THE EFFECTS OF BILINGUALISM ON CHILDREN'S PERCEPTION OF SPEECH SOUNDS

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THE EFFECTS OF BILINGUALISM ON CHILDREN'S PERCEPTION OF SPEECH SOUNDS

De Effecten van Tweetaligheid op de Perceptie van Spraakklanken bij Kinderen
(met een samenvatting in het Nederlands)

Proefschrift

ter verkrijging van de graad van doctor aan de Universiteit Utrecht op gezag van de rector magnificus, prof.dr. J.C. Stoof, ingevolge het besluit van het college voor promoties in het openbaar te verdedigen op vrijdag 24 april 2009 des middags te 2.30 uur

door

Ivana Brasileiro Reis Pereira
geboren op *4 mei 1977* te *Teresina, Brazilië*

Promotoren: Prof.dr. R.W.J. Kager
Prof.dr. W. Zonneveld

Para os meus pais, Antônio e Climene

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A long time ago a wise man confronted me with the following question: why is it that PhD students spend so much time writing their thesis and so little time writing their acknowledgements if the latter is so much more often read than the former? I do not even remember who the wise man in this story was, but I do know he was wise because of the truth in what he said. One of these upside-down truths that make you look at something differently. The fact is that I have been worrying about what I would write in my acknowledgements even before I started writing my thesis. Numerous times I promised myself to write something clever and witty, but most of all, I promised myself I would spend on my acknowledgements the time and effort it deserves. For, after all, my thesis would not exist if it were not for the much collaboration I have received. Unfortunately I have not kept my promise. Like the good procrastinator I am, I find myself facing a fast-moving deadline. This has however no effect on the gratitude I feel towards all those who have helped me on my way, towards the ones who have shared with me their knowledge, their time, their friendship, or their patience.

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INTRODUCTION

The general topic addressed by this dissertation is that of bilingualism, and more specifically, the topic of bilingual acquisition of speech sounds. The central question in this study is the following: *does bilingualism affect children's perceptual development of speech sounds?*

There is a rich and vast literature on bilingualism, a field which has enjoyed a prominent place in linguistics during the past few decades. However, the study of bilingual perceptual development has remained inconclusive in many aspects. Part of the explanation for this inconclusiveness is the great heterogeneity in what might be called the bilingual population. This heterogeneity makes it very challenging for researchers to compare results from different studies, or even within the same study, to compare, for instance, different age groups of bilingual children.

This dissertation is an attempt at clarifying some of the issues related to the bilingual perceptual development of sound contrast by comparing a large number of bilingual children and their monolingual peers. Moreover, this dissertation reduces noise in the data by limiting the term *bilingual*. Unless indicated otherwise, the term *bilingual* will be used throughout as synonymous with *simultaneously bilingual*, i.e. those speakers of (typically) two languages who have been exposed to both languages from birth. Regarding acquisition, this type of speaker is commonly referred to as a bilingual first language acquisition (BFLA) child.

This study takes an experimental approach. Bilingual children, monolingual children and monolingual adults participated on a semi-longitudinal study in which their perception was tested. The bilinguals were speakers of Dutch and Brazilian Portuguese (BP) and the monolinguals were speakers of either language. All groups were tested on their perception of the Dutch /ɑ/ - /aː/ vowel contrast. The vowels of this contrast differ in terms of spectral cues (F1 and F2) and durational cues. Participants' responses were analysed in terms of *cue reliance*, i.e. how much they rely on spectral and durational cues in their perception of the contrast. Cue reliance provides information on the phonetic details of their *perceptual categories*. A perceptual category is defined as a set of acoustic properties which listeners use to identify a contrastive sound in their language. This dissertation, however, will make no claims about the phonological status or representation of this acoustic information.

Anticipating here the major results, this dissertation will show that, although at a certain point in their development bilingual and monolingual children have identical perceptual behaviour, they differ in their developmental paths. This finding is in line with the main literature on bilingual perceptual development. However, the findings in this dissertation are unusual in *how* this difference takes places. Although patterns of bilingual *delay* and *acceleration* have both been previously attested, the bilingual learners in the current study show signs of being *simultaneously* delayed and accelerated in their perception. Specifically, bilingual children show signs of delay in their acquisition of spectral cues and signs of acceleration in their acquisition of durational cues. This dissertation will claim that the difference found between bilingual and monolingual children is the consequence of two factors: (i) the nature of the language input to the learner, which differs for bilingual and monolingual children, and (ii) the interaction between the bilinguals' linguistic systems.

The current study adds to our knowledge of speech perception by focusing on a type of learner underrepresented in the literature, that of BFLA children. Although studies on infants abound, little is known about the perceptual development in pre-school aged children. Additional strengths of this study lie in the variety of target and control groups involved and their comprehensiveness, including two groups of bilingual children who differ from each other in terms of language dominance, two groups of monolingual children, and two groups of monolingual adults.

The remainder of this introduction presents a brief overview of this dissertation.

Dissertation outline

This dissertation has 7 chapters. Chapter 1 presents an overview of previous research in two areas which are of central importance to the current study, that of bilingualism and that of sound acquisition. Regarding topics on bilingualism, Chapter 1 initially provides discussion on very broad issues, such as different definitions of what might be called a bilingual, the history of bilingual research, and the relevance of studies on bilingualism. Subsequently, Chapter 1 narrows down to topics on bilingualism which are more relevant to this dissertation, namely that of bilingual acquisition and that of bilingual language representation. The second part of Chapter 1 provides a brief introduction to the field of speech perception, introducing definitions and terminology which will be used throughout this dissertation. This introduction allows the reader to understand the main challenges language learners are faced with when acquiring the sounds of their language(s). Finally the chapter discusses issues on perceptual acquisition by both monolingual and bilingual children. The final part of the chapter is dedicated to the specific research questions addressed by this dissertation, presenting them in the context of the literature discussed.

Chapter 2 presents background information on the vowel systems under investigation and on methodological issues, which allows the reader to understand the experimental set-up used in this dissertation. The first part of the chapter briefly describes the phonological and phonetic properties of the vowel systems of the languages involved, namely Dutch and BP, with a special focus on the low vowels (/ɑ/ and /aː/ in Dutch and /a/ in BP). The second part of the chapter discusses general topics on methodologies used in speech perception research, including issues on types of stimulus and experimental tasks.

Chapter 3 describes the details of the experimental set-up used in the current study. It provides an overview of each participant group, including information about their social and linguistic background. It also describes the two experimental tasks used: the perceptual task and the vocabulary test.

Chapter 4, 5 and 6 are the three content chapters, which report the results of the experimental studies. Chapter 4 investigates the details of monolinguals' and bilinguals' perceptual categories from a synchronic perspective. Foremost, background information is provided on the perceptual acquisition of the /ɑ/ - /aː/ Dutch contrast by monolingual Dutch children. The questions addressed by this chapter concern participants' discrimination abilities as well as participants' use of acoustic cues in their perception. To answer these questions, the perceptual behaviour of the different groups is compared in a cross-sectional way, broadly speaking: bilingual versus monolingual children and adults versus children. An analysis of the results reveals that children have not yet acquired adult-like perception of the contrast. Importantly, the results discussed here present no evidence for a bilingualism effect on children's perception of the contrast, as bilingual and monolingual children showed identical perceptual behaviour.

Chapter 5 presents the result of the longitudinal study in order to access perceptual *development*. The first part of the chapter presents an overview of the literature on bilingual perceptual development, specifically patterns of bilingual delay and acceleration. The questions this chapter aims at answering regard the acquisition of acoustic cues (namely, spectral and durational cues) by bilingual and monolingual children in their perception of the Dutch /ɑ/ - /aː/ contrast. The results discussed here show that bilingual children were delayed in their use of spectral cues and accelerated in their use of durational cues. This pattern of simultaneous delay and acceleration in the perception of the same contrast is previously unattested in the literature.

Chapter 6 addresses the issue of bilingual speech perception and Language Mode (Grosjean 2000), a variable often claimed to affect bilinguals' perceptual behaviour. Specifically, bilinguals' languages are claimed to interact to a greater degree when bilinguals have both their languages activated and are in a so-called bilingual language mode (as opposed to a monolingual language mode). The first part of the chapter provides an overview of the literature on bilinguals' language representation, with a specific focus on phonetics and phonology. Subsequently the chapter introduces the term *Language Mode*, providing its definitions and explaining how it might affect bilinguals' perception. In the current study, Language Mode has been manipulated in three steps, ranging from a monolingual mode, to a bilingual mode. Our results, however, do not show any evidence to support the Language Mode Hypothesis.

The last chapter of this dissertation, Chapter 7, summarizes the main findings, referring back to the research questions presented in Chapter 1. Moreover this chapter integrates the results presented in Chapters 4, 5, and 6, providing a general discussion on the issue of bilingual speech perception, the main topic addressed by this dissertation. The differences found between bilingual and monolingual development are argued to be mainly the consequence of the nature of the input these children receive. The specific claim is that bilinguals' and monolinguals' inputs differ in terms of quantity as well as quality, which lead to different acquisition paths. Furthermore, the discussion will argue that the interaction between the bilinguals' two languages possibly plays an additional role in leading bilingual and monolingual children into different developmental paths, but that this is a smaller role than that of input differences. Finally, Chapter 7 discusses the remaining findings of this dissertation and relates them to neighbouring areas, namely, monolingual perceptual development, cue weighting development, and methodologies of bilingual research.

1 GENERAL ISSUES IN BILINGUALISM AND SOUND ACQUISITION

To fully understand the context in which the current study takes place, one needs background knowledge of two types of specialized literature, that of bilingualism and that of speech perception. Moreover, one needs in-depth knowledge on the main topic of this dissertation, i.e. that of bilingual speech perception, its state of the art, challenges, controversies and main findings. Chapter 1 of this dissertation aims at providing the reader with the necessary information on these issues.

