "this effect has been interpreted as evidence for language-non-selective access to the bilingual lexicon" (Brenders, van Hell, and Dijkstra 2011). It could be expected that a facilitation of behaviour would lead to activation decrease in executive control areas as a result of more efficient processing. However, this hypothesis was beyond the scope of this diploma thesis and thus further research is needed to support it.

19 By *closely related languages* it is understand languages in the same language family, as defined by Fromkin, that are *traceable to a common ancestor* (2000, 312). E. Lotko (1997, 145) uses for the relation between Czech and Polish *genetically close languages (geneticky blízké jazyky)*. The opposite are *unrelated languages* (Fromkin 2000, 312).

7. Conclusions

The area of research encompassing the study of code-switching and language processing in bi/multilinguals is poised for a broad range of future research directions. Despite the fact that the research in this field continues to grow quickly, there are still areas to be explored. By focusing on a unique Polish minority population multilingual sample, this thesis hoped to shed light on complex speech processes in the bi/multilingual brain.

On the basis of the questionnaire responses, it can be concluded that the participants in the study were not balanced bi/multilinguals. Behavioural data (Word Translation) also supported this finding, showing that Czech was the most frequently used and the most proficient language in all the participants.

Imaging data presented here showed that language switching elicited increased activation in areas involved in the domain of executive control but not in the classical language centres (Broca's or Wernicke's areas), which is in line with previous studies.

Based on the presented imaging results, I conclude that activation in the left caudate nucleus and the supplementary motor area were modulated by language proficiency. In contrasts to previous conclusions of other authors, the activations in the left caudate increased with proficiency, both in the switching and non-switching conditions. Furthermore, contrary to previous hypotheses, the switching between related languages did not lead to increased demands on general cognitive resources. These surprising findings emphasise the need for careful description and interpretation of results in neuroimaging studies. Last but not least, this thesis delineates possible questions for future research.

The thesis attempted to contribute to a better understanding of complex language control processes in the bi/multilingual brain and the role of language proficiency in modulating the regions involved in language control.

Shrnutí

Fenomén bi/multilingvismu je v současnosti intenzivně studován pomocí neinvazivních zobrazovacích metod, včetně funkční magnetické rezonance (fMRI). Z rozporuplných výsledků předchozích neurozobrazovacích studií nicméně vyplývá, že je stále nutné prozkoumat mnoho aspektů, například které oblasti mozku jsou zapojeny do přepínání jazyků a jakou roli hraje jazyková znalost (proficiency). Jako jedno z možných řešení, které by osvětlilo předešlé sporné výsledky, je považován výzkum zaměřený na specifický vzorek populace z jedinečného sociolingvistického prostředí.

Cílem této diplomové práce je nastínit výsledky současného neurolingvistického výzkumu a zaměřit se na jev přepínání jazyků ve vybraném vzorku polské multilingvní menšiny z Těšínského Slezska. První část práce zahrnuje teoretický úvod s řadou definic a modelů bi/multilingvismu. Krátce jsou také představeny sociolingvistické a historické aspekty užívání polštiny a angličtiny v rámci České republiky. Druhá část práce uvádí výsledky empirického dotazníkového šetření zaměřeného na univerzitní studenty pocházející z polské menšiny a podrobněji se zabývá 8 dobrovolníky, kteří se zúčastnili fMRI studie mapující struktury v mozku při přepínání jazyků. Dotazníky a jazykový test ukázaly, že mateřské jazyky respondentů, tedy polština a čeština, nejsou vyrovnané, ale jejich znalost převyšuje úroveň angličtiny. Právě angličtina byla jedním z kritérií pro zařazení do studie. Zobrazovací data potvrdila výsledky předchozích studií a prokázala zvýšenou aktivaci při přepínání jazyků v oblastech souvisejících s exekutivními funkcemi, ale ne v řečových centrech. Výsledky dále prokazují, že jak aktivace v levém nucleus caudatus, tak v suplementární motorické oblasti byly modulovány jazykovými znalostmi (proficiency). Na rozdíl od předchozích studií aktivace v levém nucleus caudatus korelovala s jazykovou znalostí bez ohledu na přepínání jazyka. Mimoto střídání jazykových kódů mezi příbuznými jazyky nebylo doprovázeno zvýšenými nároky na kognitivní oblasti. Tato zjištění zdůrazňují potřebu pečlivého popisu studované populace a opatrné interpretace výsledků neurozobrazovacíh studiích.

Tato práce má za cíl přispět k lepšímu pochopení složitých řečových procesů v bi/multilingvním mozku a také nastínit, jakou roli hraje jazyková znalost (proficiency) při modelování mentálních struktur, které jsou zapojeny do řečově komunikačních procesů.

Abstract

Behavioural and Neurophysiological Correlates of Speech Processing in Multilinguals

Author: Bc. Radka Hoková
Supervisor: Mgr. Václav Jonáš Podlipský, Ph.D.
Consultant: MUDr. Pavel Hok

Number of Pages: 117
Number of Characters:
Number of Appendices: 6

Key words: bi/multilingualism, language switching, fMRI, Polish minority, English

The phenomenon of bi/multilingualism has been recently intensively studied using modern non-invasive neuroimaging methods, such as the functional magnetic resonance imaging (fMRI). However, there are still many aspects to be explored, such as the brain structures involved in language switching and the role of language proficiency. Previous neuroimaging studies presented inconsistent reports and it was suggested that research in specific language population sample with unique sociolinguistic background might help to shed some light on these controversial results.

The aim of this diploma thesis is to outline results of contemporary neurolinguistic research and to study the phenomenon of language switching in the Polish minority multilinguals from Těšín Silesia. The first part of the thesis offers a theoretical background with a number of definitions and models of bi/multilingualism. The sociolinguistic and historical aspects of the use of Polish and English in the Czech Republic are briefly introduced as well.

The second part reports the results of the empirical survey of the Polish minority university multilinguals, focusing on 8 volunteers who participated in an fMRI study of language switching. The questionnaires together with the Word Translation Test show that their mother tongues are not balanced, but are superior to English in terms of proficiency. The imaging data confirmed the results of the previous research and showed that language switching increased activation in executive control network but not in the language centres. It is concluded that activation in both the left caudate nucleus and the supplementary motor area were modulated by language proficiency. In contrasts to previous reports, the activations in the left caudate increased with proficiency both in the switching and non-

switching conditions. Furthermore, the switching between related languages did not result in increased demand on cognitive resources. These findings emphasise the need for careful sample description and interpretation of results in neuroimaging studies. The thesis is hoped to contribute to a better understanding of complex speech processes in the bi/multilingual brain and the role of language proficiency in modulating the regions involved in language control.

Anotace

Jméno a příjmení:	Radka Hoková
Katedra:	Katedra anglistiky a amerikanistiky
Vedoucí práce: **Konzultant:**	Mgr. Václav Jonáš Podlipský, Ph.D. MUDr. Pavel Hok
Rok obhajoby:	2016

Název práce v češtině:	Behaviorální a neurofyziologické koreláty zpracování řeči u multilingvních mluvčích
Název v angličtině:	Behavioural and Neurophysiological Correlates of Speech Processing in Multilinguals
Anotace v češtině:	Cílem diplomové práce je nastínit problematiku bi/multilingualismu v neurolingvististice a prezentovat výsledky fMRI studie mapující struktury v mozku při přepínání jazyků ve vybraném vzorku polské multilingvní menšiny z Těšínského Slezska. První část práce zahrnuje teoretický úvod s řadou definic, modelů a přístupů k bi/multilingvismu. Krátce jsou představeny sociolingvistické a historické aspekty užívání polštiny a angličtiny v České republice. Druhá část uvádí výsledky empirického dotazníkového šetření zaměřeného na univerzitní studenty pocházející z polské menšiny a podrobněji se zabývá 8 dobrovolníky, kteří se zúčastnili fMRI studie. Dotazníky a jazykový test ukázaly, že mateřské jazyky respondentů nejsou vyrovnané, ale jejich znalost převyšuje úroveň angličtiny. Zobrazovací data potvrdila výsledky předchozích studií a prokázala zvýšenou aktivaci při přepínání jazyků v oblastech souvisejících s exekutivními funkcemi, ale ne v řečových centrech. Výsledky dále prokazují, že jak aktivace v levém nucleus caudatus, tak v suplementární motorické oblasti byly modulovány jazykovými znalostmi. Na rozdíl od předchozích studií aktivace v levém nucleus caudatus korelovala s jazykovou znalostí bez ohledu na přepínání jazyka. Mimoto střídání jazykových kódů mezi příbuznými jazyky nebylo doprovázeno zvýšenými nároky na kognitivní oblasti.
Klíčová slova:	bi/multilingvismus, střídání kódů, fMRI, polská minorita, angličtina
Anotace v angličtině:	The aim of this diploma thesis is to outline results of contemporary neurolinguistic research and to study the phenomenon of language switching in the Polish minority multilinguals from the Těšín Silesia Region. The first part of the thesis offers a theoretical background with a number of definitions and models of bi/multilingualism. The sociolinguistic

	and historical aspects of the use of Polish and English in the Czech Republic are briefly introduced as well. The second part reports the results of the empirical survey of the Polish minority university multilinguals, focusing on 8 volunteers who participated in an fMRI study of language switching. The questionnaires together with the Word Translation Test show that their mother tongues are not balanced, but they are superior to English in terms of proficiency. The imaging data confirmed the results of the previous research and showed that language switching increased activation in executive control network but not in the language centres. It is concluded that activation in both the left caudate nucleus and the supplementary motor area were modulated by language proficiency. In contrasts to previous reports, the activations in the left caudate increased with proficiency both in the switching and non-switching conditions. Furthermore, the switching between related languages did not result in increased demand on cognitive resources.
Klíčová slova v angličtině:	bi/multilingualism, language switching, fMRI, Polish minority, English
Přílohy vázané v práci:	6 příloh
Rozsah práce:	132 stran, 274 238 znaků
Jazyk práce:	angličtina

References

Abrahamsson, N., and K. Hyltenstam. 2009. “Age of Onset and Nativelikeness in a Second Language: Listener Perception Versus Linguistic Scrutiny.” *Language Learning* 59 (2): 249–306. doi:10.1111/j.1467-9922.2009.00507.x.

