CHAPTER ONE

Theories and Methods in the Cognitive Neuroscience of Bilingualism

An Introduction

Learning Objectives

- Identify the differences between the definitions of who is a bilingual and understand the impact of this discrepancy and the consequent need for uniformity of research on bilingualism.
- Learn about various neuroimaging methods and the research questions for which they are suitable.
- Become familiar with the advantages and disadvantages of research methods in the cognitive neuroscience of bilingualism.
- Develop an understanding of the notion of ecological validity in research on bilingualism.

1.1 Introduction

Cognitive neuroscience is a discipline that aims to understand the relationship between the brain and the mind. It is fundamentally based on human neuropsychology, which focuses on revealing the neural bases of cognition and describing mental processes in the human brain; however, cognitive neuroscience goes beyond these foci. Moreover, it is nourished by a strong interdisciplinary combination and integration of approaches and knowledge from neuroscience, medical science, cognitive psychology, and computer science.

   In this book, we set out to explore the brain's mental capacities, and in particular, one aspect of cognition – language. Our primary aim is to examine how the neurological organization and functioning of the brain supports bilingual language acquisition and language processing.

1.2 Theoretical and Empirical Issues of Bilingualism Research

1.2.1 Bilingualism Research: Who Is a Bilingual?

Sixty percent of the world's population knows two or more languages. It is estimated that 43 percent of people are bilingual, and an additional

17 percent know at least three languages (iLanguages.org, 2023). The word *bilingual* is composed of the prefix "bi-" and the adjective "lingual." Both parts of the word are derived from Latin, with "bi" meaning "two," and "lingual" from the noun "lingua," meaning "language." The adjective *bilingual* refers to two languages. While the direct translation into one's dominant language, for instance, seems easy and its meaning clear-cut, up until now, definitional issues regarding bilingualism have not been solved. In this section, we dive into the world of definitional difficulties concerning the term *bilingualism*. Unfortunately, this definition is rather confusing. At first glance, *bilingualism* appears to be dichotomous, but a closer look shows that it is much more complex. However, examining and characterizing bilingualism is of great importance, and, as will become clear throughout this book, many dimensions shed light on the complicated term *bilingualism*. For research (in particular, grouping of participants and clear-cut research findings), an accurate characterization of bilingualism is vital. Many of these dimensions are intermingled or even intertwined, and therefore looking at only one dimension and using its extrema for selection purposes in studies on bilingualism is often too short-sighted.

Differences in the interpretation of bilingualism are based on various aspects:

1. The level of fluency (proficiency):
    * According to an early, extremely restrictive definition of bilingualism by Bloomfield (1933), a bilingual has "native-like control of two languages" (p. 56). A perfect, ideal native speaker speaks the language fluently and has a rich vocabulary, perfect command over complicated sentence structures and norms of the language including spelling, perfect grammar skills, and mastery of communicative conventions and stylistic variation. Clearly, only proficiency level was used here as a criterion, ignoring all other dimensions of bilingualism (Dewaele, 2015).
    * But, of course, not all "native" speakers show this high level of language command in their "native" language. Consequently, would individuals who do not have perfect command over two languages be excluded from being labeled as a bilingual?

    This leads to several more questions:

    * What is the minimal level of language competence acquired by a speaker to be categorized as bilingual (i.e., are language learners in their initial stage already bilingual or should the term *bilingual* refer

only to advanced language learners)? For Haugen (1953), a bilingual is an individual who produces "complete and meaningful utterances in other languages" (p. 6), whereas for Diebold (1961), a bilingual is someone who begins to understand utterances in another language, though not yet able to produce utterances in this language. Is it enough to just know a few words such as "good morning" or "thank you" in another language to be bilingual, as suggested by Edwards (2004)? These criteria are – although very vague – flexible and could thus be considered a first step toward viewing **bilingualism as a continuum** rather than a category (Dewaele, 2015).

- Is high proficiency required in all four linguistic skills (speaking, listening, reading and writing) or only in some of them?
- What about languages that do not have a written form, for example, some Arabic and Chinese language varieties? Would someone not be called a bilingual because he/she is unable to write in these languages?
- There is also the issue of speed and accuracy (or, in psychological terms, speed–accuracy tradeoff): In the definition of bilingualism, does fluency include accuracy, or can a speaker be accurate, but not very fluent when speaking a language and still be called a bilingual?