Section 1.1 discusses the main topics in bilingualism. The first issue I address is the definition of a bilingual speaker / listener (Section 1.1.1). The long history of research on bilingualism is summarized in Section 1.1.2, which will underpin a better understanding of why bilingualism has so often been seen as negatively affecting language development. After this historical sketch, Section 1.1.3 addresses the relevance of research on bilinguals for linguistics. Section 1.1.4 turns to the main topic of this dissertation, i.e. bilingual sound acquisition. Bilingual acquisition is discussed firstly in general terms, concerning the ways in which bilinguals are usually raised, a discussion which will lead to more specific topics such as patterns of delay and acceleration found in bilingual development. Section 1.1.5 addresses the topic of bilingual language representation, specifically the question whether bilinguals' language systems are (partially or wholly) shared or separate.

Section 1.2 is dedicated to general topics on sound acquisition. Section 1.2.1 presents an overview of the literature on speech perception, describing its main findings and challenges. Section 1.2.2 deals with L1 perceptual development, presenting the problems faced by children when learning to perceive the sounds of their language and how they overcome these problems. Section 1.2.3 narrows down the topic to discuss the specific case of development in the perception of infants and children exposed to two or more languages. I will argue that bilingual children face challenges in each of their languages similarly to those of monolingual children, in addition to challenges specific to their bilingual situation. The more specialized issues of *cue weighting*, the use of different acoustic cues in speech perception, and its development are introduced and discussed in Section 1.2.4. As there are no studies investigating the perceptual cue weighting in bilingual children I will discuss the topic in L1 and L2 acquisition and will speculate about what the bilingual situation might be.

The chapter closes with Section 1.3, which introduces the specific research questions addressed in this dissertation, relating them to the literature reviewed in Sections 1.1 and 1.2.

1.1 General issues in bilingualism

Bilingualism has long been the object of interest in and outside the field of linguistics. This section is a selection of its vast literature and discusses general issues on the topic. The information presented here will allow the reader to understand bilingualism research in its social and historical context. However, before discussing these topics, I will start in 1.1.1 by asking the question that seems to be the most basic of all: what exactly is a bilingual? As we shall see, approaches to this question have led to some controversy, and it will be this first section's goal to disentangle some of the issues, proposals, and approaches to arrive at a definition suitable to my own research.

1.1.1 How bilingual does a bilingual have to be to be considered a bilingual?

Genesee (2001) points out that bilingual children present unique features, which make them ideal subjects for addressing linguistic issues. They are however not always ideal subjects for linguistic research due to their great heterogeneity. In addition to all the typical individual variation found in monolingual children, bilingual children can greatly vary in their history in each of their languages: bilingual children can differ not only in the age of first exposure to each of their languages but also in the frequency and amount of exposure to each language; moreover, due to external factors (e.g., entering kindergarten, or emigration), frequency and amount of exposure to each language can oscillate during acquisition. This heterogeneity makes a comparison between different bilingual children, or, for the same child, a comparison between the acquisition paths in each language, at least problematic.

Considering the remarkable differences that can occur in bilingual acquisition one might question what a bilingual is or, as the title of this section puts it, *how bilingual does a bilingual have to be to be considered a bilingual?*

Generally speaking, a bilingual (or, in more general terms, a multilingual) is someone in the possession of two (or more) languages. Wei (2007) lists 4 concepts which should be considered in the definition of a bilingual: (1) age and manner of acquisition; (2) proficiency level in specific languages; (3) domains of language use; and (4) self-identification and attitude. Genesee (2001) argues that a definition of bilingualism should include age of first exposure, regularity and extent of exposure to each language.

There is a certain amount of agreement in the literature that it is not necessary for the bilingual to be equally proficient in all of his or her languages to be considered a bilingual. It is actually very rare for a child to acquire native-like proficiency in more than one language (see e.g. Pearson *et al.* 1993). In most cases, bilinguals have greater proficiency in one language, which is referred to as their *dominant* (or stronger) language, the other language being referred to as their *non-dominant* (or weaker) language.

If native-like acquisition of both languages is not a necessary factor for considering someone a bilingual, how proficient does a bilingual have to be to be considered one? Some researchers (e.g. Paradis 2001) consider the spontaneous production of (full) sentences in both languages to be a prerequisite for considering a simultaneous bilingual a 'true' bilingual. Although this may be a relevant factor when one is working with bilinguals' production, it is not crucial for this study, which deals with bilinguals' *perception*. Moreover, it is not unusual for bilinguals to resist speaking one of their languages (Baker 2000, pp. 64), and this is especially so for bilingual *children*, the target group in this study. This behaviour is more often the result of their sociolinguistic awareness than of their knowledge of the languages.

Throughout this dissertation I regard as bilinguals those who have been consistently exposed to both languages from birth. The definition of what *consistent exposure* means is a relative and abstract one. In this dissertation I consider it to mean exposure that takes place regularly, daily or at least weekly, in an interactive form, regardless of the relative amount of exposure in each language. This means that even if a speaker has only passive knowledge of one of his or her languages, he or she may still be considered a bilingual for the purposes of this study.

1.1.2 A brief history of bilingualism research

In the early days, dating back to the beginning of the twentieth century, there were two prominent branches of the study of bilingualism: child biographies and psychometric tests (Hamers & Blanc 2000). The child biographies, even when systematically put together, were written by laymen or linguists not specialized in language acquisition. They consisted mainly of observations of bilingual children's development, often the authors' own children, who were being raised with two languages (Meisel 2002). Among these biographies the most widely cited and well-known are those by Ronjat (1913) and Leopold (1939-1949). Ronjat's work is very important for being the first of its kind, opening the field for a series of similar studies that would follow. However, the most famous work in the early history of bilingual acquisition is that by Leopold. Leopold systematically followed the development of his two bilingual daughters, which resulted in the famous four volumes published between 1939 and 1949.

Hamers & Blanc (2000) point out that, whereas the biographies suggested a well-balanced development of the bilinguals' languages, psychometric tests of the same period claimed that bilingualism had negative effects on children's cognitive development. Pintner & Keller (1922) refer to 'linguistic handicap' in bilingual children, and Saer (1923) to 'mental confusion', claiming that bilingual children had lower IQ values than their monolingual peers. These studies reflect the dominant ideology of that period and despite their serious methodological and interpretational flaws, they have had a considerable impact on the way bilingualism has been perceived by society.

Early models of bilingualism focused on trying to describe and explain the delayed development which bilingual children supposedly went through. One prominent model of this period was that of Macnamara (1966). Macnamara explained the alleged developmental delay in bilinguals as the result of a so-called 'balance effect'. In this model proficiency is understood as existing in a limited space: increasing proficiency in one language implies decreasing proficiency in the other, so that the overall proficiency in both languages never exceeds that of monolinguals. One of the predictions of this model is that it is impossible for bilinguals to achieve a high level of proficiency in both languages. The literature, however, has extensively attested cases in which bilinguals achieve high proficiency in their languages, proving wrong this notion of a 'balance effect'.

Another widespread misconception about bilingualism was that it was possible for bilinguals never to acquire full competence in any of their languages. Such bilinguals were called 'semilinguals'. Semilingualism was a very popular idea among scholars, including prominent linguists such as Bloomfield (e.g. 1927). It is important to add, however, that the term 'semilingualism' appeared in the context of ethnic minority studies. Evidence supporting this idea came from studies in North America and Scandinavia in which minority children were put into schools in the majority language and taught through this medium (Wei 2007).

This pessimistic view of bilingualism has been questioned and criticized since the 1960s, however. Hamers & Blanc (2000) consider Peal & Lambert's (1962) investigation of bilingual children's development to be a milestone in changing the negative way bilingualism was seen. Peal & Lambert were very careful in their methodological design, paying great attention to matching their research groups not only for age, sex and socio-economic level, but also for language proficiency. They compared ten-year-old English-French bilinguals with their monolingual peers in each language in various measures of intelligence. Bilinguals scored significantly higher than monolinguals in a number of these tests, in verbal as well as non-verbal intelligence. Since Peal & Lambert's publication a number of studies have confirmed their findings, claiming cognitive advantages for bilinguals. To mention just a few of these (adapted from Blanc & Hammers 2000):

1. Ability in reconstructing perceptual situation (Balkan 1970);
2. Verbal and non-verbal intelligence tests (Cummins & Gulutsan 1974);
3. Sensitivity to semantic relation between words (Ianco-Worrall 1972, Cummins 1978);
4. Divergent thinking (Scott 1973, Da Silveira 1989);
5. Solving non-verbal perceptual tasks and group tests (Ben-Zeev 1972, 1977a);
6. Verbal-transformation and symbol-substitution (Ekstrand 1981);
7. Correction of ungrammatical sentences (Diaz 1985);
8. Analogical reasoning tasks (Diaz & Klinger 1991).

In the last two decades of the twentieth century, a large number of researches on bilingualism focused on the relationship between cognitive development and *metalinguistic awareness* (e.g. Bialystok 1990, 1992, Perregaux 1994 and Rubin & Turner 1989). The results of many such studies suggest that bilinguals' exposure to two languages leads them to develop metalinguistic awareness earlier and to a higher level than monolinguals and that this skill may generalise to other cognitive processes (Mohanty & Perregaux 1997, but see e.g. Bialystok *et al.* 2003 discussing the limits of the advantages of bilingualism on the development of metalinguistic awareness).

In addition to these cognitive consequences of bilingualism, scholars have also stressed the communicative advantage of bilinguals. For instance, Wei (2007) points out that being bilingual is increasingly seen as an economic advantage given the multiculturalism of the modern world: bilinguals are able to communicate with their parents and grandparents in their native language, with members of the community they live in and even across communities; they enjoy full access to two different cultures and all the knowledge that comes with it.