Abutalebi, J. 2013. “Bilingualism beyond Languages: The Impact of Bilingualism upon the Brain: Comment on ‘The Bilingual Brain: Flexibility and Control in the Human Cortex’ by Buchweitz and Prat.” *Physics of Life Reviews* 10 (4): 444–45. doi:10.1016/j.plrev.2013.09.003.

Abutalebi, J., S. M. Brambati, J. M. Annoni, A. Moro, S. F. Cappa, and D. Perani. 2007. “The Neural Cost of the Auditory Perception of Language Switches: An Event-Related Functional Magnetic Resonance Imaging Study in Bilinguals.” *The Journal of Neuroscience* 27 (50): 13762–69. doi:10.1523/JNEUROSCI.3294-07.2007.

Abutalebi, J., P. Della Rosa, G. Ding, B. Weekes, A. Costa, and D. W. Green. 2013. “Language Proficiency Modulates the Engagement of Cognitive Control Areas in Multilinguals.” *Cortex* 49 (3): 905–11. doi:10.1016/j.cortex.2012.08.018.

Abutalebi, J., and D. Green. 2007. “Bilingual Language Production: The Neurocognition of Language Representation and Control.” *Journal of Neurolinguistics* 2007 (20): 242–75. doi:10.1016/j.jneuroling.2006.10.003.

Abutalebi, J., and D. W. Green. 2008. “Control Mechanisms in Bilingual Language Production: Neural Evidence from Language Switching Studies.” *Language and Cognitive Processes* 23 (4): 557–82. doi:10.1080/01690960801920602.

Abutalebi, J., A. Miozzo, and S. F. Cappa. 2000. “Do Subcortical Structures Control ‘Language Selection’ in Polyglots? Evidence from Pathological Language Mixing.” *Neurocase* 6 (1): 51–56. doi:10.1080/13554790008402757.

Abutalebi, J., P. A. Della Rosa, D. W. Green, M. Hernandez, P. Scifo, R. Keim, S. F. Cappa, and A. Costa. 2012. “Bilingualism Tunes the Anterior Cingulate Cortex for Conflict Monitoring.” *Cerebral Cortex (New York, N.Y.: 1991)* 22 (9): 2076–86. doi:10.1093/cercor/bhr287.

Alladina, S., and V. Edwards. 1991. *Multilingualism in the British Isles: Africa, the Middle East and Asia*. Longman.

Altarriba, J. 2005. “Bilingualism.” Edited by P. Strazny. *Encyclopedia of Linguistics: A-L*. New York: Fitzroy Dearborn Publishers.

Altarriba, J., and J. M. Basnight-Brown. 2009. “Empirical Approaches to the Study of Code-Switching in Sentential Contexts.” In *Multidisciplinary Approaches to Code Switching*, edited by L. Isurin, D. Winford, and K. de Bot. Amsterdam / Philadelphia: John Benjamins Publishing.

Athanasopoulos, P. 2015. “New Research Shows Bilingual People Have yet Another Advantage.” *Business Insider*. August 4. http://uk.businessinsider.com/how-language-changes-views-of-the-world-2015-8.

“Autochthon.” 2016. *Merriam-Webster Dictionary*. http://www.merriam-webster.com/dictionary/autochthon.

Baehr, M., and M. Frotscher. 2012. *Duus’ Topical Diagnosis in Neurology: Anatomy, Physiology, Signs, Symptoms*. 5th edition edition. Stuttgart: Thieme.

Baker, C. 2004. “Bilingualism and Multilingualism.” Edited by K. Malmkjaer. *The Linguistics Encyclopedia*. London; New York: Routledge.

Balhar, J. 1984. “K Dvojímu Výročí Profesora Adolfa Kellnera.” *Naše řeč*, 1, 67: 41–43.
Beckmann, Ch. F., M. Jenkinson, and S. M. Smith. 2003. “General Multilevel Linear Modeling for Group Analysis in FMRI.” *NeuroImage* 20 (2): 1052–63. doi:10.1016/S1053-8119(03)00435-X.
Bělič, J. 1972. *Nástin české dialektologie*. 1. ed. Praha: Státní pedagogické nakladatelství.
———. 1975. “O jazykové příslušnosti nářečí na Těšínsku.” *Naše řeč* 58 (4). http://nase-rec.ujc.cas.cz/archiv.php?art=5857.
Bergmann, C. 1976. “Interference vs. Independent Development in Infant Bilingualism.” In *Bilingualism in the Bicentennial and beyond*, edited by G. D. Keller and S. V. Teschner, 86–95. New York: Bilingual Press/Editorial Bilingüe.
Bermel, N. 2001. “Střídání Kódů či Míšení Jazykových Prostředků? (K Popisu Dialogu v české Beletrii).” *Naše řeč* 84 (1): 16–30.
Bernstein, B. B. 2003. *Class, Codes and Control: Theoretical Studies towards a Sociology of Language*. Psychology Press.
Bhatia, T.K., and W.C. Ritchie. 2012. “Introduction.” In *The Handbook of Bilingualism and Multilingualism: Second Edition*, xxi – xxiii.
Bhattacharjee, Y. 2012. “The Benefits of Bilingualism.” *The New York Times*, March 17. http://www.nytimes.com/2012/03/18/opinion/sunday/the-benefits-of-bilingualism.html.
Bialystok, E. 2011. “Reshaping the Mind: The Benefits of Bilingualism.” *Canadian Journal of Experimental Psychology = Revue Canadienne de Psychologie Experimentale* 65 (4): 229–35. doi:10.1037/a0025406.
———. 2016. “How Hazy Views Become Full Pictures.” *Language, Cognition and Neuroscience* 31 (3): 328–30. doi:10.1080/23273798.2015.1074255.
Blommaert, J., J. Collins, and S. Slembrouck. 2005. “Spaces of Multilingualism.” *Language & Communication*, Multilingualism and diasporic populationsSpatializing practices, institutional processes, and social hierarchies, 25 (3): 197–216. doi:10.1016/j.langcom.2005.05.002.
Bobb, S. C., and Z. Wodniecka. 2013. “Language Switching in Picture Naming: What Asymmetric Switch Costs (do Not) Tell Us about Inhibition in Bilingual Speech Planning.” *Journal of Cognitive Psychology* 25 (5): 568–85. doi:10.1080/20445911.2013.792822.
Boeckx, C., A. Martinez-Alvarez, and E. Leivada. 2014. “The Functional Neuroanatomy of Serial Order in Language.” *Journal of Neurolinguistics* 32 (November): 1–15. doi:10.1016/j.jneuroling.2014.07.001.
Bogoczová, I. 1993. *Jazyková komunikace mládeže na dvojjazyčném území českého Těšínska: Zpráva o dotazníkovém průzkumu.* Ostrava: Sfinga.
———. 1994. “K jazykové a komunikativní kompetenci polské dvojjazyčné mládeže na Těšínsku.” In *Časopis pro moderní filologii*, 76:9–19. 1. Praha: Ústav pro jazyk český Akademie věd ČR.
———. 2006. “Příspěvek k národnostní a jazykové situaci na území kolem města Český Těšín v ČR.” 5. Czeski Cieszyn / Český Těšín Papers. Bolzano: EURAC. http://www.eurac.edu/en/research/autonomies/commul/Documents/Teschen/Czeski_Cieszyn_5_2%20Bog_tsch.pdf.
Borák, M., and I. Gabal. 1999. “Polská Menšina v České Republice [Polish Minority in the Czech Republic].” In *Etnické Menšiny ve Střední Evropě*, 120–27. Praha: G plus G.
Bosq, M. 2014. “Episode 37: Addressing Common Misconceptions about Multilinguals.” *Bilingual Avenue*. http://www.bilingualavenue.com/episode-37-addressing-

common-misconceptions-about-multilinguals/.
Boudewyn, M. A., C. S. Carter, and T. Y. Swaab. 2012. "Cognitive Control and Discourse Comprehension in Schizophrenia." *Schizophrenia Research and Treatment* 2012: e484502. doi:10.1155/2012/484502, 10.1155/2012/484502.
Brenders, P., J. G. van Hell, and T. Dijkstra. 2011. "Word Recognition in Child Second Language Learners: Evidence from Cognates and False Friends." *Journal of Experimental Child Psychology* 109 (4): 383–96. doi:10.1016/j.jecp.2011.03.012.
Broca, P. 1861. "Remarques Sur Le Siège de La Faculté Du Langage Articulé, Suivies D'une Observation D'aphémie (perte de La Parole)." *Bulletins de La Société D'anatomie (Paris), 2e Serie 1861c* 6: 330–57.
Bryant, J. B. 2013. "Language in Social Contexts: Development of Communicative Competence." In *The Development of Language*, 163–85. Boston: Pearson.
Buchweitz, A., and Ch. Prat. 2013. "The Bilingual Brain: Flexibility and Control in the Human Cortex." *Physics of Life Reviews* 10 (4): 428–43. doi:10.1016/j.plrev.2013.07.020.
Bullock, B. E., L. Hinrichs, and A. J. Toribio. 2014. "World Englishes, Code-Switching, and Convergence." *Oxford Handbooks Online*. http://www.academia.edu/2651844/World_Englishes_code-switching_and_convergence.
Cantone, K. F. 2007a. "Bilingual First Language Acquisition." In *Code-Switching in Bilingual Children*, 5–11. Springer Science & Business Media.
———. 2007b. "Early Mixing." In *Code-Switching in Bilingual Children*. Springer Science & Business Media.
Caplan, D. 1981. "On the Cerebral Localization of Linguistic Functions: Logical and Empirical Issues Surrounding Deficit Analysis and Functional Localization." *Brain and Language* 14 (1): 120–37. doi:10.1016/0093-934X(81)90070-5.
Český statistický úřad. 2011. "Dvacet Let Sociodemografické Transformace." *Demografie, Revue pro Výzkum Populačného Vývoje* 52 (4).
Christoffels, I. K., Ch. Firk, and N. O. Schiller. 2007. "Bilingual Language Control: An Event-Related Brain Potential Study." *Brain Research* 1147 (May): 192–208. doi:10.1016/j.brainres.2007.01.137.
Clyne, M. G. 2003. *Dynamics of Language Contact: English and Immigrant Languages*. Cambridge University Press.
Coelho, E., and D. Rivers. 2004. *Adding English: A Guide to Teaching in Multilingual Classrooms*. Pippin Publishing Corporation.
Costa, A., A. Caramazza, and N. Sebastian-Galles. 2000. "The Cognate Facilitation Effect: Implications for Models of Lexical Access." *Journal of Experimental Psychology. Learning, Memory, and Cognition* 26 (5): 1283–96.
Costa, A., and M. Santesteban. 2004. "Lexical Access in Bilingual Speech Production: Evidence from Language Switching in Highly Proficient Bilinguals and L2 Learners." *Journal of Memory and Language* 50 (4): 491–511. doi:10.1016/j.jml.2004.02.002.
Costa, A., and N. Sebastián-Gallés. 2014. "How Does the Bilingual Experience Sculpt the Brain?" *Nature Reviews. Neuroscience* 15 (5): 336–45. doi:10.1038/nrn3709.
"CPLP Multilingual Schools – Our Schools." 2015. Accessed August 18. http://cplpmultilingualschools.com/our-schools/.
Crinion, J., R. Turner, A. Grogan, T. Hanakawa, U. Noppeney, J. T. Devlin, T. Aso, et al. 2006. "Language Control in the Bilingual Brain." *Science* 312 (5779): 1537–40.