2. Relative competence in both languages:
   - Balanced bilinguals are speakers with an equal mastery of two languages. But does this necessarily apply to all linguistic skills and domains, topics, settings?
   - Unbalanced bilinguals have an unequal mastery of two languages; that is, they have a higher proficiency in one language, which is their dominant language, than in the other, nondominant, language. Are these individuals not classified as bilinguals when they speak a dialect or language without script as their first, dominant language?
   - Balanced bilingualism does not necessarily imply a high level of proficiency; for example, two non-native languages can be mastered at an intermediate level of proficiency. If an individual learns two languages but has not yet reached full competence in these languages, is he/she not considered a bilingual according to the definition in point 1?

3. Frequency of language use:
   - According to a more recent, less narrow definition by Grosjean (2010), a bilingual is someone who uses two (or more) languages in everyday life.
   - Does a bilingual use the two languages on a regular (maybe even daily) basis and to the same extent?

- Are the languages used in private context and/or in occupational situations and are all four linguistic skills regularly used?
- Are heritage language speakers considered to be bilingual if they do not use one of their languages often, given their life circumstances?
- Do individuals count as a bilingual when they do not speak the language regularly but "only" read in it frequently?
- What is more intertwined with language use frequency – length of residence in a country where the second language (L2) is spoken (suggesting little language exposure and L2 use) or length of exposure to an L2 (suggesting more active language use in L2)?

4. Number of languages:
   - Does bilingualism refer to the knowledge and use of **exactly two languages** or can it mean "two or more" languages (often referred to as multilingualism/plurilingualism)?
   - What is a language? Do dialects, sociolects, and so on count as languages?

1.2.1.1 Dimensions for Classifying Bilinguals

In studies across all disciplines involved in research on bilingualism, important factors for categorizing individuals as bilinguals (such as the language proficiency attained in the languages, language use frequency, and the number of languages) are still quite problematic, because they are not precise, as illustrated by the many questions raised in Section 1.2.1.

A factor that is apparently already accepted in research communities of linguists, psychologists, and cognitive neuroscientists and is widely used is **age of acquisition**. There is some agreement in the field that the cut-off line for early bilingualism lies in early childhood, but it is not exactly clear at what age – around the age of three (according to McLaughlin, 1984) or somewhat later, say, at the age of six? What is more, De Houwer (1995) distinguished between *bilingual first language acquisition* (BFLA) and *bilingual second language acquisition*, with the former referring to regular exposure to two languages within the first month of birth and the latter to exposure starting later than one month after birth but before the age of two. Hence, even the chronological division in bilingualism terms is difficult to define (see Section 3.3.3 for an overview and further discussion).

This being said, a more recent **life-span-oriented perspective on language acquisition and learning** offers a close, detailed description of

subgroups, of early as well as late language learners, including adolescent, adult, and third-age learners. For instance, Pfenninger, Festman, and Singleton (2023) suggest that general language use, frequency of use per linguistic skill, and language switching habits may vary across a lifespan depending on social settings and change along with mobility and new living conditions in speech communities and workplaces. Language attrition (i.e., the decline or loss of a language once mastered to a certain degree) can happen to languages acquired after birth within the family or from a family member who is no longer around; it can happen to languages learned at school, languages learned in the course of migration through different countries, or languages learned for work-related needs or during a temporary stay abroad. Bilinguals use their languages in different ways, their frequency of use dynamically changes, and it seems that this frequency plays a critical role in language skill development.

Some additional factors (listed in Table 1.1) as well as an understanding of their effect on bilingual language processing are equally important. Hence, more and more studies include (at least some of) these factors when describing their bilingual participants. Failure to do so leads to research findings being hardly comparable to other studies and blurring of the overall picture of the cognitive neuroscience of bilingualism.