From the brief historical overview presented here we can see that bilingualism research has had both an interesting and turbulent history. Research seems to have moved from one side of the spectrum straight to the opposite, skipping the middle ground: whereas the early 20th century studies strongly focused on the disadvantages of bilingualism, later work aimed to show how superior bilinguals are to monolinguals. Current research seems to be more moderate. The dominant idea is not that bilinguals are better or worse off than monolinguals, but simply different. They are similar in that they go through the same paths in each language as their monolingual counterparts, but different because they have issues specific to their bilingual situation.

1.1.3 Why study bilinguals?

The study of bilingualism has had a relatively long history but despite these early beginnings, linguistic research in the field has remained sparse until recently. It was only during the last 20 to 30 years that the field has faced both quantitative increase and qualitative improvement (Genesee 2001). This growing interest seems utterly justifiable considering the frequency with which exposure to dual (or more) languages occurs. Tucker (1998) speculates that probably more than half of the children of the world grow up bilingual, which makes bilingual acquisition the rule instead of the exception. The number of bilinguals in the world is likely to increase even more considering the modern boost in mobility and multiculturalism.

Moreover, research in bilingual acquisition provides an important field for general theories of language acquisition. Most theories of language acquisition are based on monolingual data, and although they do not exclude the possibility of bilingualism, they are not explicit about it. If a theory of acquisition is to be complete, however, it should be able to deal with facts concerning bilingualism as well. Moreover, bilingual children form a unique population for the purpose of testing questions raised by acquisition theories and theories of the human mind. The study of bilingual acquisition allows us to understand the limits of the mind's capacity to represent and use two or more linguistic systems, sometimes involving drastically different structural properties (Genesee 2001).

1.1.4 Acquiring two languages

Considering all that we know and, most importantly, what we do *not* know about bilingualism, the decision to raise a child bilingually is a very relevant one for parents and caretakers. In the overwhelmingly monolingual western societies many parents and caretakers are faced with questions concerning a wide array of potential consequences bilingualism will have on their children's development. Even when they decide to raise their children bilingually they are still left with questions concerning the *hows*, the *whats* and the *whens*. Researchers have questions of their own, often very basic ones, such as what exactly a bilingual is (see Section 1.1.1 of this dissertation for a discussion on this topic).

It is not the aim of this dissertation to provide full answers to these questions. I will, however, briefly deal with some of these issues in this section in so far as they directly concern the current study.

Raising a child bilingually

There are many different ways to raise children bilingually. The most frequently applied method is the *one parent – one language* method. In this situation each parent speaks exclusively his or her own native language with the child, ensuring sufficient input in both languages. This is often the situation in mixed marriages. In some other situations bilingualism requires an active choice by the parents, such as when hiring a caregiver from another linguistic background, or when the child is sent to a day-care centre, and later to a school providing a language environment different from that of the community (Genesee 2001). Sometimes, however, bilingualism happens more naturally when, for example, the community as a whole is bilingual and the child is exposed to both languages on a daily basis.

Most commonly, in monolingual communities, raising a child bilingually is a conscious choice of the parents. Once this choice is made, it requires some effort and consistency, as bilingual development does not always proceed effortlessly. For one thing, parents have to ensure that children receive enough and varied input in both languages. This is not to say that bilingualism in itself poses a problem for language acquisition, as will become clear from the discussion and results presented in this dissertation.

In the current study most of the participants come from so-called "linguistically mixed marriages". Typically, the mother is a speaker of the minority language and spends more time with the child than the father, a speaker of the majority language. Children in this situation are often very proficient in both languages during their first few years of life or may be even more proficient in the minority language. They show an abrupt dominance shift towards the majority language, however, at around 4 years of age, when they enter school.

Patterns of bilingual development

From a social point of view, raising children bilingually in a monolingual community often requires extra effort from the caretakers. For the bilingual it might be extra challenging to manage school in both of their languages. Not less importantly, there might also be linguistic consequences of bilingualism, as bilinguals' languages interact with each other. Paradis & Genesee (1996) explains that there are three kind of possible interaction between the bilinguals' languages: *transfer*, *acceleration*, and *delay*. *Transfer* refers to the incorporation of features from one language into the other. One speaks of bilingual *acceleration* when bilinguals acquire a property in one of their languages earlier than monolinguals typically do. *Delay* constitutes an inverse pattern, when bilinguals show signs of a late acquisition compared to their monolingual peers.

One field where bilingual delay has been widely claimed to occur is that of vocabulary (or lexical) acquisition (e.g. Ben-Zeev 1977b, Rosenblum & Pinker 1983), sometimes in both languages (e.g. Umbel, Pearson, Fernández, & Oller 1992). Pearson, Fernándes & Oller (1993), however, point out that determining what constitutes lexical delay in bilingual children is not a straightforward matter. Measuring performance in only one of the bilinguals' languages is likely to underrate the bilingual as it ignores the knowledge in the untested language; summing up performance in both the bilinguals' languages is likely to overrate the bilingual as some knowledge is shared between the two languages. To face this problem Pearson *et al*. (1993) used an innovative vocabulary measure to study lexical development in Spanish-English bilingual children. In this measure vocabularies in both of the bilinguals' languages were combined, accounting for the number of items which had been lexicalized in one or the other language, or in both. The bilingual children were followed between 8 and 30 months of age. Pearson *et al.* found no signs of bilingual developmental delay, as the bilingual children performed within the monolingual range.

Paradis & Genesee's claim about transfer, delay and acceleration was made with reference to syntax. In this field, robust evidence has been presented for each of these patterns (see e.g. Döpke 2000 and Yip & Matthews 2000 for delay and Kupisch 2003 and Hulk 2004 for acceleration). Kehoe, Trujillo & Lleó (2001), Kehoe (2002), and Paradis (2000), however, have observed the same patterns in phonology. I will return to this issue in Chapter 5 of this dissertation, with specific reference to cases of bilingual perceptual acquisition of speech sounds.

1.1.5 Bilingual language representation

An important question concerning bilingual acquisition is whether bilinguals have a common storage for their languages or whether they have two separate, independent systems. Research on the simultaneous acquisition of two first languages has traditionally focused on syntax. Recently, however, the topic of bilingual representation has received increased interest in phonology. The majority of these studies focus on production rather than in perception. For this reason most of the studies mentioned in this section address that field.

There has been a good amount of work addressing the representation of bilinguals' language systems in relation to that of monolinguals. At one extreme, there is the view that the bilingual's second language is stored separately from his first language (Lambert 1969, in Thomas 1997). At the opposite extreme, there is the view that the two languages are stored in one and the same system (Schwanenflugel & Rey 1986, Fox 1996). Intermediate views propose that children who acquire two languages simultaneously go through an early fusion stage in which the languages are in fact one system. As these children grow older, they slowly differentiate their languages, first separating their lexicons and then their grammars (e.g. Leopold 1939-1949; Volterra & Taeschner 1978). This position has been labelled the Unitary Language System (ULS) hypothesis (Genesee 1989). Evidence for the ULS hypothesis comes, for instance, from the observation of language mixing in very young bilinguals and from the fact that there is a gradual reduction of mixing over age (Grosjean 2000).

More recently this view has been challenged as an increasing amount of research shows that children at a very young age already differentiate their languages. In syntax it has been shown that bilinguals acquire language-specific structures of their languages very early in development, corresponding to the patterns exhibited by monolingual children (see Genesee 2001, de Houwer 1990, 2005 and Meisel 2001 for reviews). Paradis & Genesee (1996), for instance, show evidence for differentiation of the bilinguals' two languages from very early on, possibly already at the two-word stage.

Research on phonological differentiation of the bilinguals' languages, however, provides mixed results. Some studies found that at around two years of age a bilingual's phonological representations are completely undifferentiated (e.g. Vogel 1975); some found that they are partially differentiated (e.g. Deuchar & Clark 1996); while others argue that bilingual children differentiate their phonological system at or before two years of age (e.g. Johnson & Lancaster 1998; Paradis 1996). The more recent studies, however, especially the ones looking into the phonetic details of bilinguals' categories, suggest differentiation. The bilingual children in Johnson & Wilson's (2002) study, for instance, were seemingly using the same system in the production of their two languages, but detailed acoustic analysis showed they had two distinct systems, which differed from that of monolingual children.

Language differentiation, however, does not entail independent development. In other words, stating that bilinguals have separate independent systems does not imply that these languages do not interact. As a matter of fact there seems to be a strong trend in the current literature assuming language differentiation in bilinguals but focusing on questions around the relationship between them (see for instance Paradis 2001, Lleó & Kehoe 2002 and the other papers in that volume. See also Chapter 6 in this dissertation).

When discussing the interaction between bilinguals' languages, specialists often address the issue of the so-called bilinguals' Language Modes (Grosjean 2000). Language Mode refers to the relative activation of bilinguals' languages and predicts that the bilinguals' languages are most likely to interact when they are both strongly activated. I will address the topic of the bilinguals' language representation in more detail in Chapter 6 when discussing the bilingual's Language Modes and the effects they may have on bilinguals' performance.

In the next section I will present a brief overview of the current literature dealing with the acquisition of speech sounds, the second major field that this study draws from, in addition to bilingualism. I will discuss topics such as the problems faced by monolingual and bilingual children in their acquisition of the sounds of their language(s), and how these are overcome.

1.2 General issues in sound acquisition

Jusczyk (1997) notes that acquiring the phonological system of a language involves varied abilities and degrees of analysis. The acquisition of phonemes or phonological categories, for instance, presupposes the ability to segment the speech signal into smaller units like words, syllables and sounds, and to subsequently categorize these sounds.