doi:10.1126/science.1127761.
Cruz-Ferreira, M. 2010a. “Multilingualism, Language Norms and Multilingual Contexts.” In *Multilingual Norms*. Frankfurt: Peter Lang Publishing Group.
———. 2010b. *Multilinguals Are...?* Battlebridge: Battlebridge Publications.
———. 2015. “Being Multilingual: More about Multilinguals.” *Being Multilingual*. http://beingmultilingual.blogspot.cz/p/more-about-multilinguals.html.
Crystal, D. 1987. *The Cambridge Encyclopedia of Language*. Cambridge Cambridgeshire ; New York: Cambridge University Press.
———. 2003. *The Cambridge Encyclopedia of the English Language*. 2 edition. Cambridge, U.K. ; New York: Cambridge University Press.
———. 2007a. *How Language Works: How Babies Babble, Words Change Meaning and Languages Live or Die*. London: Penguin.
———. 2007b. “How the Brain Handles Language.” In *How Language Works: How Babies Babble, Words Change Meaning and Languages Live or Die*. London: Penguin.
———. 2010. *The Cambridge Encyclopedia of Language*. 3 edition. Cambridge ; New York: Cambridge University Press.
———. 2011. “From the World to the Word - and Back Again.” In . Vol. 15th. Liverpool. http://ww.davidcrystal.com/David_Crystal/articles.htm.
Cummins, J. 1984. *Bilingualism and Special Education: Issues in Assessment and Pedagogy*. Austin, Tex: Pro ed.
Cummins, J., and M. Swain. 2014. *Bilingualism in Education: Aspects of Theory, Research and Practice*. Routledge.
Davies, M. 2008. “The Corpus of Contemporary American English: 520 Million Words, 1990-Present.” http://corpus.byu.edu/coca/.
de Baene, W., W. Duyck, M. Brass, and M. Carreiras. 2015. “Brain Circuit for Cognitive Control Is Shared by Task and Language Switching.” *Journal of Cognitive Neuroscience* 27 (9): 1752–65. doi:10.1162/jocn_a_00817.
de Bot, K. 1992. “Applied Linguistics.” *Applied Linguistics* 13 (1): 1–24. doi:10.1093/applin/13.1.1.
de Bruin, A., A. Roelofs, T. Dijkstra, and I. FitzPatrick. 2014a. “Domain-General Inhibition Areas of the Brain Are Involved in Language Switching: FMRI Evidence from Trilingual Speakers.” *NeuroImage* 90 (April): 348–59. doi:10.1016/j.neuroimage.2013.12.049.
———. 2014b. “Domain-General Inhibition Areas of the Brain Are Involved in Language Switching: FMRI Evidence from Trilingual Speakers.” *NeuroImage* 90 (April): 348–59. doi:10.1016/j.neuroimage.2013.12.049.
de Bruin, A., and S. D. Sala. 2016. “The Importance of Language Use When Studying the Neuroanatomical Basis of Bilingualism.” *Language, Cognition and Neuroscience* 31 (3): 335–39. doi:10.1080/23273798.2015.1082608.
Desikan, R. S., F. Ségonne, B. Fischl, B. T. Quinn, B. C. Dickerson, D. Blacker, R. L. Buckner, et al. 2006. “An Automated Labeling System for Subdividing the Human Cerebral Cortex on MRI Scans into Gyral Based Regions of Interest.” *NeuroImage* 31 (3): 968–80. doi:10.1016/j.neuroimage.2006.01.021.
Dijkstra, T., and W. J.B. van Heuven. 2002. “The Architecture of the Bilingual Word Recognition System: From Identification to Decision.” *Bilingualism: Language and Cognition* 5 (03): 175–97. doi:10.1017/S1366728902003012.
Dokoupil, L., M. Myška, and J. Svoboda. 2005. *Kulturně-Historická Encyklopedie českého*

Slezska a Severovýchodní Moravy. Ostrava: Ústav pro regionální studia FF OU. http://ff.osu.cz/ceres/index.php?id=809.
Dreifus, C. 2011. "The Bilingual Advantage." *The New York Times*, May 30. http://www.nytimes.com/2011/05/31/science/31conversation.html.
Duyck, W., E. V. Assche, D. Drieghe, and R. J. Hartsuiker. 2007. "Visual Word Recognition by Bilinguals in a Sentence Context: Evidence for Nonselective Lexical Access." *Journal of Experimental Psychology. Learning, Memory, and Cognition* 33 (4): 663–79. doi:10.1037/0278-7393.33.4.663.
Edwards, J. 2012. "Bilingualism and Multilingualism: Some Central Concepts." In *The Handbook of Bilingualism and Multilingualism: Second Edition*, 5–25.
Erb, J., and J. Obleser. 2013. "Upregulation of Cognitive Control Networks in Older Adults' Speech Comprehension." *Frontiers in Systems Neuroscience* 7: 116. doi:10.3389/fnsys.2013.00116.
Ford, A., K. M. McGregor, K. Case, B. Crosson, and K. D. White. 2010. "Structural Connectivity of Broca's Area and Medial Frontal Cortex." *NeuroImage* 52 (4): 1230–37. doi:10.1016/j.neuroimage.2010.05.018.
Ford, M. 2013. "What Is Priming? A Psychological Look at Priming & Consumer Behavior." *Motive Metrics*. http://blog.motivemetrics.com/What-is-Priming-A-Psychological-Look-at-Priming-Consumer-Behavior.
Fouser, R. 1995. "Problems and Prospects in Third Language Acquisition Research." *Language Research* 31 (2): 387–414.
Freedman, M., S. Alladi, H. Chertkow, E. Bialystok, F. I. M. Craik, N. A. Phillips, V. Duggirala, S. B. Raju, and T. H. Bak. 2014. "Delaying Onset of Dementia: Are Two Languages Enough?" *Behavioural Neurology* 2014. doi:10.1155/2014/808137.
Fromkin, V. 2000. "Cross-Linguistic Variation: Beyond English." In *Linguistics: An Introduction to Linguistic Theory*. Oxford: Blackwell.
Galantucci, B., C. A. Fowler, and M. T. Turvey. 2006. "The Motor Theory of Speech Perception Reviewed." *Psychonomic Bulletin & Review* 13 (3): 361–77.
Garbin, G., A. Costa, A. Sanjuan, C. Forn, A. Rodriguez-Pujadas, N. Ventura, V. Belloch, M. Hernandez, and C. Ávila. 2011. "Neural Bases of Language Switching in High and Early Proficient Bilinguals." *Brain and Language* 119 (3): 129–35. doi:10.1016/j.bandl.2011.03.011.
García-Pentón, L., Y. F. García, B. Costello, J. A. Duñabeitia, and M. Carreiras. 2016a. "'Hazy' or 'jumbled'? Putting Together the Pieces of the Bilingual Puzzle." *Language, Cognition and Neuroscience* 31 (3): 353–60. doi:10.1080/23273798.2015.1135247.
———. 2016b. "The Neuroanatomy of Bilingualism: How to Turn a Hazy View into the Full Picture." *Language, Cognition and Neuroscience* 31 (3): 303–27. doi:10.1080/23273798.2015.1068944.
Glover, G. H. 1999. "Deconvolution of Impulse Response in Event-Related BOLD fMRI." *NeuroImage* 9 (4): 416–29.
Grabner, G., A. L. Janke, M. M. Budge, D. Smith, J. Pruessner, and D. L. Collins. 2006. "Symmetric Atlasing and Model Based Segmentation: An Application to the Hippocampus in Older Adults." *Medical Image Computing and Computer-Assisted Intervention: MICCAI ... International Conference on Medical Image Computing and Computer-Assisted Intervention* 9 (Pt 2): 58–66.
Grahn, J. A., J. A. Parkinson, and A. M. Owen. 2008. "The Cognitive Functions of the Caudate Nucleus." *Progress in Neurobiology* 86 (3): 141–55.