1.2.1.2 What the Classification of Bilinguals Means for Research on Bilingualism

Given the number of important factors influencing bilingual acquisition, learning, and use (mentioned earlier, but not necessarily complete), it goes without saying that **each individual bilingual has a unique combination of different bilingual characteristics**. Bilinguals differ not only in their personal language acquisition history (i.e., the setting, amount, and quality of exposure to two languages), but also in their personal use patterns and preferences, and the dynamic changes of language use, proficiency, and so on. Surprisingly, even speech motor areas vary individually; that is, there is a "high degree of variation across subjects in the mapping of motor and sensory aspects of human language" (Andrews, 2019, p. 28). For example, before bilingual patients undergo brain surgery (e.g., related to epilepsy or tumor), the areas related to language production (motor) and comprehension (sensory) are located by a highly invasive method, cortical stimulation mapping (CSM), during object picture naming. An overview of the data from CSM, accumulated since the 1970s and extensively examined by Ojemann and Whitaker (1978), revealed variability from brain to brain in how the language centers are organized

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Table 1.1 Relevant dimensions for classifying bilinguals

Dimension	Categories and characteristics
Acquisition context – chronological details	
• Age of acquisition	• **Early (simultaneous) bilingual** = parallel acquisition of two languages in early childhood (**simultaneous bilingualism** of two first languages before the age of three, McLaughlin, 1984)
	• **BFLA** (regular exposure to two languages within the first month of birth) vs. **bilingual second language acquisition** (exposure starting later than one month after birth but before the age of two) (De Houwer, 1990)
	• **Early sequential bilingual** = acquisition of two languages with the L2 usually before the age of six (Beatens Beardsmore, 1986)
	• **Late bilingual/late language learner** = **sequential acquisition** of two languages with the L2 usually after the age of three (or six) (e.g., Lambert, 1985; McLaughlin, 1984)
Acquisition/learning context – environmental details	
• Circumstances of acquisition/ manner of acquisition	• **Informal** (natural setting) = at home, in the family
	• **Formal** (educational, institutional setting) = at school, with textbooks
• Sociocultural environment	• Migration status and experience
	• Length of residence/exposure
	• Socioeconomic status (SES)
	• Communicative habits of the speech environment (two separate cultures with one using only one language vs. one culture that uses both languages)
• Linguistic environment	• Amount of time spent with monolinguals and with bilinguals (using one language only) or using both languages (De Houwer, 1990)
	• (Continuity of) exposure to each language (e.g., Byers-Heinlein, 2015)
	• Quality and quantity of input (e.g., Unsworth, 2016)

Table 1.1 (cont.)	
Dimension	Categories and characteristics
Language use context – social psychological details	
• Language status/prestige	• Both languages valued = **additive bilingualism**; both languages and cultures bring complementary positive elements to a person's overall development
	• One language (usually the minority language) being socially devalued, social pressure to avoid its use, replacement through prestigious language of the majority = **subtractive bilingualism** (e.g., Lambert, 1975)
Language outcome/competence – language skill details	
• Language dominance	• **Balanced bilingual** = same level of proficiency in both languages: "native-like" competence in both (Haugen, 1973) or same ability in both but not "native-like"
	• **Unbalanced bilingual** = language dominance in one language (better skills in that language compared to the skills in the other language)
• Level of language fluency	• **Beginner, intermediate, advanced learner**
	• **"Native speaker," "native-like command"**
• Literacy	• Ability to read and write = **literate**
	• Lack of ability to read and write = **illiterate**
	• **Monoliterate** vs. **biliterate bilingual**
Language use/contact – language use details	
• Individual speaking habits	• Daily language use, frequency of language use per language
	• Ease with translation and interpreting and frequency of acting as translator/interpreter
• Switching habits	• Weinreich (1953) considers bilingualism "the practice of alternately using two languages" (p. 1); see Rodriguez-Fornells et al. (2012) for language switch habits
	• More recently, different language contexts have been suggested (Green & Abutalebi, 2013):
	• In **single-language contexts**, each of the languages is used separately (e.g., home vs. school),

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Table 1.1 (cont.)

Dimension	Categories and characteristics
	• In **dual-language contexts**, the languages are both used but separately with different interlocutors, and • In **dense code-switching contexts**, speakers switch freely between their languages with their multilingual interlocutors.
• Domains of language use and context of exposure	• Family, leisure, work (e.g., Grosjean, 1998); superior knowledge in certain domains of language use (and topics), e.g., work, school

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(for review, see the excellent chapter by Andrews, 2019). More recent research adds to this "dynamic nature of language mapping" by shedding light on the language organization of a single patient having undergone multiple surgeries (see Serafini, Grant, & Haglund, 2013).