To acquire the sounds of their native language infants have to learn to discriminate between different sounds and learn that some sounds, despite their acoustic differences, belong to the same category and should be treated as such. This means that infants have to learn to ignore non-meaningful differences between speech sounds, which could be due to linguistic factors, such as the position of the sound in a word (e.g. the English /l/ in syllable-initial or syllable-final position) or to non-linguistic factors such as speech rate, speaker, etc. Conversely acoustically similar sounds will sometimes have to be classified as belonging to different categories, as for instance the English vowels in 'bad' and 'bed'.

In the next section (1.2.1), I will briefly present some background literature on the topic of speech perception in general. The results reported in this literature are of crucial importance for understanding the challenges children and adults face when perceiving the sounds of their native language or that of a foreign language.

1.2.1 A brief introduction to speech perception

During the past few decades speech perception research has focused on the mapping between acoustic properties of the speech signal and linguistic units such as phonemes and features (Diehl et al 2004). This mapping has turned out to be very complex as there is no one-to-one relationship between the acoustic signal and linguistic units, regardless of how small we take these units to be. The question of how humans perceive smaller units of the speech stream, such as consonants and vowels, has not yet been fully answered.

A large amount of research has been devoted to finding constancy in the speech signal. In phonetic research the term *acoustic correlate* is often used to indicate an acoustic property which co-varies with a phonemic distinction. An acoustic correlate which influences the perception of a phonemic distinction is often referred to as an *acoustic cue* to that distinction (van Alphen & Smits 2004).

Despite the fact that *some* consistency is found in acoustic correlates and acoustic cues, one of the main issues speech perception researchers have to deal with is the *variability* of speech sounds. Even when looking at low-level speech units such as phonetic segments, these units turn out to be very multifaceted. Phonemes are not specified by one unique set of acoustic properties. Dellattre *et al.* (1955), for example, found that the acoustic realizations of [d] varied greatly when combined with different following vowels ([da] versus [di], for example). This difference is a result of *coarticulation*, a phenomenon in which information about multiple sounds is encoded in the same portion of the acoustic signal (Jusczyk 1992). This implies, for instance, that the [d] in [da] contains some acoustic properties of the [a] and, similarly, the [d] in [di] contains acoustic properties of the [i]. It is worth noting, however, that despite the potential problems coarticulation causes for acquisition it also provides the listener with important information about, for instance, speaking rate or about the lexical characteristics of a spoken word (Wright 2004).

Even the same segment or segment combination varies greatly when spoken by different speakers. Peterson & Barney (1952) found that vowels produced by a particular speaker sometimes overlap with the production of a different vowel produced by another speaker.

Variability is found even when we dissect speech units a bit further into distinctive features. On the one hand, various acoustic properties can be used to cue a single contrast. Slis & Cohen (1969), for instance, point out that the feature 'voice' has 6 acoustic correlates: duration of pre-voicing, duration of the burst, power of the burst, spectral centre of gravity of the burst, F0 immediately after the burst offset, and F0 movement into the vowel. On the other hand, the same acoustic property can be used to cue different contrasts. This point becomes clear when we take a look at the voicing contrast in stop consonants in English. In syllable initial position Voice Onset Time (VOT) is the most important among all properties cueing voicing (Lisker & Abramson 1964). The interpretation of this cue in English, however, depends on its linguistic context. In word initial position the voicing contrast of English stops is made acoustically in terms of aspiration: unaspirated stops (short VOT) are perceived as voiced and aspirated stops (long VOT) are perceived as voiceless. In most other linguistic contexts there is no aspiration and voiced stops can be produced with a short VOT. In this case other cues, like the length of the previous vowel, play a crucial role in perceptually marking the contrast. Jusczyk (1992) refers to these cases where a single acoustic property can be associated with different contrasts as *cue ambiguity*.

Despite the challenges they pose for acquisition, multiple associations between acoustic signal and linguistic units provide the listener with valuable information. Repp (1984) claims that sound contrasts are more easily perceived when multiple acoustic cues are involved because of an increase in redundancy. This means that even if one specific acoustic cue cannot be readily perceived as a consequence of, for instance, background noise, listeners can still rely on other cues to accurately perceive the contrast.

The relative contribution of each acoustic cue can vary between different languages or, within the same language, between the contrasts. Specifically this implies that not all cues are equally important for a contrast, as we have seen in the previous paragraph, when discussing the voicing contrast in English. The term *cue weighting* refers to how heavily each acoustic cue counts for one specific contrast. Van Alphen & Smits (2004), for example, found that of all 6 cues involved in marking the voice contrast in Dutch, pre-voicing was clearly the most important one. I will return to this issue later in this chapter, when dealing with the acquisition of cue weighting (Section 1.2.4).

1.2.2 Monolingual perceptual development

Given the variability of speech signal discussed in Section 1.2.1, the question arises as to how children are able to successfully acquire the speech sounds of their native language. Jusczyk (1992) mentions specifically two important problems:

1. Segmentation problem: how do children learn to place word, syllable, and segment boundaries, how do they deal with coarticulation and cue ambiguity?
2. Mapping problem: how do children learn to relate the phonetic categories to phonological categories?

In this section I give an overview of the literature on how infants work around these problems to successfully acquire their native language's speech sounds.

Many perception studies have shown that very young infants are better at perceiving phonetic distinctions than adults. Cross-linguistic studies and studies in second language acquisition have been of fundamental importance to the field of first language acquisition. For instance these studies show that it is easier for adults to discriminate between speech sounds that are contrastive in their native language, i.e. sounds that distinguish word meaning, than sounds that are not (Liberman *et al.* 1957). Perhaps the best-known example of this is that of Japanese native speakers in their perception of the English /l-r/ contrast. English has two liquids (/l/ and /r/) whereas Japanese only has one, which is acoustically between the two English liquids, but closer to the English /l/. Native speakers of Japanese who learn English as a second language have been shown to have great difficulty with the production as well as with the perception of this English contrast (e.g. Goto 1971, Miyawaki *et al.* 1975, Best & Strange 1992). This is in sharp contrast to infants' discrimination abilities. During the first six months of life, infants have the capacity to discriminate virtually all phonetic categories, even the ones outside their native language. This has been shown to hold for consonants (e.g. Streeter 1976, Aislin *et al.* 1981, Trehub 1976) as well as for vowels (Trehub 1976). Adults on the other hand have their perception to a certain degree limited by their native language.

From a very early age, around six months onwards, infants start paying greater attention to the structure of their native language. As language experience increases, infants gradually modify their initial sensitivities to perceiving contrasts outside their native language. This process seems to take place first at the prosodic level (e.g. Juscyzk *et al*. 1993a) and then at the phonetic level (e.g. Werker & Tees 1984); at the phonetic level this happens earlier in vowels than in consonants (Bosch & Sebastián-Gallés 2003).

This decline in sensitivity indicates that infants at a very early age tune in to their native language and start to focus only on the dimensions that are relevant for this specific language. This has been repeatedly demonstrated in many studies, in particular by Werker and colleagues. Werker *et al.* (1981), for instance, have tested English infants and adults on a Hindi speech contrast. Their results show that English-speaking adults were not able to perceive the contrast that does not exist in English. English infants as young as 6-8-months-old, however, were able to discriminate this non-native contrast as well as Hindi native adults. At 12 months of age, English infants had lost this sensitivity and started to show signs of having formed categories based on their native language (Werker & Tees 1984).

As pointed out by Kuhl (2000), the view of speech perception as described above is *selectionist* in nature. The idea is that children are born with the ability to discriminate all possible phonetic units. The role of language experience would be to produce either preservation or atrophy of contrasts or features. Everything stimulated by the input language would be maintained; everything else would be lost.

It has been previously suggested that infants' loss of sensitivity to perceiving contrasts that fall outside their native language is related to word learning (e.g. Best 1995, Jusczyk 1985, Werker & Pegg 1992). When infants are confronted with a minimal pair, i.e. words with distinct meanings that differ by one single sound, such as *big* vs. *pig*, they may realize that *b* vs. *p* is a relevant contrast in their language and will pay greater attention to that. This explanation seems very plausible given its intuitiveness. Minimal pairs are after all par excellence the classroom example of the difference between phonemes and allophones.

There are, however, a number of problems with using word learning to account for the acquisition of sound categories. The first problem is that not all contrastive sounds can actually be used in a minimal pair, as gaps are not uncommon in the languages of the world. Most importantly, the change in perception has been shown to precede infant's abilities to perceive minimal pairs distinction (Maye *et al.* 2002). As extensively shown by Werker's studies, some of which were discussed above, infants are able to distinguish native sound contrasts in nonsense syllables ([ba] vs. [pa]) at around the age of 12 months. Conversely infants have only been shown to discriminate minimal pairs (*big* vs. *pig*) at around the age of 17 months (Stager & Werker 1997, Swingley & Aslin 2000, Werker, Fennell, Corcoran & Stager 2002).

A second account put forward to explain infants' organization of the perceptual space relies on their sensitivity to the distributional properties of their native language (Kuhl 2000). Recent studies have shown that infants are able to acquire very sophisticated information about their language's properties only by listening to speech. Infants have been shown to have excellent skills in recognizing patterns in speech. Immediately after birth, infants show a preference for the language spoken by their mothers during pregnancy as opposed to other languages

(Mehler *et al*. 1988) or to their mother's voice as opposed to other females' voices (De Casper & Fifer 1980). This preference implies some knowledge of stress and intonation patterns, information which can be transmitted to the womb. Within a few months after birth, infants refine this ability. They are able to perceptually sort vowels that vary across speakers and intonation contours (Kuhl 1979, 1983), syllables that differ in their initial consonant even when they vary between speakers and vowel contexts (Hillenbrand 1983), and syllables based on a phonetic feature shared by their initial consonants (Hillenbrand 1983). Between 6 and 9 months, infants start to exploit prosodic patterns and identify higher-level units such as stress and phonotactics. American infants, for instance, show a preference for listening to words with the dominant English trochaic (strong/weak) pattern as opposed to the iambic (weak/strong) pattern. This preference is not found in 6-month-old infants (Jusczyk *et al*. 1993a). Similarly, 9- but not 6-month-old infants prefer to listen to words that follow the phonotactics of their ambient language. At this age they do not yet recognize words, but they do recognize the pattern (Jusczyk *et al*. 1993b).