doi:10.1016/j.pneurobio.2008.09.004.
Green, D. W. 1998. “Mental Control of the Bilingual Lexico-Semantic System.” *Bilingualism: Language and Cognition* 1 (02): 67–81. doi:10.1017/S1366728998000133.
Green, D. W., and J. Abutalebi. 2013. “Language Control in Bilinguals: The Adaptive Control Hypothesis.” *Journal of Cognitive Psychology (Hove, England)* 25 (5): 515–30. doi:10.1080/20445911.2013.796377.
———. 2016. “Language Control and the Neuroanatomy of Bilingualism: In Praise of Variety.” *Language, Cognition and Neuroscience* 31 (3): 340–44. doi:10.1080/23273798.2015.1084428.
Grosjean, F. 1982a. “The Bilingualism in Society.” In *Life with Two Languages: An Introduction to Bilingualism*, 113–61. Cambridge, MA: Harvard University Press.
———. 1982b. “The Psycholinguistics of BIlingualism.” In *Life with Two Languages: An Introduction to Bilingualism*. Cambridge, MA: Harvard University Press.
———. 1984. “Bilingualism in the World.” In *Life with Two Languages: An Introduction to Bilingualism*, 1–36. Cambridge, MA: Harvard University Press.
———. 1985. “Polyglot Aphasics and Language Mixing: A Comment on Perecman (1984).” *Brain and Language* 26 (2): 349–55. doi:10.1016/0093-934X(85)90048-3.
———. 1989. “Neurolinguists, Beware! The Bilingual Is Not Two Monolinguals in One Person.” *Brain and Language*, Bilingualism and Neurolinguistics, 36 (1): 3–15. doi:10.1016/0093-934X(89)90048-5.
———. 1994. “Individual Bilingualism.” In *The Encyclopedia of Language and Linguistics*. Oxford: Pergamon Press.
———. 2001. “The Bilingual’s Language Modes.” In *One Mind, Two Languages: Bilingual Language Processing*, edited by J. L. Nicol, 1 edition, 1–22. Malden, MA: Wiley-Blackwell.
———. 2014. “Understanding the Bilingual Brain: The Neural Bases of Bilingualism.” Psychology Today. *Life as a Bilingual*. September 19. https://www.psychologytoday.com/blog/life-bilingual/201409/understanding-the-bilingual-brain.
———. 2015. “Dementia, Later-Life Cognition and Bilingualism.” Psychology Today. *Life as a Bilingual*. August 5. https://www.psychologytoday.com/blog/life-bilingual/201508/dementia-later-life-cognition-and-bilingualism.
Grygar, J. 2003. “Jazyk Jako Nástroj Sociální Diverzifikace. Poznámky K Jazykové Situaci ve Stonavě Na Těšínsku.” Edited by Z. R. Nešpor. *Lidé Města*, no. 5: 47–80.
Guo, T., H. Liu, M. Misra, and J. F. Kroll. 2011. “Local and Global Inhibition in Bilingual Word Production: fMRI Evidence from Chinese-English Bilinguals.” *NeuroImage* 56 (4): 2300–2309. doi:10.1016/j.neuroimage.2011.03.049.
Haines, D. E. 2012. *Neuroanatomy: An Atlas of Structures, Sections, and Systems*. Wolters Kluwer/ Lippincott Williams & Wilkins Health.
Harding-Esch, E., and P. Riley. 2008. *Bilingvní Rodina*. Portál. http://www.kosmas.cz/knihy/139475/bilingvni-rodina/.
Herdina, P., and U. Jessner. 2002. “Stages in Research on Multilingualism.” In *A Dynamic Model of Multilingualism: Perspectives of Change in Psycholinguistics*, edited by J. Edwards. Clevedon: Multilingual Matters.
Heredia, R. R., and J. Altarriba. 2001. “Bilingual Language Mixing: Why Do Bilinguals Code-Switch?” *Current Directions in Psychological Science* 10 (5): 164–68. doi:10.1111/1467-8721.00140.

Heredia, R. R., and J. M. Brown. 2005. “Code-Switching.” Edited by P. Strazny. *Encyclopedia of Linguistics: A-L*. New York: Fitzroy Dearborn Publishers.
Hernandez, A. E. 2009. “Language Switching in the Bilingual Brain: What’s Next?” *Brain and Language* 109 (2–3): 133–40. doi:10.1016/j.bandl.2008.12.005.
Hernandez, A. E., M. Dapretto, J. Mazziotta, and S. Bookheimer. 2001. “Language Switching and Language Representation in Spanish-English Bilinguals: An fMRI Study.” *NeuroImage* 14 (2): 510–20. doi:10.1006/nimg.2001.0810.
Hernandez, A. E., A. Martinez, and K. Kohnert. 2000a. “In Search of the Language Switch: An fMRI Study of Picture Naming in Spanish–English Bilinguals.” *Brain and Language* 73 (3): 421–31. doi:10.1006/brln.1999.2278.
———. 2000b. “In Search of the Language Switch: An fMRI Study of Picture Naming in Spanish-English Bilinguals.” *Brain and Language* 73 (3): 421–31. doi:10.1006/brln.1999.2278.
Hickok, G. 2012. “Computational Neuroanatomy of Speech Production.” *Nature Reviews. Neuroscience* 13 (2): 135–45. doi:10.1038/nrn3158.
Hickok, G., and D. Poeppel. 2007. “The Cortical Organization of Speech Processing.” *Nature Reviews Neuroscience* 8 (5): 393–402. doi:10.1038/nrn2113.
Hindle, J. V., P. A. Martin-Forbes, A. J. M. Bastable, K. L. Pye, A. Martyr, Ch. J. Whitaker, F. I. M. Craik, et al. 2015. “Cognitive Reserve in Parkinson’s Disease: The Effects of Welsh-English Bilingualism on Executive Function.” *Parkinson’s Disease* 2015 (April): e943572. doi:10.1155/2015/943572, 10.1155/2015/943572.
Hoffmann, Ch. 2014. *Introduction to Bilingualism*. Routledge.
Holm, S. 1979. “A Simple Sequentially Rejective Multiple Test Procedure.” *Scandinavian Journal of Statistics* 6 (2): 65–70.
Hosoda, C., T. Hanakawa, T. Nariai, K. Ohno, and M. Honda. 2012. “Neural Mechanisms of Language Switch.” *Journal of Neurolinguistics* 25 (1): 44–61. doi:10.1016/j.jneuroling.2011.08.007.
Houlton, D., and R. Willey. 1983. *Supporting Children’s Bilingualism: Some Policy Issues for Primary Schools and Local Education Authorities*. Longman for Schools Council.
Hronek, J. 1992. “Poznámky K Mluvené češtině.” *Naše řeč* 75 (3): 120–29.
Hufeisen, B., and G. Neuner. 2004. “Introduction.” In *The Plurilingualism Project: Tertiary Language Learning : German After English*, edited by B. Hufeisen and G. Neuner, European Centre for Modern Languages. Strasbourg: Council of Europe.
Ikome, O. 1994. “Reviews.” *Applied Linguistics* 15 (3): 351–54. doi:10.1093/applin/15.3.351.
Jackson, G. M., R. Swainson, R. Cunnington, and S. R. Jackson. 2001. “ERP Correlates of Executive Control during Repeated Language Switching.” *Bilingualism: Language and Cognition* 4 (02): 169–78.
Janda, L. A. 2008. “Czech.” *Concise Encyclopedia of Languages of the World*. Elsevier.
Jenkinson, M., P. Bannister, M. Brady, and S. Smith. 2002. “Improved Optimization for the Robust and Accurate Linear Registration and Motion Correction of Brain Images.” *NeuroImage* 17 (2): 825–41. doi:10.1006/nimg.2002.1132.
Jenkinson, M., Ch. F. Beckmann, T. E. J. Behrens, M. W. Woolrich, and S. M. Smith. 2012. “FSL.” *NeuroImage* 62 (2): 782–90. doi:10.1016/j.neuroimage.2011.09.015.
Jenkinson, M., and S. Smith. 2001. “A Global Optimisation Method for Robust Affine Registration of Brain Images.” *Medical Image Analysis* 5 (2): 143–56.
Jeřábek, J., and J. Tupý. 2009. “The Framework Educational Programme for Basic

Education (FEP BE).” Praha: Výzkumný ústav pedagogický v Praze. http://www.msmt.cz/vzdelavani/zakladni-vzdelavani/framework-education-programme-for-basic-education.
Jessner, U. 2008. “Teaching Third Languages: Findings, Trends and Challenges.” *Language Teaching* 41 (1): 15–56. doi:10.1017/S0261444807004739.
Jha, A. 2011. “Being Bilingual May Delay Alzheimer’s and Boost Brain Power.” *The Guardian*, February 18, sec. Science. http://www.theguardian.com/science/2011/feb/18/bilingual-alzheimers-brain-power-multitasking.
Jordà, M. P. S. 2005. “Third Language Acquisition.” In *Third Language Learners: Pragmatic Production and Awareness*, edited by D. Singleton, 9–39. Second Learners Acquisition 12. Dublin: Multilingual Matters.
Kadłubiec, K. D. 1997. *Polská Národní Menšina Na Těšínsku v České Republice: 1920-1995*. Ostrava: Filozofická fakulta Ostravské univerzity.
Kalia, V., M. P. Wilbourn, and K. Ghio. 2014. “Better Early or Late? Examining the Influence of Age of Exposure and Language Proficiency on Executive Function in Early and Late Bilinguals.” *Journal of Cognitive Psychology* 26 (7): 699–713. doi:10.1080/20445911.2014.956748.
Komůrková, T. 2015. “Jednotlivé etnické a národnostní menšiny v ČR.” *Národní informační centrum pro mládež*. http://www.icm.cz/mensiny-jednotlive-etnicke-a-narodnostni-mensiny-v-cr.
Kovelman, I., S. A. Baker, and L. A. Petitto. 2008. “Bilingual and Monolingual Brains Compared: A Functional Magnetic Resonance Imaging Investigation of Syntactic Processing and a Possible ‘Neural Signature’ of Bilingualism.” *Journal of Cognitive Neuroscience* 20 (1): 153–69. doi:10.1162/jocn.2008.20011.
Krčmová, M. 2005. “Stratifikace současné češtiny.” *Linguistica online*. http://www.phil.muni.cz/linguistica/art/krcmova/krc-012.pdf.
Kroll, J. F., and E. Stewart. 1994. “Category Interference in Translation and Picture Naming: Evidence for Asymmetric Connections Between Bilingual Memory Representations.” *Journal of Memory and Language* 33 (2): 149–74. doi:10.1006/jmla.1994.1008.
Kroll, J. F., J. G. van Hell, N. Tokowicz, and D. W. Green. 2010. “The Revised Hierarchical Model: A Critical Review and Assessment.” *Bilingualism (Cambridge, England)* 13 (3): 373–81. doi:10.1017/S136672891000009X.
Kubala, O. 2011. “Předběžné výsledky Sčítání lidu, domů a bytů 2011.” Praha: Český statistický úřad. https://www.czso.cz/csu/sldb/predbezne_vysledky_scitani_lidu_domu_a_bytu_2011.
Kutas, M., and K. D. Federmeier. 2007. “Event-Related Brain Potential (ERP) Studies of Sentence Processing.” In *The Oxford Handbook of Psycholinguistics*, 1st ed., 385–406. Oxford, UK: Oxford University Press.
Levelt, W. J. M. 1989. *Speaking: From Intention to Articulation*. Cambridge: The MIT Press.
Liberman, A. M., and I. G. Mattingly. 1985. “The Motor Theory of Speech Perception Revised.” *Cognition* 21: 1–36.
———. 1989. “A Specialization for Speech Perception.” *Science (New York, N.Y.)* 243 (4890): 489–94.
Liberman, A. M., and D. H. Whalen. 2000. “On the Relation of Speech to Language.”