We go along with De Groot (2011) who states that "the bilingual community is a colorful lot" (p. 5), and we also keep in mind that individuals categorized as monolingual speakers of a language are a colorful lot, too. De Groot's book is about both individuals who have reached the "end point" of language proficiency (i.e., following the definition focusing on level of proficiency) in both languages *and* language learners/users at different stages of proficiency and with different lengths of exposure (focusing on the acquisition and timing aspects). Her book also includes studies published on bilinguals, that is, those who speak two languages, and on studies reporting on two (among possibly more) languages that individuals have been asked to use for a certain task.

The difficulty in experimental research – which applies to studies on bilinguals based on neuroimaging techniques (as shown in Section 1.3) – is that it usually involves comparisons of conditions. More specifically, researchers contrast an experimental condition with a control condition, and these conditions should differ in only one property. The change of a dependent variable can then be attributed to this property. Problems arise when these two conditions differ in more than one property. Consequently, explanations of experimental effects can stem from a number of properties and leave much room for interpretation and speculation. Confounding factors are those that covary with the

independent variable and bring more "noise" into the original study design and argumentation.

Previously, research on bilingualism seems to have been easier: Speakers were categorized into one of the two dichotomous categories of bilingualism, for example, early bilinguals versus monolinguals, with the former being the experimental group and the latter serving as the control group. Both groups performed a certain task in the monolingual's language known to both groups. In such a **between-group design**, the performance of the participants was compared on a **dependent variable** (the variable that is measured). This study design was used to identify differences between mono- and bilinguals; bilingualism was used as the variable that influenced performance and as the genuine cause of the difference. It goes without saying that it was assumed that both groups were identical on all other variables.

More recently, it appears that we have come to grips with the impact of single factors and the "noise" caused by confounding factors. **Confounding factors** are those variables that are neither manipulated in terms of an independent variable nor measured in terms of a dependent variable. They influence the performance and results of the dependent variable in addition to the independent variable. In bilingualism research, a recent focus on individual differences and participant characteristics has elaborated on this issue (e.g., Lauro, Core, & Hoff, 2020; Pfenninger, Festman, & Singleton, 2023). Additionally, some variables have been found to confound others, in particular socio-economic status (SES), migration background, and lexicon size (for a review, see Festman, Czapka, & Winsler, 2023). However, one must be very careful to not hastily draw conclusions from this belief. Not everyone who migrates to another country is automatically poor, not everyone who is poor automatically has a small vocabulary, not all poor people automatically are educational underachievers, and so on. These conclusions would be simply inaccurate as they do not apply to all members of these groups, but rather stigmatize the individuals.

1.2.2 Language and Language Domains Relevant for Bilingualism Research

When we talk about language, we may refer to the *representation* aspects of language, that is, how different language subcomponents are structured and organized. With regard to bilingualism, this means how two languages are represented in the brain, where they are located, and how they are organized.

Table 1.2 Domains of language	
Domain	Referring to
• Phonological	• Sound structure
• Orthographic	• Spelling
• Semantic	• Meaning of words, sentence, etc.
• Morphological	• Word-forming elements of language, often grammatical aspects such as gender, number (singular/plural), inflection, and prefixes and suffixes, etc.
• Syntactic	• Phrase and sentence structure
• Pragmatic	• Language use in various contexts
• Discourse	• Series of speech events or sentences

We may also consider the processing aspects of language, that is, how language and, more specifically, its different subcomponents are activated, how they interact with each other, and, concerning bilingualism, how languages interact with each other.

For research to be conducted in the realms of bilingualism and the brain, both must be examined in greater detail: Language is broken down into different subcomponents, which are usually mapped onto specific brain regions and linked to neural functions (Banich & Compton, 2018). This means that only very specific aspects of a bilingual's languages can be tested in a single study in the domain of cognitive neuroscience.

Language knowledge is commonly divided into different subcomponents: (a) **sound** (speech perception and production, sound patterns and contrasts), (b) **words**, **morphology** (word structure, grammatical knowledge related to word formation), and **semantics** (meaning), and (c) **syntax** (phrase, sentence and discourse structure). In particular, psycholinguistic approaches to studying language rely on an even more fine-grained distinction and division into different types of linguistic information. Table 1.2 briefly explains these different domains of language.

1.3 Methodological Considerations

From early on, researchers in the fields of linguistics, psychology, and sociolinguistics have largely been involved in the study of bilingualism