Infants are not only able to extract and recognize patterns in their native language, but they are also able to exploit this information and use it in language acquisition. Infants as young as 6 months of age have been shown to have their vowel perception affected by the phonetic distribution of their native language (Kuhl *et al.* 1992). Kuhl *et al.* tested the perception of American and Swedish infants on two vowels: the American /i/ and the Swedish /y/. Sixty-four 6-month-old infants were tested using the head turn paradigm to access their abilities to discriminate between one of the prototype vowels (either the American /i/ or the Swedish /y/) and a number of manipulated variants. These variants differed in the acoustic properties from the prototypical vowels but were still perceived as belonging to the same category (either /i/ or /y/) by adult listeners. Half of the American infants were tested on the American vowel and the other half on the Swedish vowel. In the same way, half of the Swedish infants were tested on the Swedish vowel and the other half on the American vowel. Their results show that American infants more often perceived acoustically different vowels as belonging to the same /i/ category than they did for Swedish /y/. Similarly, Swedish infants perceived other vowels to be more similar to their native category /y/ than they did for the American vowel /i/. This finding suggests that native categories work as a *magnet* attracting acoustically similar vowels or, in more general terms, it shows that infants as young as 6 months of age have their perception altered by the distribution of honetic properties of their native language. It is worth noting once again that around this age children have not yet acquired words.

More direct evidence for the fact that infants are using this ability to recognize patterns in language acquisition, and to actually shape their sound categories, comes from Maye *et al.*'s work (2002) with English 6- and 8-month-old infants. These infants were trained on either a *unimodal* or a *bimodal* distribution of a [da]-[ta] continuum. In a unimodal distribution the stimuli in the middle of the continuum were presented more often than the stimuli on the edges of the continua. Conversely, in the bimodal distribution, the stimuli on the edges of the continua were presented more often than the stimuli in the middle of the continua. These infants were subsequently tested on their discrimination of the contrast. The results show that all infants familiarized with the bimodal distribution learned to perceive the contrast. Infants that were exposed to the unimodally distributed sounds, however, did not acquire the distinction. These findings show that infants from 6-months of age onwards are sensitive to the frequency distribution of the speech sounds in their input and that this sensitivity plays a relevant role in the development of speech perception at an early age. This ability is referred to as *distributional* or *statistical learning*.

Studies on infant perception have been crucial in providing meaningful insights into speech acquisition. They are, however, not able to tell the full story. The development of language-specific sound perception goes beyond the first years of life. Werker & Tees (1984) suggest that the ability of young children to discriminate non-native sounds continues to decline with age. They tested the discrimination of 4-, 8-, and 10-year-old English learning children on two Hindi contrasts (/ʈ/ - /t̪/ and /t^h/ - /d^h/). All three groups had difficulty discriminating the contrasts, as compared to English-learning infants (6- to 8-month-old, Werker et al. 1981). Sundara *et al.* (2006) interpret this to mean that the decline in sensitivity to non-native contrasts continues throughout pre-school years. Moreover they pertinently point out that there is a gap in the speech perception literature on pre-school aged children as most studies are done with either infants or adult second language learners.

1.2.3 Bilingual perceptual development

In order to acquire the speech sounds of their languages, bilingual infants acquiring the sounds of their languages have to deal with the same challenges as monolingual children. Moreover, they have to deal with various additional factors, such as structural differences between their languages (e.g. phoneme inventories and allophones), frequency of each sound in each language and the level of overlap between different categories. (Bosch & Sebastián-Gallés 2003).

There have been numerous cross-linguistic studies with infants (e.g. Aslin *et al.* 1998) but not many phonetic perception studies on bilingual infants. Given all these different factors and the roles they possibly play in language acquisition, it is understandable that the results found in studies involving bilingual infants are to a certain degree different from those typically found in monolingual infants.

One possible factor in explaining differences between bilingual and monolingual sound acquisition is related to difference in input. Specifically bilinguals' input is more complex than that of monolinguals. In the case of vowel acquisition, for instance, bilingual children have to acquire a greater number of vowels than monolingual children, since their input presents them with two vowel systems. To add to the complexity it should be borne in mind that there is a certain degree of acoustic overlap between the vowels in each language, as well as between the languages, as discussed earlier in Section 1.2.1. This also means that bilinguals are exposed to an array of allophones (within each language but also between languages) and the task to categorize the speech signal is a challenging one.

Moreover bilingual children have to potentially deal with cross-linguistic differences, such as the fact that some acoustic cues are used phonemically in one language but not in the other. Finally, we also need to consider the relative frequency of exposure to each of these categories. Generally speaking, dual exposure results in reduction of bilingual children's input. Even assuming the ideal 50%-50% exposure to each of the languages, bilingual input is reduced to half of the input a monolingual child receives. This input could be even more drastically reduced if the proportions change to, for instance, 70% - 30%. Since there is no ethical way to quantitatively equal bilinguals' and monolinguals' input levels (the only imaginable way would be to regularly prevent monolingual children from getting any language input during part of the day) quantitative differences in input between bilingual and monolingual children will likely remain an unresolved issue in bilingual research.

To sum up, bilingual children face the same challenges as monolingual children in speech acquisition (as discussed in Section 1.4.2) with additional issues specific to their bilingual situation. They have to handle a more complex input with a more limited language exposure. One could in this case hypothesize a delay in the acquisition of a contrast by children acquiring two languages. A brief review of the literature in bilingual sound acquisition seems to confirm this hypothesis.

In their study involving Catalan-Spanish bilingual infants, Bosch & Sebastián-Gallés (2003) found that 8-month-old monolingual Catalan infants, but not Catalan-Spanish bilinguals were able to discriminate the /ɛ/ - /e/ Catalan contrast, which is absent in Spanish. The ability to distinguish the contrasts is recovered in bilinguals by 12 months of age, about a 4 month delay when compared to monolinguals.

French and English bilingual infants also seem to be delayed in their perception of consonants as shown by Burns *et al.*'s (2002) study on the perception of the /pa/ - /ba/ contrast. Six to 8-month-old monolinguals of each language and bilinguals showed identical perceptual behaviour, suggesting no effect from their language input in this age group, a pattern similar to that found by, for instance, Werker *et al*. (1981, see also Section 1.2.2). Between 10 and 12 months of age, however, monolingual infants were able to perceive the contrast according to their native language, whereas bilinguals showed no signs of being able to discriminate the sounds involved. A few months later, between 14 and 17 months of age, bilingual infants caught up with their monolingual peers and were able to either (a) perceive the contrast in only one of their dominant language, suggesting a pattern of dominance in that language; or (b) perceive the contrast in both of the languages, suggesting a certain degree of balance between their languages. In this case the apparent group delay found in 14- to 17-month-old bilinguals was merely a consequence of different patterns of language dominance.

In one of the few studies in the perceptual development of bilinguals involving older children (as opposed to infants) Sundara *et al.* tested 4-year-olds acquiring English and French. The children were tested on the English /d/ - /ð/ contrast, which is absent in French. French has the dental voiced plosive /d/ but lacks the interdental /ð/ as well as its voiceless counterpart /θ/. The results for the bilingual children where compared to those for the monolingual French and English infants tested by Polka *et al.* (2001), who had used the same contrast and methodology. Sundara *et al.* included a group of adults, monolinguals and bilinguals in their study in order to investigate age differences. Their analysis shows that the 4-year-old bilingual children could not perceive the contrast as well as English monolingual children, despite their exposure to English. There were, however, no differences between the bilingual adults and their monolingual counterparts. Their results suggest that discriminations of native sounds can be affected by bilingualism, and that dual language exposure can delay the facilitative effect of language experience. This delay is, however, temporary, since there was no difference between bilingual and monolingual adults. Considering the reduced input bilinguals receive in each of their languages it is possible that quantity of input, and not bilingualism *per se*, is the cause of this perceptual delay. I will return to this discussion in Chapter 5.

In the next section I will discuss the acquisition of cue weighting by monolingual children. Although to my knowledge no study has addressed the acquisition of cues and cue weighting in simultaneous bilinguals, I will discuss possible patterns of bilinguals' performance based on the literature on monolingual acquisition.

1.2.4 The perceptual development of cue weighting

As discussed in Section 1.2.1, phonemes or even features can be cued by different acoustic properties. Not all cues are equally important to a contrast, however. When learning the sounds of a language, children have to acquire not only the specific cues involved in a contrast, but also the adult-like cue weighting. Cue weighting is a very sophisticated way of categorizing sounds and poses a great challenge in language development. Even in a monolingual situation, which offers the learner the complexities of a single language rather than two (or more), adult-like cue weighting is only acquired very late in language development.

In many speech perception studies, children have been shown to differ from adults in the relative use of the many acoustic cues involved in sound contrasts (Nittrouer 1996). Jusczyk (1993), for instance, shows that children assign different perceptual weights than adults do to some kinds of acoustic information. Similar results were found by Gerrits (2001), who shows that Dutch children up until 9 years of age are still not adult-like in the weighting of fricative noise in the perception of the /ʃ/ - /s/ contrast. When tested on the vowel contrast (/ɑ/ - /aː/) the children in Gerrits' study revealed adult-like weighting of the durational cue before the age of 4 whereas spectral cues were not weighted in an adult-like fashion until after 6 years of age. These results suggest that cue weighting in vowel contrasts is acquired earlier than that in consonant contrasts.