Trends in Cognitive Sciences 4 (5): 187–96.
Linhart, J. 2005. *Slovník Cizích Slov pro Nové Století*. Litvínov: Dialog.
Li, P., S. Sepanski, and X. Zhao. 2006. "Language History Questionnaire: A Web-Based Interface for Bilingual Research." *Behavior Research Methods* 38 (2): 202–10. doi:10.3758/BF03192770.
Lipski, J. M. 1982. "Spanish-English Language Switching In Speech and Literature: Theorie and Models." *Bilingual Review / La Revista Bilingüe* 9 (3): 191–212.
Lotko, E. 1994. "O jazykové komunikaci polské národnostní menšiny v České republice." In *Časopis pro moderní filologii*, 76:1–9. 1. Praha: Ústav pro jazyk český Akademie věd ČR.
———. 1997. *Synchronní konfrontace češtiny a polštiny: soubor statí*. Olomouc: Vydavatelství Univerzity Palackého.
Luk, G., and C. Pliatsikas. 2016. "Converging Diversity to Unity: Commentary on The Neuroanatomy of Bilingualism." *Language, Cognition and Neuroscience* 31 (3): 349–52. doi:10.1080/23273798.2015.1119289.
Lust, B. 2006. "Brain and Language Development." In *Child Language: Acquisition and Growth*, 73–100. Cambridge: Cambridge University Press.
———. 2008. "Child Language: Acquisition and Growth." presented at the Human Development CCE Research Update, Ithaca, New York, May 29.
Mack, Jennifer E., Aya Meltzer-Asscher, Elena Barbieri, and Cynthia K. Thompson. 2013. "Neural Correlates of Processing Passive Sentences." *Brain Sciences* 3 (3): 1198–1214. doi:10.3390/brainsci3031198.
Macura, J. 1998. *Z Dziejów Szkolnictwa Polskiego Na Zaolziu*. Czeski Cieszyn: Towarzystwo nauczycieli polskich.
Ma, H., J. Hu, J. Xi, W. Shen, J. Ge, F. Geng, Y. Wu, J. Guo, and D. Yao. 2014. "Bilingual Cognitive Control in Language Switching: An fMRI Study of English-Chinese Late Bilinguals." *PLoS ONE* 9 (9). doi:10.1371/journal.pone.0106468.
Makoni, S., and A. Pennycook. 2007. "Disinventing and Reconstituting Languages." In *Disinventing and Reconstituting Languages*. Bilingual Education and Bilingualism 62. Multilingual Matters.
Marian, V., and A. Shook. 2012. "The Cognitive Benefits of Being Bilingual." *Cerebrum: The Dana Forum on Brain Science* 2012 (13). http://www.ncbi.nlm.nih.gov/pmc/articles/PMC3583091/.
Marian, V., and M. Spivey. 2003. "Competing Activation in Bilingual Language Processing: Within- and Between-Language Competition." *Bilingualism: Language and Cognition* 6 (2): 97–115.
Marshall, J. C., and G. R. Fink. 2003. "Cerebral Localization, Then and Now." *NeuroImage* 20 Suppl 1 (November): S2–7.
Martin, C. D., B. Dering, E. M. Thomas, and G. Thierry. 2009. "Brain Potentials Reveal Semantic Priming in Both the 'Active' and the 'Non-Attended' Language of Early Bilinguals." *NeuroImage* 47 (1): 326–33. doi:10.1016/j.neuroimage.2009.04.025.
Mattheier, K. J., and E. Radtke, eds. 1997. "Über Destandardisierung, Umstandardisierung und Standardisierung in modernen europäischen Standardsprachen." In *Standardisierung und Destandardisierung europäischer Nationalsprachen*, 1–9. Frankfurt am Main: Peter Lang. http://www.peterlang.com/index.cfm?urlpath=index.cfm&event=cmp.ccc.seitenstruktur.detailseiten&seitentyp=produkt&cid=5&pk=16404&concordeid=31663.
Matthews, P. M. 2001. "An Introduction to Functional Magnetic Resonance Imaging of the

Brain." In *Functional Magnetic Resonance Imaging: An Introduction to Methods*, 1st edition. Oxford ; New York: Oxford University Press.
Max Planck Institute for Psycholinguistics. 2001. "WebCelex." http://celex.mpi.nl/scripts/export.pl.
Meisel, J. M. 2001. "The Simultaneous Acquisition of Two Languages." In *Trends in Bilingual Acquisition*, 11–41. Amsterdam: John Benjamins Publishing.
———. 2005. "Bilingual Acquisition." Edited by P. Strazny. *Encyclopedia of Linguistics: A-L*. New York: Fitzroy Dearborn Publishers.
Melzi, G., and A. R. Schick. 2013. "Language and Literacy in the School Years." In *The Development of Language*, 329–55. Boston: Pearson.
Meuter, R. 2009a. "Language Selection and Performance Optimisation in Multilinguals." In *Multidisciplinary Approaches to Code Switching*, edited by L. Isurin, D. Winford, and K. D. Bot, 27–52. Amsterdam / Philadelphia: John Benjamins Publishing.
———. 2009b. "Neurolinguistic Contributions to Understanding the Bilingual Mental Lexicon." In *The Bilingual Mental Lexicon: Interdisciplinary Approaches*, edited by A. Pavlenko, 1–25. Bristol, England, United Kingdom: Multilingual Matters. http://www.multilingual-matters.com.
Meuter, R., and A. Allport. 1999. "Bilingual Language Switching in Naming: Asymmetrical Costs of Language Selection." *Journal of Memory and Language* 40: 25–40.
Moritz-Gasser, S., and H. Duffau. 2009. "Cognitive Processes and Neural Basis of Language Switching: Proposal of a New Model." *Neuroreport* 20 (18): 1577–80. doi:10.1097/WNR.0b013e328333907e.
Moritz-Saladino, A. 2015. "The New York Times on Bilingual Babies." *Brainscape Blog*. https://www.brainscape.com/blog/2011/10/new-york-times-bilingual-babies/.
Müller, H. M., and P. Strazny. 2005. "Speech Processing." *Encyclopedia of Linguistics: M-Z*. New York: Fitzroy Dearborn Publishers.
Muryc, J. 2013. "Mezijazyková interference ve zvukovém plánu češtiny a polštiny." *Opera Slavica* 19 (4): 1–19.
Myler, T. 1998. "Key Advantages and Disadvantages of Being Bilingual." Edited by S. Ager. *Omniglot − Writing Systems and Languages of the World*. http://www.omniglot.com/language/articles/bilingualadvantages.htm.
"Národnostní struktura obyvatel." 2014. Praha: Český statistický úřad. https://www.czso.cz/documents/10180/20551765/170223-14.pdf/d0d27736-ef15-4f4f-bf26-e7cb3770e187?version=1.0.
Neustupný, J. V., and J. Nekvapil. 2003. "Language Management in the Czech Republic." *Current Issues in Language Planning* 4 (3-4): 181–366. doi:10.1080/14664200308668057.
Nordhoff, S., H. Hammarström, R. Forkel, and M. Haspelmath, eds. 2013. *Glottolog 2.2*. Leipzig: Max Planck Institute for Evolutionary Anthropology. http://glottolog.org/.
Novotná, J., G. Klečková, L. Tejkalová, P. Jahnová, and M. Hlaváčová. 2015. "Pojetí CLIL a Bilingvní Výuky." Accessed September 6. http://clanky.rvp.cz/clanek/c/Z/8879/pojeti-clil-a-bilingvni-vyuky.html/.
Oganian, Y., M. Conrad, A. Aryani, K. Spalek, and H. R. Heekeren. 2015. "Activation Patterns throughout the Word Processing Network of L1-Dominant Bilinguals Reflect Language Similarity and Language Decisions." *Journal of Cognitive Neuroscience* 27 (11): 2197–2214. doi:10.1162/jocn_a_00853.

Ogawa, S. F., R. S. Menon, D. W. Tank, S. G. Kim, H. Merkle, J. M. Ellermann, and K. Ugurbil. 1993. “Functional Brain Mapping by Blood Oxygenation Level-Dependent Contrast Magnetic Resonance Imaging. A Comparison of Signal Characteristics with a Biophysical Model.” *Biophysical Journal* 64 (3): 803–12.

Oldfield, R. C. 1971. “The Assessment and Analysis of Handedness: The Edinburgh Inventory.” *Neuropsychologia* 9 (1): 97–113.

Olulade, O. A., N. I. Jamal, D. S. Koo, C. A. Perfetti, C. LaSasso, and G. F. Eden. 2015. “Neuroanatomical Evidence in Support of the Bilingual Advantage Theory.” *Cerebral Cortex*, July, bhv152. doi:10.1093/cercor/bhv152.

Orrison, W. W. 2008. *Atlas of Brain Function*. 2nd ed. Stuttgart: Thieme Publishing Group.

Ouzia, J., and T. Folke. 2016. “There Are Also Drawbacks To Being Bilingual.” *IFLScience*. April 26. http://www.iflscience.com/brain/there-are-also-drawbacks-being-bilingual.

Paap, K. R. 2016. “The Neuroanatomy of Bilingualism: Will Winds of Change Lift the Fog?” *Language, Cognition and Neuroscience* 31 (3): 331–34. doi:10.1080/23273798.2015.1082607.

Paap, K. R., O. M. Sawi, Ch. Dalibar, J. Darrow, H. A. Johnson, and Language, Attention, and Cognitive Engineering (LACE) Lab, Department of Psychology, San Francisco State University, San Francisco, CA, USA;Language, Attention, and Cognitive Engineering (LACE) Lab, Department of Psychology, San Francisco State University, San Francisco, CA, USA. 2014. “The Brain Mechanisms Underlying the Cognitive Benefits of Bilingualism May Be Extraordinarily Difficult to Discover.” *AIMS Neuroscience* 1 (3): 245–56. doi:10.3934/Neuroscience.2014.3.245.

Papen, R. A. 2005. “Bilingual Mixed Languages.” Edited by P. Strazny. *Encyclopedia of Linguistics: A-L*. New York: Fitzroy Dearborn Publishers.

Paradis, M. 2004. *A Neurolinguistic Theory of Bilingualism*. Studies in Bilingualism. Amsterdam/Philadelphia: John Benjamins Publishing Company. https://benjamins.com/#catalog/books/sibil.18/main.

———. 2009. “Key Concepts, Frameworks, and Clarifications.” In *Declarative and Procedural Determinants of Second Languages*, 1–39. Amsterdam/Philadelphia: John Benjamins Publishing.

Paulston, Ch. B. 1978. “Education in a Bi/multilingual Setting.” *International Review of Education* 24 (3): 309–28. doi:10.1007/BF00598047.

Pavlenko, A. 2015. “What Languages Do Bilinguals Count In?” Psychology Today. *Life as a Bilingual*. April 21. https://www.psychologytoday.com/blog/life-bilingual/201504/what-languages-do-bilinguals-count-in.

Peal, E., and W. E. Lambert. 1962. “The Relation of Bilingualism to Intelligence.” *Psychological Monographs: General and Applied* 76 (27): 1–23. doi:10.1037/h0093840.

Peck, K. K., M. Bradbury, E. L. Psaty, N. P. Brennan, and A. I. Holodny. 2009. “Joint Activation of the Supplementary Motor Area and Presupplementary Motor Area during Simultaneous Motor and Language Functional MRI:” *NeuroReport* 20 (5): 487–91. doi:10.1097/WNR.0b013e3283297d71.

Phillips, C. G., S. Zeki, and H. B. Barlow. 1984. “Localization of Function in the Cerebral Cortex: Past, Present and Future.” *Brain* 107 (1): 328–61. doi:10.1093/brain/107.1.328.

Plaza, M., P. Gatignol, M. Leroy, and H. Duffau. 2009. “Speaking without Broca’s Area

after Tumor Resection." *Neurocase* 15 (4): 294–310. doi:10.1080/13554790902729473.
Poarch, G. J., and E. Bialystok. 2014. "Bilingualism as a Model for Multitasking." *Developmental Review* 35. doi:10.1016/j.dr.2014.12.003.
Poulisse, N., and T. Bongaerts. 1994. "First Language Use in Second Language Production." *Applied Linguistics* 15 (1): 36–57. doi:10.1093/applin/15.1.36.
Price, C., G. Thierry, and T. Griffiths. 2005. "Speech-Specific Auditory Processing: Where Is It?" *Trends in Cognitive Sciences* 9 (6): 271–76. doi:10.1016/j.tics.2005.03.009.
Průcha, J., E. Walterová, and J. Mareš. 2001. *Pedagogický slovník*. Praha: Portál.
Rampton, A. 1981. "West Indian Children in Our Schools (Interim Report of the Committee of Inquiry into the Education of Children from Ethnic Minority Groups)." London: Her Majesty's Stationery Office.
Rauschecker, J. P, and S. K. Scott. 2009. "Maps and Streams in the Auditory Cortex: Nonhuman Primates Illuminate Human Speech Processing." *Nature Neuroscience* 12 (6): 718–24. doi:10.1038/nn.2331.
Rawling, A. 2014. "10 Monolingual Countries Where You Need to Know the Language – Pt. 2." *The Memrise Blog*. August 25. https://blog.memrise.com/2014/08/25/10-monolingual-countries-where-you-need-to-know-2/.
Ringbom, H. 2007. "Item Transfer in Production: Areas of Language." In *Cross-Linguistic Similarity in Foreign Language Learning*, 61–78. Dublin: Multilingual Matters.
Samuel, A. G., and S. Larraza. 2015. "Does Listening to Non-Native Speech Impair Speech Perception?" *Journal of Memory and Language* 81: 51–71.
Sánchez-Casas, R., and J. E. García-Albea. 2005. "The Representation of Cognate and Noncognate Words on Bilingual Memory: Can Cognate Status Be Characterized as a Special Kind of Morphological Relation?" In *Handbook of Bilingualism*, edited by A. M. B. de Groot and J. F. Kroll, 226–50. Oxford: Oxford University Press.
Saur, D., B. Schelter, S. Schnell, D. Kratochvil, H. Küpper, P. Kellmeyer, D. Kümmerer, et al. 2010. "Combining Functional and Anatomical Connectivity Reveals Brain Networks for Auditory Language Comprehension." *NeuroImage* 49 (4): 3187–97. doi:10.1016/j.neuroimage.2009.11.009.
Schepens, J., T. Dijkstra, F. Grootjen, and W. J. B. van Heuven. 2013. "Cross-Language Distributions of High Frequency and Phonetically Similar Cognates." *PLoS ONE* 8 (5): e63006. doi:10.1371/journal.pone.0063006.
Shi, L. F. 2011. "How 'Proficient' Is Proficient? Subjective Proficiency as a Predictor of Bilingual Listeners' Recognition of English Words." *American Journal of Audiology* 20 (1): 19–32. doi:10.1044/1059-0889(2011/10-0013).
Sierpowska, J., A. Gabarrós, P. Ripollés, M. Juncadella, S. Castañer, Á. Camins, Gerard Plans, and Antoni Rodríguez-Fornells. 2013. "Intraoperative Electrical Stimulation of Language Switching in Two Bilingual Patients." *Neuropsychologia* 51 (13): 2882–92. doi:10.1016/j.neuropsychologia.2013.09.003.
Šimáčková, Š., V. J. Podlipský, and K. Chládková. 2012. "Czech Spoken in Bohemia and Moravia." *Journal of the International Phonetic Association* 42 (02): 225–32. doi:10.1017/S0025100312000102.
Skutnabb-Kangas, T. 2000. *Menšina, Jazyk a Rasizmus*. Bratislava: Kalligram.
Skutnabb-Kangas, T. 2008. "Bilingual Education and Sign Language as the Mother Tongue of Deaf Children." In *English in International Deaf Communication*. Bern: Peter Lang.
Skutnabb-Kangas, T., and T. L. McCarty. 2008. "Key Concepts in Bilingual Education:

Ideological, Historical, Epistemological, and Empirical Foundations." *Encyclopedia of Language and Education*. Bilingual Education. New York: Springer.
Smith, I. R. 2005. "Language Contact–Overview." Edited by P. Strazny. *Encyclopedia of Linguistics: A-L*. New York: Fitzroy Dearborn Publishers.
Smith, S. M. 2002. "Fast Robust Automated Brain Extraction." *Human Brain Mapping* 17 (3): 143–55. doi:10.1002/hbm.10062.
Smith, S. M., M. Jenkinson, M. W. Woolrich, Ch. F. Beckmann, T. E. J. Behrens, H. Johansen-Berg, P. R. Bannister, et al. 2004. "Advances in Functional and Structural MR Image Analysis and Implementation as FSL." *NeuroImage* 23 Suppl 1: S208–19. doi:10.1016/j.neuroimage.2004.07.051.
Snodgrass, J. G., and M. Vanderwart. 1980. "A Standardized Set of 260 Pictures: Norms for Name Agreement, Image Agreement, Familiarity, and Visual Complexity." *Journal of Experimental Psychology. Human Learning and Memory* 6 (2): 174–215.
Štefánik, J. 2000. *Jeden človĕk, Dva Jazyky: Dvojjazyčnost U Dĕtí – Předsudky a Skutečnosti*. Bratislava: AEP.
Těšitelová, M. 1972. "Kvantitativní Hodnocení Lexikálních Prostředků a Jejich Stylistické Využití." *Naše řeč* 55 (2-3): 144–50.
"Tower of Babel." 2015. *Wikipedia, the Free Encyclopedia*. https://en.wikipedia.org/w/index.php?title=Tower_of_Babel&oldid=682851676.
Úřad vlády ČR. 2015. "Zpráva o situaci národnostních menšin v České republice za rok 2014." Praha: Úřad vlády ČR, Sekretariát Rady vlády pro národnostní menšiny. http://www.vlada.cz/assets/ppov/rnm/aktuality/zprava_2014_vlada_tisk.pdf.
Ústav Českého národního korpusu FF UK. 2010. "Český Národní Korpus: Srovnávací Frekvenční Seznamy." http://ucnk.ff.cuni.cz/srovnani10.php.
Valenti, A. V., and M. J. Scheutz. 2013. "A Computational Model of Bilingual Inhibitory Control in a Lexical Decision Task." In . Canada. http://iccm-conference.org/2013-proceedings/papers/0042/paper0042.pdf.
van Heuven, W. J. B., and T. Dijkstra. 2010. "Language Comprehension in the Bilingual Brain: fMRI and ERP Support for Psycholinguistic Models." *Brain Research Reviews* 64 (1): 104–22. doi:10.1016/j.brainresrev.2010.03.002.
Verhoef, K., A. Roelofs, and D. J. Chwilla. 2009. "Role of Inhibition in Language Switching: Evidence from Event-Related Brain Potentials in Overt Picture Naming." *Cognition* 110 (1): 84–99. doi:10.1016/j.cognition.2008.10.013.
Volterra, V., and T. Taeschner. 1978. "The Acquisition and Development of Language by Bilingual Children." *Journal of Child Language* 5 (02): 311–26. doi:10.1017/S0305000900007492.
Wang, Y., P. K. Kuhl, C. Chen, and Q. Dong. 2009. "Sustained and Transient Language Control in the Bilingual Brain." *NeuroImage* 47 (1): 414–22. doi:10.1016/j.neuroimage.2008.12.055.
Wang, Y., G. Xue, Ch. Chen, F. Xue, and Q. Dong. 2007. "Neural Bases of Asymmetric Language Switching in Second-Language Learners: An ER-fMRI Study." *NeuroImage* 35 (2): 862–70. doi:10.1016/j.neuroimage.2006.09.054.
Warren, P. 2012. "Introduction." In *Introducing Psycholinguistics*, 1st edition. Cambridge: Cambridge University Press.
Wartenburger, I., H. R. Heekeren, J. Abutalebi, S. F. Cappa, A. Villringer, and D. Perani. 2003. "Early Setting of Grammatical Processing in the Bilingual Brain." *Neuron* 37