Although cue weighting strategies used by children appear to change as they grow older (Jusczyk 1993), it has been suggested that these age-related differences are not the consequence of linguistic development, but of differences in auditory processing abilities between children and adults (e.g. Sussman 2001). Sussman suggests that children are not as sensitive as adults to differences in subtle acoustic properties and hence base their distinctions on the more prominent property. This means that differences between children's and adults' cue weighting are not a matter of learning to process speech but a matter of maturation of the auditory system. Nittrouer (1996) directly addresses this issue and her results confirm that 3-year olds are less sensitive to changes in acoustic cues than adults. This factor by itself, however, could not account for the age-differences found in her study, leading to the conclusion that there is indeed development in the perception of cue weighting. Nittrouer uses the term "Developmental Weighting Shift" to refer to this phenomenon (from Nittrouer, Manning and Meyer 1993)

For bilingual children cue weighting has to be acquired separately for each of their languages. As previously stated, bilingual children face the same challenges as monolingual children in language acquisition while at the same time having to cope with particular issues related to their dual language exposure. Specifically they have to handle dual input with a more limited language exposure. Given the extra complexity in the input of the bilingual child (discussed in Section 1.2.3), one could hypothesize that bilingual children will be faced with an even harder challenge than monolingual children in the acquisition of cue weighting. This could lead to delays in acquisition, which would be in line with the findings by Bosch & Sebastián-Gallés (2003) and Sundara *et al.* (2006) discussed above.

Conversely, it is equally plausible to suggest that the acquisition of a specific cue in one of the languages might trigger the acquisition of this cue in the bilingual's other language. Paradis & Genesee (1996) suggest that bilingual exposure may accelerate the acquisition of some properties. They point out that acceleration is likely to occur when one specific feature of one of the bilingual's languages is acquired earlier than in the other language. In phonological / phonetic acquisition, for instance, Lleó, Kuchenbrandt, Kehoe & Trujillo (2003) show that bilingual children in German and Spanish were faster than Spanish monolingual children in the acquisition of syllable codas in Spanish. I will return to this discussion in Chapter 5.

1.3 Research questions

The main topic I address in this dissertation is the possible effect of simultaneous bilingualism on the acquisition of speech sound categories. In order to deal with this core issue, I single out 4 sub-questions, which are presented below.

1 Do perceptual categories in bilingual children differ from those in monolingual children?

In order to investigate whether simultaneous bilingualism has any effect on perceptual categorization, I will address the detailed specification of sound categories in bilinguals as compared to monolinguals. As discussed in the introduction of this dissertation, I will specifically investigate cue weighting in the

/ɑ/ - /aː/ Dutch vowel contrast in children who are simultaneously bilingual in Dutch and Brazilian Portuguese (BP) as compared to monolingual Dutch children.

To disentangle a possible age effect from a possible bilingualism effect, I also compare bilingual and monolingual children to monolingual adults.

Two groups of BP monolinguals are also included in this study: a group of children and a group of adults. The results from these groups will be used to determine any possible effects originating from the BP vowel(s) on the Dutch contrast in bilingual children.

I will specifically address this question in Chapter 4 of this dissertation, when comparing cross-sectional data of bilingual and monolingual children and adults. On the basis of the reviewed literature I expect monolingual children still to be in the process of acquiring the adult-like cue weighting. Moreover, bilingual children are expected to lag behind monolingual children.

2 What is the influence of language dominance on bilingual children's acquisition of perceptual categories?

Bilingual children vary greatly regarding their language dominance. Even if we consider only bilingual children being raised in the Netherlands, having all been exposed to both of their languages from their first year of life on, the group is very heterogeneous. Some children are relatively balanced, whereas others are strongly dominant in one of their languages.

To directly approach the question concerning the role played by language dominance, I have manipulated this variable by splitting the group of bilingual children into two subgroups: one group that was raised in the Netherlands (mostly Dutch dominant) and another group that was raised in Brazil (mostly BP dominant). The two bilingual groups mirror each other in language dominance. Although they have all been exposed to both languages from birth, they differ regarding quantity and quality of input they received in either language.

A comparison between bilingual children who are Dutch dominant and bilingual children who are BP dominant is addressed similarly as described in Question 1. Their cue weighting in the /ɑ/ - /aː/ Dutch vowel contrast will be calculated and compared to each other as well as to their monolingual peers and adults.

I will discuss this question in Chapter 4 when cross-sectionally comparing the phonetic details of different groups of listeners. My hypothesis is that language dominance plays a significant role in sound acquisition due to its relation to amount of input. Specifically, children who are dominant in BP have a reduced exposure to Dutch, which might lead them to need a longer period of time to acquire adult-like cue weighting. As mentioned above, bilingual children are expected to be lagging behind monolingual children in their cue weighting. I expect this to be especially the case with bilinguals who are non-dominant in Dutch.

3 *Do bilingual and monolingual children follow the same developmental path in their perceptual acquisition?*

Possible, non mutual exclusive, answers for Question 1 are: (a) that bilingual and monolingual children's categories differ from each other; or (b) that bilingual and monolingual children's categories differ from the adult ones. In either of these cases it would be relevant to observe whether bilingual and monolingual children follow the same developmental path, either in catching up with each other or with the adults. Differences in developmental paths may point to qualitative differences between bilingual and monolingual children.

In order to gain insight into these developmental paths, I have set up a (semi)longitudinal study in which children are tested using the same methodology and stimuli at three stages over a period of three years. The starting age is around 4 years of age. The main reason why 4-year-olds were chosen as a starting point was to avoid a shift in language dominance during the period of this study, since this is the age at which children first go to school in the Netherlands. If we were to work with younger children chances that they would shift in language dominance would be higher because they would move from a home environment, where BP input is prominent, to a school environment, where Dutch input is prominent. Moreover, this age group has been shown not to have achieved adult-like perception yet (Gerrits 2001), which allows us to follow their development paths.

I will specifically address questions concerning the developmental paths exhibited by bilingual and monolingual children in Chapter 5 of this dissertation when reporting on the longitudinal data. Considering the literature on bilingual speech perception, I expect bilingual development to differ from monolingual development in that they are delayed in their acquisition. Although I expect both groups of children to develop towards the adult norm as they grow older, the hypothesis is that bilinguals will develop more slowly, showing a less steep growing curve.

4 *Do bilingual children change their perception of vowel contrasts as a result of a change in the relative activation of each of their languages (i.e. is there a Language Mode effect)?*

In Section 1.1.5 I have briefly discussed Grosjean's (2000) theory of the bilingual's Language Modes and how this variable might affect bilinguals' performance in sound perception, and specifically their sound perception in an experimental set. In this study I directly address the hypothesized Language Mode effect by manipulating this variable. In order to do this, children and adults are tested under three different settings where experimenter and languages being used are adjusted according to the Language Mode the experiment is trying to trigger.

The Language Mode issue will be addressed in Chapter 6 of this dissertation when discussing the results of the manipulation just described. The Language Mode theory states that when bilinguals are in a bilingual mode (as opposed to being in a monolingual mode) both of their languages are activated and interactions are more likely to occur. Hence the prediction that in a bilingual mode, bilingual children will behave less like Dutch monolingual children and more like BP children.

2 BACKGROUND: VOWEL SYSTEMS AND METHODOLOGY

This chapter aims to provide the reader with background information regarding two important aspects of this dissertation: first, that of the vowel systems of Dutch and Brazilian Portuguese, and second, that of experimental methodology in the study of (bilingual) speech perception. The information provided here will enable the reader to understand the methodology, and methodological design (stimuli, tasks) used in this study, whereas the design of the experiment itself will be discussed in the next chapter. Moreover, the information provided here clarifies why certain choices have been made rather than others. Insight into these issues is of crucial importance for a correct interpretation of this study's results.

Section 2.1 of this chapter introduces the vowel systems of the languages of this study, Dutch and Brazilian Portuguese; this includes a comparison between subsets of the two systems, specifically Dutch /ɑ/ and /aː/, and Brazilian Portuguese /a/. This discussion will be especially relevant in the next chapter, which describes the stimuli used in this study and their manipulation. Section 2.2 briefly discusses relevant methodological issues in speech perception research, discussing different types of stimuli (section 2.2.1) and tasks (section 2.2.2), and their advantages and disadvantages. Section 2.3 is a brief summary of the main points.

2.1 Dutch and Brazilian Portuguese vowels

This study addresses the perception of a vowel contrast by bilingual children in Dutch and Brazilian Portuguese (BP). The following sections introduce the vowel systems of these languages (Section 2.1.1 for Dutch and Section 2.1.2 for BP) followed by a comparison of the currently relevant subset of vowels (section 2.1.3). In doing so, it is not my intention to present an in-depth analysis of the phonetic and phonological aspects of these systems; rather, I aim at a general level of understanding that allows sufficient insight into these inventories, and the way they compare.

2.1.1 A brief description of the Dutch vowel system

The two major varieties of modern Dutch are northern standard Dutch, spoken in the Netherlands, and southern standard Dutch, spoken in Flanders in Belgium. The current study addresses the former variety, to be described in this section.

Netherlandic, or northern standard Dutch, is traditionally described as having 12 monophthongal vowels /i y ɪ ʏ øː eː ɛ aː ɑ oː ɔ u/, a contrastive schwa /ə/ and 3 diphthongs /ɛɪ ɔu œy/ (e.g. Booij 1995, Heemskerk & Zonneveld 2000, Moulton 1962, Nooteboom & Cohen 1995 and Zonneveld & Trommelen 1979; but see Adank *et al*. 2004 showing that the /ø e o/ are actually diphthongized). Figure 2.1 displays values for the monophthongal vowels on an F1 x F2 plot.