(1): 159–70. doi:10.1016/S0896-6273(02)01150-9.
Wei, L. 2000. “Dimensions of Bilingualism.” In *The Bilingualism Reader*, 3–26. New York: Routledge.
Weinreich, U. 1968. *Languages in Contact: Findings and Problems*. New York: Mouton & Co.
Werker, J. F., K. Byers-Heinlein, and Ch. T. Fennell. 2009. “Bilingual Beginnings to Learning Words.” *Philosophical Transactions of the Royal Society B: Biological Sciences* 364 (1536): 3649–63. doi:10.1098/rstb.2009.0105.
Wernicke, C. 1874. *Der Aphasische Symptomencomplex: Eine Psychologische Studie Auf Anatomischer Basis*. Cohn. https://books.google.com/books?hl=en&lr=&id=pe9AAAAAYAAJ&oi=fnd&pg=PA3&dq=Wernicke+1874&ots=ZKoYuY-4D9&sig=Bjlt5WfyJXrdd1zHJoHbU9i70PA.
Whalen, D. H., R. R. Benson, M. Richardson, B. Swainson, V. P. Clark, S. Lai, W. E. Mencl, R. K. Fulbright, R. T. Constable, and A. M. Liberman. 2006. “Differentiation of Speech and Nonspeech Processing within Primary Auditory Cortex.” *The Journal of the Acoustical Society of America* 119 (1): 575–81. doi:10.1121/1.2139627.
White, Lydia, and F. Genesee. 1996. “How Native Is near-Native? The Issue of Ultimate Attainment in Adult Second Language Acquisition.” *Second Language Research* 12 (3): 233–65. doi:10.1177/026765839601200301.
Williams, J. N. 2006. “Incremental Interpretation in Second Language Sentence Processing.” *Bilingualism: Language and Cognition* 9 (01): 71–88. doi:10.1017/S1366728905002385.
Williams, S., and B. Hammarberg. 1998. “Language Switches in L3 Production: Implications for a Polyglot Speaking Model.” In *Applied Linguistics*, 295–333. 19 3. http://applij.oxfordjournals.org/content/19/3/295.abstract.
Wong, A. 2005. “Diglossia.” Edited by P. Strazny. *Encyclopedia of Linguistics: A-L*. New York: Fitzroy Dearborn Publishers.
Wong, B., B. Yin, and B. O’Brien. 2016. “Neurolinguistics: Structure, Function, and Connectivity in the Bilingual Brain.” *BioMed Research International* 2016. doi:10.1155/2016/7069274.
Woolrich, M. W. 2008. “Robust Group Analysis Using Outlier Inference.” *NeuroImage* 41 (2): 286–301. doi:10.1016/j.neuroimage.2008.02.042.
Woolrich, M. W., T. E.J. Behrens, Ch. F. Beckmann, M. Jenkinson, and S. M. Smith. 2004. “Multilevel Linear Modelling for FMRI Group Analysis Using Bayesian Inference.” *NeuroImage* 21 (4): 1732–47. doi:10.1016/j.neuroimage.2003.12.023.
Woolrich, M. W., S. Jbabdi, B. Patenaude, M. Chappell, S. Makni, T. Behrens, Ch. Beckmann, M. Jenkinson, and S. M. Smith. 2009. “Bayesian Analysis of Neuroimaging Data in FSL.” *NeuroImage* 45 (1 Suppl): S173–86. doi:10.1016/j.neuroimage.2008.10.055.
Woolrich, M. W., B. D. Ripley, M. Brady, and S. M. Smith. 2001. “Temporal Autocorrelation in Univariate Linear Modeling of FMRI Data.” *NeuroImage* 14 (6): 1370–86. doi:10.1006/nimg.2001.0931.
Woolsey, T. A., J. Hanaway, and M. H. Gado. 2008. *The Brain Atlas: A Visual Guide to the Human Central Nervous System*. 3rd Edition. New Jersey: John Wiley & Sons.
Worsley, K.J. 2001. “Statistical Analysis of Activation Images.” In *Functional MRI: An Introduction to Methods*, edited by P. Jezzard, P.M. Matthews, and S.M. Smith. Oxford [England]; New York: Oxford University Press.

Worsley, K. J., and K. J. Friston. 1995. “Analysis of fMRI Time-Series Revisited--Again.” *NeuroImage* 2 (3): 173–81. doi:10.1006/nimg.1995.1023.
Wu, Y. J., and G. Thierry. 2010. “Investigating Bilingual Processing: The Neglected Role of Language Processing Contexts.” *Frontiers in Psychology* 1. doi:10.3389/fpsyg.2010.00178.
Wydawnictwo Naukowe PWN. 2014. “Korpus Języka Polskiego PWN.” *Korpus Języka Polskiego PWN*. http://sjp.pwn.pl/korpus.
Yang, H., A. Hartanto, and S. Yang. 2016. “The Importance of Bilingual Experience in Assessing Bilingual Advantages in Executive Functions.” *Cortex* 75: 237–40. doi:10.1016/j.cortex.2015.11.018.
Yang, S., H. Yang, and B. Lust. 2011. “Early Childhood Bilingualism Leads to Advances in Executive Attention: Dissociating Culture and Language.” *Bilingualism: Language and Cognition* 14 (03): 412–22. doi:10.1017/S1366728910000611.
York, G.K., and D.A. Steinberg. 1994. “Hughlings Jackson’s Theory of Cerebral Localization.” *Journal of the History of the Neurosciences* 3 (3): 153–68. doi:10.1080/09647049409525605.
Yow, W. Quin, and Xiaoqian Li. 2015. “Balanced Bilingualism and Early Age of Second Language Acquisition as the Underlying Mechanisms of a Bilingual Executive Control Advantage: Why Variations in Bilingual Experiences Matter.” *Frontiers in Psychology* 6 (February). doi:10.3389/fpsyg.2015.00164.
Yule, G. 2014a. “Second Language Acquisition/learning.” In *The Study of Language*, 187–89. Cambridge University Press.
———. 2014b. “The Critical Period.” In *The Study of Language*, 163–64. Cambridge University Press.
“Zákon O Právech Příslušníků Národnostních Menšin - č. 273/2001 Sb. - Aktuální Znění [Law on the Rights of Ethnic Minorities and Amendment of Some Laws Made on 10th July 2001, No. 273/2001].” 2016. *Zákony pro Lidi*. Accessed April 6. http://www.zakonyprolidi.cz/cs/2001-273.
Zeman, J. 1994. “K problému výzkumu česko-polského kontaktu z hlediska komunikace [On Czech-Polish contact from the point-of-view of communication].” *Ksztalcenie porozumiewania sie*, Opole, , 155–120.
Zou, L., G. Ding, J. Abutalebi, H. Shu, and D. Peng. 2012. “Structural Plasticity of the Left Caudate in Bimodal Bilinguals.” *Cortex; a Journal Devoted to the Study of the Nervous System and Behavior* 48 (9): 1197–1206. doi:10.1016/j.cortex.2011.05.022.

List of Tables

List of Figures

List of Appendices

Appendices

Appendix 1: Current Methodology in Neurolinguistics

Currently used functional brain imaging methods exploit directly the electrical neuronal activity, or indirectly the changes in glucose metabolism, blood oxygenation and blood flow. The information they bring could be compared in terms of temporal and spatial resolutions (Matthews 2001, 4) and they have their advantages and disadvantages.

Electrophysiological methods, including EEG (electroencephalography) and ERP (event-related potential) which directly maps transient brain electrical dipoles, or MEG (magnetoencephalography) which maps transient brain magnetical dipoles, show underlying cortical neuronal events in real time, but have relatively low spacial resolution (Matthews 2001, 4).

Other methods localizing physiological changes, such as fMRI and PET (positron emission tomography), provide fairly high spatial resolution, but are limited in terms of temporal resolution which is hindered by much slower haemodynamic changes accompanying neuronal activity (Matthews 2001, 4; van Heuven and Dijkstra 2010).

Optical imaging methods, such as NIRS (near infrared spectroscopy), also make use of the changes in blood flow but they offer limited spatial resolution since they can only study the cortical surface. MRSI (magnetic resonance spectroscopic imaging) method has poorer spatial resolution as well as poorer temporal resolution, despite these facts, it provides very useful and specific information (Matthews 2001, 5).

To sum it up, Matthews (2001, 4) underlines the fact that fMRI is a very sensitive and unique technique among recent functional imaging methods because it "has potential to link high spatial and temporal resolution studies to an understanding of systems organization across the brain" and it also allows "mapping of neuronal activation deep in the brain".

Functional Magnetic Resonance Imaging (fMRI)

The fMRI is currently one of the most exploited neuroimaging methods in the human brain mapping research. The method is not invasive, which means no radiocontrast agents have to be swallowed or injected and no ionizing radiation, as in x-ray Computed Tomography (CT), is needed. This is why it has been used *in vivo* in healthy participants in

clinical and non-clinical neuroscience disciplines for the last two decades and became essential to understand how the human brain works.

Since the fMRI combines the recent advances in Physics, Statistics, and Neurophysiology, a multi-disciplinary approach is required. For a correct interpretation of the results, it is essential to acquire basic knowledge of its principles.

Physiology behind the fMRI

The fMRI utilizes the change of the blood flow in the brain areas as a surrogate of the neural activity under given task conditions. The changes of the blood flow can be registered as changes in blood hemoglobin oxygenation, resulting in so called BOLD (blood oxygenation level-dependent) contrast, i.e., changes in the magnetic resonance imaging (MRI) signal (Ogawa et al. 1993). This contrast is caused by the change of magnetization between oxygen-rich and oxygen-poor blood (Matthews 2001, 3). In the next section, a brief description of the underlying physiology will follow.

The nervous system consists of neurons, i.e., polarized cells responsible for information processing and transmission (Baehr and Frotscher 2012, 2). Neurons transfer the information from one to another through synapses by the release of chemical substances known as neurotransmitters (Baehr and Frotscher 2012, 2). The synapse consists of the presynaptic and postsynaptic membrane which is separated by the synaptic cleft (Baehr and Frotscher 2012, 3–5). Synaptic transmission consists of several processes. Initially, the excitatory electrical impulse causes the release of neurotransmitters from the presynaptic membrane. The released molecules then diffuse towards the postsynaptic membrane where they bind to specific receptors leading to a change of the electrical potential of the postsynaptic membrane (depolarization) (Baehr and Frotscher 2012, 3–5). These processes are energy demanding and require increased oxygen and glucose inflow (Matthews 2001, 3). This increase is mediated via supportive neural cells, so called astrocytes, which wrap around the synapses and the nearby blood vessels. The astrocytes are therefore responsible for a phenomenon called “neuro-vascular” coupling, which essentially stands for the local increase in blood volume and blood flow elicited by neurotrasmitter release at the surrounding synapses, reflecting the neuronal activity (Baehr and Frotscher 2012, 8; Matthews 2001, 8–10).