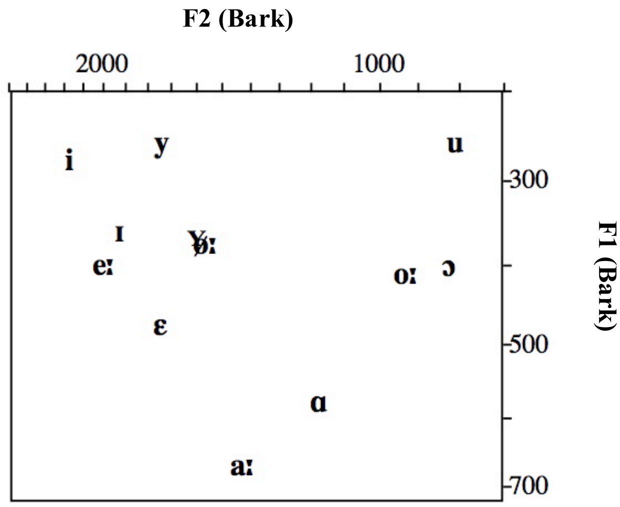

Figure 2.1: The 12 Dutch monophthongal vowels in stressed positions presented on an F1 x F2 plot (values from Adank *et al*. 2004). F1 and F2 values are given in Bark. Vowels were produced in monosyllabic non-words (sVs) embedded in a carrier sentence.

It is important to observe that the F1 and F2 specifications of the vowels displayed in Figure 2.1 are represented by average values. Acoustic reality is fuzzier, and there can be a great degree of overlap between vowels, given appropriate circumstances. An illustration of such fuzziness is shown in Figure 2.2, which displays F1 and F2 for multiple productions of 8 Dutch monophthongs, by different female and male speakers (the data are taken from a test reported by van der Harst 2008).

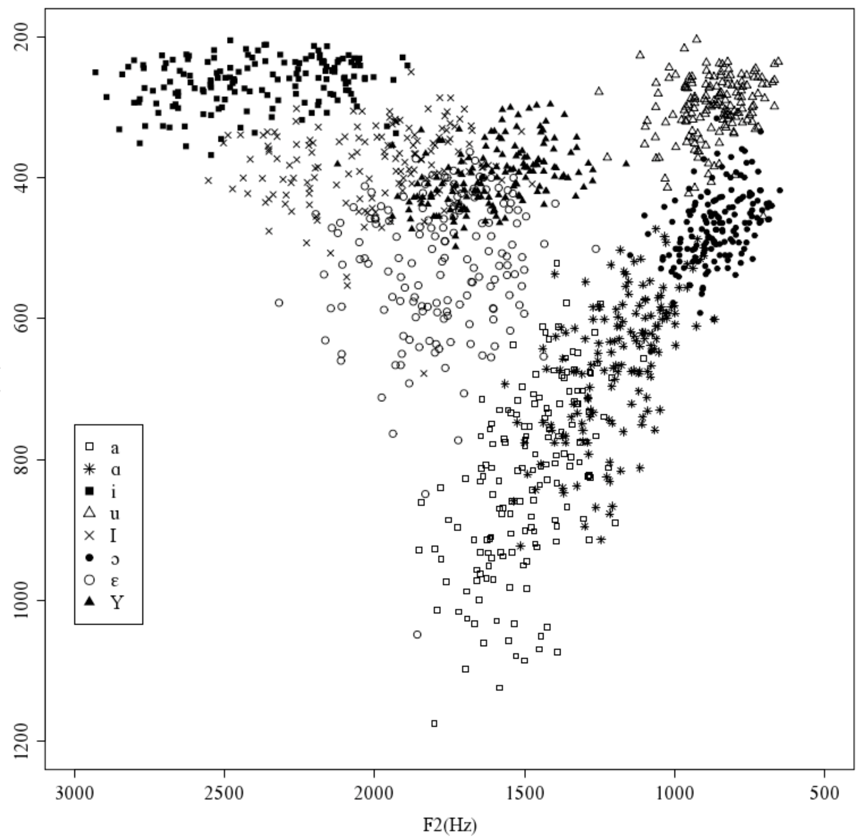

Figure 2.2: Eight Dutch monophthongal vowels (N = 1280) presented on an F1 x F2 plot (data from van der Harst 2008). F1 and F2 values are given in Hertz. Vowels were produced by male and female speakers in monosyllabic words in a read-aloud task.

Regarding overlap, Figure 2.2 reveals that, for instance, an [ɑ] as produced by one individual may have acoustic properties similar to an [aː] produced by a different individual. Or more drastically, the same vowel produced by the same speaker may have different spectral properties depending on the linguistic context in which it was produced, or depending on speech rate (see Section 1.4.1 in Chapter 1 for a discussion of this topic).

In addition to the spectral differences illustrated in Figures 2.1 and 2.2, there is an intrinsic durational difference among the Dutch vowels, implying that in similar contexts vowels of the 'long' variety are approximately twice as long as the 'short' ones. Duration, however, is never used as a single cue to mark vowel contrasts in Dutch, but is always combined with other acoustic parameters, such as spectral cues. See for instance work by van Heuven, van Houten & de Vries (1986), Nooteboom & Cohen (1995), and Heeren (2006) on the /ɑ/ - /aː/ contrast, which is central in this dissertation, all pointing that both spectral and durational information are used as cues. In other long vowels diphthongization is used to cue vowel identity, as for the midvowels /øː eː oː/ (e.g. Nooteboom & Cohen 1995, Adank *et al* 2004).

In the next paragraphs, I will address the topic of length in more detail. This will be followed by a discussion on geographical variation of the vowels of standard Dutch within the Netherlands.

The vowel length distinction in Dutch

Despite the prominent durational difference between two groups of Dutch vowels, the notion of *length* is a traditionally controversial topic among investigators of the Dutch sound system. To a certain extent, notions of quantity and quality, and especially of phonetic vs. phonological quantity and quality are intertwined. In the following paragraphs I will briefly address this discussion, allowing the reader to understand the main lines of the controversy. We will see at the end of the discussion that the contrast in this dissertation /ɑ/ - /aː/ is in fact least affected by the controversy. Presentation of the broader picture, however, will give the reader at least some idea of the position of the contrast in the overall vowel system.

In a traditional phonemic description of the Dutch vowel inventory, Moulton (1962) divides the Dutch monophtongal vowel into two classes, the so-called A-vowels and B-vowels (see discussion in Zonneveld & Trommelen 1980, van Oostendorp 1995):

A vowels: /ɪ ʏ ɛ ɑ ɔ/
B vowels: /i y ø e a o u/

The main evidence for grouping these vowels together comes from their distributional properties. If we concentrate on the /ɑ/ - /aː/ distinction, as members of each class, we can observe the following differences:

A:	*r[ɑ]	r[ɑ]m	r[ɑ]p	r[ɑ]mp
	-	'ram'	'quick'	'disaster'
	*st[ɑ]	st[ɑ]m	st[ɑ]p	st[ɑ]mp
	-	'stem'	'step'	'(to) thump'
B:	r[aː]	r[aː]m	r[aː]p	*r[aː]mp
	'yard'	'window'	'turnip'	-
	p[aː]	p[aː]l	p[aː]p	*p[aː]lp
	'daddy'	'pole'	'papist'	-

As clearly seen in these examples, A-vowels and B-vowels differ in their distribution within the Dutch language.

Although the details of the actual analysis are more sophisticated than briefly presented here, in later theoretical phonology (Zonneveld & Trommelen 1980, Trommelen 1983, Kager & Zonneveld 1986, Kager 1989) this distribution is explained by a number of cooperating assumptions about syllable structure: the rhyme constituent of a Dutch syllable must contain at least two sound segments (the *minimal rhyme constraint*), and, at the same time, it cannot contain more than two (the *maximal rhyme constraint*). 'Extra-rhymal' consonant clusters can only be coronals. When, now, B-vowels are analysed as bipositional, the distribution falls out: √ *r-am-p*, *st-am-p* vs. * *r-aa-mp*, *p-aa-lp*. Since, simply put, two elements are more than one (and also since diphthongs pattern with B-vowels: * *r-au-mp*, *p-ei-lp*), A-vowels can plausibly be viewed as short, and B-vowels as long, at least phonologically so.

Not only are /ɑ/ and /aː/ each a member of the two respective classes, alternations in fact suggest that they can be called each other's *counterparts*, i.e. they are 'a pair'. Below are some well-known phenomena supporting this suggestion.

Open syllable lengthening in plurals of nouns:

d[ɑ]g	'day'	d[aː]g-en	'days'
d[ɑ]k	roof'	d[aː]k-en	'roofs'
p[ɑ]d	'path'	p[aː]d-en	'paths'
sl[ɑ]g	'hit'	sl[aː]g-en	'hits'

Open syllable lengthening in past tense plurals of verbs:

kw[ɑ]m	'came, sg.'	kw[aː]m-en	'came, pl.'
st[ɑ]l	'stole, sg.'	st[aː]l-en	'stole, pl.'
z[ɑ]g	'saw, sg.'	z[aː]g-en	'saw, pl.'

Nouns derived from verbs:

dr[ɑ]ch-t	'attire'	dr[aː]g-en	'to wear'
g[ɑ]ng	'gait, corridor'	g[aː]-n	'to go'
sl[ɑ]g	'hit'	sl[aː]-n	'to hit, beat'
st[ɑ]nd	'posture'	st[aː]-n	'to stand'

Other morphology:

Sp[ɑ]nje	'Spain'	Sp[aː]n-s	'Spanish'

Much of the controversy surrounding the classification of the Dutch monophthongic vowels arises from an imperfect match with their phonetic characteristics, specifically with 'phonetic length'. Three of the B-vowels, namely /i y u/, are phonetically short in all contexts (that before tautomorphemic /r/ excluded, e.g. Nooteboom 1972). Notice, however, that these observations, which typically concern the high vowels, leave the class membership of /ɑ/ and /aː/ uncontested, as does their being a pair.

This behaviour was recently confirmed by the results of Adank *et al.*'s (2004) detailed work on the vowels of standard Dutch, which show a patent durational difference between two groups of vowels, the long ones /øː eː aː oː ɛiː ɔuː œyː/ vs. the short ones /i y ɪ ʏ ɛ ɑ ɔ u/. Adank *et al.* also show that there is hardly any overlap between the durational realizations of short and long vowels, even when comparing different speakers from different locations.