In other words, brain energy production depends on oxidative metabolism so that increase in the synaptic activity requires increase in the oxygen delivery. Hence, the

neuronal activation goes hand in hand with the increase in the local blood flow (Matthews 2001, 3). The coupling between the neuronal activity and the blood flow, mainly in small capillaries, is a stable and reliable marker, and could be detected directly using perfusion imaging, e.g., ASL (arterial spin labeling) (Matthews 2001, 10–11). In fMRI, this increase is measured indirectly based on blood oxygenation. Since it is well established that the increased blood volume overcompensates the increased demand for oxygen, the neuronal activity results in net increase of blood oxygen (Matthews 2001, 3).

Both cerebral blood flow and blood oxygenation increase with a certain delay after the neuronal activity takes place. The hemodynamic response peaks approximately 5-7 seconds after the onset of the sustained neuronal activity and returns to baseline about 10-15 second after the activity is over. Although the latency varies slightly among different areas, it can be observed in all neuronal tissues in the central nervous system and the typical shape of the blood oxygenation timecourse has been termed as hemodynamic response function (HRF) (Glover 1999).

Nevertheless, the changes in oxygenation can be detected only indirectly, because the conventional MRI detects signal only from the hydrogen nuclei (protons) (Haines 2012, 3). Oxygen-rich and oxygen-poor blood differ in their behavior in a magnetic field, because the oxygenated and deoxygenated hemoglobin molecules have distinct magnetic properties, they affect the surrounding magnetic field in opposite way. The oxygenated hemoglobin is diamagnetic repelling the background magnetic field, while the deoxygenated hemoglobin is paramagnetic attracting he surrounding magnetic field and causing its local distortions and inhomogeneities (Matthews 2001, 11). As the blood oxygen content increases, the magnitude of these local magnetic field distortions lowers, giving rise to the BOLD contrast (Matthews 2001, 12).

Physics of MRI/fMRI

MRI scanner, used for acquisition of fMRI data, consists of a strong electromagnet (usually 1.5 or 3.0 Tesla), radio-frequency transmitter, antenna, and a computer which processes the signals (Woolsey, Hanaway, and Gado 2008, 16). The electro-magnet creates a background magnetic field in which the hydrogen nuclei (protons) achieve a steady state aligned along the field's.

The protons have the function similar to small spinning magnets, in the normal state, they are placed in a random way to each other, which is caused by the change of the

magnetic field. This property of protons is used by MRI imaging methods to obtain scans of the body, and the brain (Haines 2012, 3). Radiofrequency pulse (RP) waves of different strength are sent and subsequently absorbed by the protons, causing the magnetic resonance phenomenon. After the RP waves are turned off, the protons with absorbed energy emit "an echo" signal to the antenna and using a sophisticated spatial encoding techniques, an image of the examined part of the body can be reconstructed (Haines 2012, 3; Woolsey, Hanaway, and Gado 2008, 16–17).

The relatively good temporal resolution of fMRI is made possible by rapid acquisition techniques, such as gradient-echo echo-planar imaging (GE EPI). Thus, a whole brain image can be acquired in just a few seconds, enough to sample the slow HRF, although with relatively lower spatial resolution. Since high-resolution anatomical brain images are usually produced in the same imaging session, the registration of functional images with fine anatomical structures is possible (Ogawa et al. 1993).

Statistical Analysis

The fMRI data are affected by several sources of noise. Although this is beyond the scope of this thesis, it has to be noted that the detection of BOLD signal changes is only possible after several repetitions of the same experimental paradigm and that statistical methods, such as general linear modelling (GLM), are necessary (Worsley and Friston 1995).

Appendix 2: Language History Questionnaire

1. Środowisko i biegłość językowa[20]
   a) Jakim/-i językiem/-ami czy dialektem/-ami posługujesz się w domu (tzn. od dzieciństwa)?
   b) Czy przebywałeś/-aś przez dłuższy czas poza RC?
      i) Jeżeli tak, to gdzie?
      ii) Jeżeli tak, to przez jaki czas?
   c) Czy uczęszczałeś/-aś do przedszkola z polskim językiem nauczania?
      Jeżeli tak, to ile lat spędziłeś w polskim przedszkolu?
   d) Czy uczęszczałeś/-aś do szkoły podstawowej z polskim językiem nauczania?
   e) Czy uczęszczałeś/-aś do szkoły średniej z polskim językiem nauczania?
      i) Jeżeli tak, to przez ile lat uczęszczałeś/-aś do szkoły średniej?
      ii) Zdawałeś/-aś maturę z języka polskiego?
   f) Czy aktywnie używasz języka polskiego (w formie pisemnej lub ustnej)? Jeżeli tak, jak często (na co dzień, raz do tygodnia itp.), ewentualnie w jakich sytuacjach? (np. często po polsku piszę maile, ale rozmawiam rzadko)
   g) Czy aktywnie używasz gwary śląskiej?
   h) Jakie języki znasz oprócz czeskiego i polskiego?
      Jakie języki znasz oprócz czeskiego i polskiego? [Język angielski], [Język niemiecki], [Język francuski], [Język rosyjski], [Język hiszpański], [Język włoski],
      i) Kiedy rozpocząłeś/-ęłaś ich naukę?
      ii) Na jakim poziomie oceniasz swoje aktualne zdolności (A1-C2 wg europejskiego poziomu biegłości językowej)
      iii) Znasz także inne języki?
2. Dane osobiste
   a) Ile masz lat?
   b) Jesteś kobieta/mężczyzna?
   c) Jesteś praworęczny/-a lub leworęczny/-a?
   d) Masz tatuaż/makijaż permanentny/piercing/inne przedmioty zawierające metale w okolicy głowy lub szyi, których nie można zdjąć?
   e) Masz kardiostymulator/implant ślimakowy/stały aparat ortodontyczny?
   f) Chciał/-a byś wziąć udział w badaniach?*
   g) Działający kontakt:
      i) Adres skrzynki poczty elektronicznej (e-mail):
         Telefon: …

20 Only example questions are provided here. English translation is provided in the section 5. Results.

Appendix 3: Extended Language Background Questionnaire

Dotazník dodatek[21]: Jméno: Datum:
[Extended Questionnaire] [Name] [Date]

1. Jak často mluvíte česky? **[How often do you speak Czech?]**

a. V jakém jazykovém prostředí? [In which language situations / where?]

b. Kolik hodin denně/týdně mluvíte česky? [How many hours per day/week?]

c. S kým a kde mluvíte výhradně česky? [With whom and where do you speak only CZ?]

2. Jak často mluvíte polsky? **[How often do you speak Polish?]**

a. V jakém prostředí? [In which language situations / where?]

b. Kolik hodin denně/týdně mluvíte polsky? [How many hours per day/week?]

c. S kým a kde mluvíte výhradně polsky? [With whom and where do you speak only PL?]

3. Jak často mluvíte *po naszymu*? **[How often do you speak *po naszymu*?]**

a. V jakém prostředí? [In which language situations / where?]

b. Kolik hodin denně/týdně mluvíte *po naszymu*? [How many hours per day/week?]

c. S kým a kde mluvíte výhradně *po naszymu*? [With whom and where do you use only dialect?]

4. Jak často mluvíte anglicky? **[How often do you speak English?]**

a. V jakém prostředí? [In which language situations / where?]

b. Kolik hodin denně/týdně? [How many hours per day/week?]

c. S kým a kde mluvíte výhradně anglicky? [With whom and where do you speak only EN?]

5. Další detaily a poznámky **[Other details and notes]**

...

21 Only example questions are provided here.

Appendix 4: Test preference používání ruky

Test preference používání ruky (Edinburgh) (Oldfield 1971)

Jméno:

Datum narození:

Prosím, označte + při kterých níže uvedených činnostech používáte pravou nebo levou ruku. Pokud výhradně používáte pravou či levou ruku a nikdy byste nepoužil(a) tu druhou, označte ++. V případech, kdy používáte obě (nejste vyhraněný pravák ani levák při dané činnosti), zapište + do obou sloupců.

A)

Kterou ruku používáte při:	LEVÁ:	PRAVÁ:
1 PSANÍ		
2 KRESLENÍ		
3 HÁZENÍ		
4 STŘÍHÁNÍ NŮŽKAMI – ve které ruce držíte nůžky		
5 ČIŠTĚNÍ ZUBŮ		
6 NŮŽ – bez vidličky, např. při krájení chleba		
7 LŽÍCE		
8 SMETÁK, KOŠTĚ – která ruka je nahoře při držení za rukojeť		
9 ŠKRTÁNÍ SIRKOU O KRABIČKU – ve které ruce držíte sirku		
10 OTVÍRANÍ KRABICE (SEJMUTÍ VÍČKA)		

B) Kterou nohou kopete do míče? (zakroužkujte) **levou pravou**

C) Kterým okem se díváte, když máte jedno oko zavřít? **levým pravým**

D) Kdo z vaší rodiny je levák?

	LEVÁK	PRAVÁK
OTEC		
MATKA		
SESTRA		
BRATR		
DĚTI		

Appendix 5: Edinburgh Handedness Inventory

Edinburgh Handedness Inventory (Oldfield 1971)

Surname_____Given Name_____

Date of
Birth_____Sex_____

Please indicate your preferences in the use of hands in the following activities by *putting + in the appropriate column*. Where the preference is so strong that you would never try to use the other hand unless absolutely forces to, *put ++*. If any case you are really indifferent put + in both columns.

Some of the activities require both hands. In these cases the part of the task, or object, for which hand preference is wanted is indicated in brackets.

Please try to answer all the questions, and only leave a blank if you have no experience at all of the object or task.

	Left	Right
1. Writing		
2. Drawing		
3. Throwing		
4. Scissors		
5. Toothbrush		
6. Knife (without fork)		
7. Spoon		
8. Broom (upper hand)		
9. Striking Match (match)		
10. Opening box (lid)		
i. Which foot do you prefer to kick with?		
ii. Which eye do you use when using only one?		

Appendix 6: Example MRI Scan