Geographical variation

Even considering only the standard language, there is still a large geographical variation among the Netherlandic Dutch vowels. Adank *et al.* (2007) describe the acoustic properties of Dutch vowels in the standard language of four regions of the Netherlands: (1) the *Randstad*, which is the economic and cultural centre of the Netherlands, comprising the four largest cities, Amsterdam, Rotterdam, The Hague, and Utrecht, and situated in the western half of the country; (2) a Northern region; (3) a Southern region; and (4) an intermediate region. Their results show a significant difference in duration between the regions, in that the vowels in the central area, i.e. *Randstad*, are consistently overall shorter than the vowels in the other regions. Comparatively speaking, however, the long vowels are always longer than the short vowels and there is no length overlap between a short vowel and their long counterpart, such as the /ɑ/ - /aː/ pair. This is true even when comparing vowels across different regions.

Concerning spectral properties, Adank *et al.* report that the shape of the vowel system varies across the four regions. Comparing F1 and F2 of the Dutch monophthongal vowels in their steady state they found that there is a regional effect for /ɪ ʏ ɛ ɑ ɔ u/. The largest effects were found in F1 for /ɛ/, which is lower in the South than in the other three regions, and in F2 for /ɑ/, which is the most fronted in the Northern regions. In section 2.1.3, when comparing the phonetic details between Dutch and BP vowels, I will return to the issue of spectral characteristics of Dutch /ɑ/ and /a:/ and their differences across regions.

2.1.2 A brief description of the Brazilian Portuguese (BP) vowel system

Brazilian Portuguese has 7 oral and 5 nasal vowels. In this section only the oral vowels will be addressed. The average formant values for these vowels are displayed in Figure 2.3 on an F1 x F2 plot.

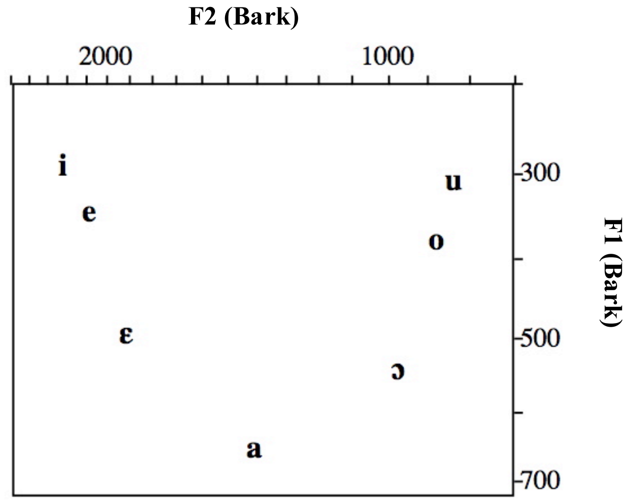

Figure 2.3: The Brazilian Portuguese vowel system in stressed positions presented on an F1 x F2 plot (values from Rauber 2006). F1 and F2 values are given in Bark. Vowels were produced in stressed positions in dissyllabic (non-)words embedded in a carrier sentence.

The same observation made for the Dutch vowels concerning the fuzzy boundaries holds for the BP vowels. The BP acoustic space, however, is less crowded than the Dutch one, with a consequent decrease in the degree of overlap between the vowels.

Traditionally the oral vowel system of Brazilian Portuguese has been studied in three different contexts: stressed, pre-stress, and post-stress (Dukes 1993). Major (1982) claims that tonic syllables carry primary stress, pre-tonic syllables carry secondary stress, and post-tonic syllables carry no stress. Different vowel sets are licensed in different prosodic positions. These are schematically shown below in Figure 2.4:

Tonic				**Pre-tonic**			**Post-tonic**	
i			u	i		u	i	u
e		o		e	o			
ɛ	ɔ							
	a				a		a(ə̆)	

Figure 2.4: Schematic illustration of the Brazilian Portuguese vowel systems in three prosodic positions.

Figure 2.4 shows that the complete 7-vowel inventory of BP only surfaces in stressed position. In pre-tonic position the inventory is reduced to a 5-vowel system, consisting of a subset of the vowels in tonic position. The inventory is further reduced in post-tonic position to a 3-vowel system. It should however be pointed out that the systems presented in Figure 2.4 refer to the most prestigious variety of BP as spoken in regions such as São Paulo and Rio de Janeiro. Some varieties will differ in the vowels they allow in each prosodic position. Some Northeastern varieties, for instance, allow all 7 vowels in the pre-tonic position; whereas some Southern varieties allow 5 vowels (the system illustrated in Figure 2.3 as pre-tonic) in final position.

Contrary to Dutch, there is no length distinction (phonetic nor phonological) between the vowels in BP (Rauber 2006). Duration is used in this language to cue stress only, where tonic syllables are longest, post-tonic are shortest, and pre-tonic are intermediate (Major 1982). In this context duration is a very prominent cue, and stressed vowels are about twice as long as unstressed syllables.

Geographical variation. In terms of geographical variation, the main difference mentioned in the literature refers to the mid-peripheral vowels /e ɛ o ɔ/ in the South as compared to the Northern parts of the country (Célia 2004). In general we can say that in many of the Northern regions, the vowel systems in tonic and pre-tonic positions are identical, and include all seven oral vowels: /i e ɛ a ɔ o u/. This means that Northern speakers retain the [e] - [ɛ] and [o] - [ɔ] contrast in pre-tonic position.

To my knowledge no geographical differences between the other oral vowels have been signalled. My assumption is then that there is no meaningful variation between the other oral vowels.

2.1.3 A comparison between the Dutch and the Brazilian Portuguese low vowels

In this study I focus on two subsets of the Dutch and BP vowel inventories, namely the low vowels: /ɑ/ and /aː/ for Dutch and /a/ for BP. There are three reasons for focusing on these vowels. First, the Dutch /ɑ/ - /aː/ contrast involves spectrum and duration only, as opposed to for instance /ɛ/ - /eː/ and /ɔ/ - /oː/ where the long vowels of each pair are also phonetically diphthongized (Adank *et al.* 2004).

Secondly, there is a good background literature on the /ɑ/ - /aː/ contrast (e.g., Nooteboom 1972) and its perceptual acquisition by Dutch children (Gerrits 2001, Heeren 2006). Finally, in second language speech perception research, the Dutch contrast /ɑ/ - /aː/ has been shown to be problematic for Brazilian Portuguese listeners (Brasileiro 2004, Brasileiro & Escudero 2006). Many learners, including advanced ones, were unable to fully acquire the native-like combination of spectral and durational cues. This raises questions about *bilingual* listeners' perception of the same vowel pair.

In the next paragraphs I will specifically address these vowels, referring to the phonological systems of Dutch and BP, and comparing the vowels' acoustic properties.

In terms of their phonological inventories, Dutch has two low vowels (/ɑ/ and /aː/) whereas Brazilian Portuguese has only one (/a/). As discussed earlier, there is an intrinsic durational difference between the two Dutch vowels and, in similar contexts, /aː/ is always longer than /ɑ/, about twice as long in monosyllabic words (see, for instance, the data in Adank *et al* 2004 and in Koopmans-Van Beinum 1980).

Acoustically, the BP vowel is located in between the two Dutch vowels, slightly closer to the Dutch long vowel. There are no large durational differences between BP vowels, and in similar contexts, they are all about the same length. Table 2.1 summarizes duration, F1 and F2 values for the two Dutch vowels and the Brazilian Portuguese vowel.

	Dutch /ɑ/	**Dutch /aː/**	**BP /a/**
Duration (ms)	96	203	130
F1 (Hz)	578	670	651
F2 (Hz)	1172	1425	1405

Table 2.1: Average duration, F1 and F2 of Dutch /ɑ/ and /aː/ spoken by male speakers of standard Dutch as spoken in the Netherlands (Adank *et al* 2004) and BP /a/ spoken by male speakers of Southern Brazil (Rauber 2006). All vowels were elicited in stressed positions.

As I have previously pointed out, the vowel boundaries are not as clear-cut as the values in Table 2.1 leads one to suspect and in real life situations there is some degree of overlap between different vowels. These are, however, average values, and illustrate the place in the acoustic space where productions of these vowels are most likely to be.

Since studies of geographical variation have shown that there are durational as well as spectral differences (specifically F2 for /ɑ/) between regions in the Netherlands in their production of the /ɑ/ and the /aː/ (Adank *et al.* 2007), I investigate these differences in more detail here. The values of duration, F1 and F2 for each of these two vowels in the 4 regions studied by Adank *et al.* are displayed in Table 2.2 (recall that these were the regions mentioned in Section 2.1.1).

/ɑ/	Dur. (ms)	F1 (Hz)	F2 (Hz)
Randstad	95	668	1226
Intermediate	120	639	1202
South	125	663	1150
North	112	677	1351

/aː/	Dur. (ms)	F1 (Hz)	F2 (Hz)
Randstad	209	791	1499
Intermediate	236	751	1520
South	227	808	1501
North	236	760	1581

Table 2.2: Mean duration, F1 and F2 of Dutch /ɑ/ (on the top) and /aː/ (on the bottom) in 4 geographic regions of the Netherlands (Adank *et al.* 2007), averaged across males and females in a total of 40 tokens per region. All vowels were elicited in stressed positions.

Concerning duration, Adank *et al.* (2007) point out that speakers from the Randstad produce overall shorter vowels than speakers from the other three regions. Table 2.2 shows that this is also the case for the /ɑ/ and the /aː/. For the purpose of this study, however, the relationship between the duration of the two vowels is more relevant than the actual durational values for each vowel. This means that it is more important that the long vowel be equally longer than the short vowel in each region than that the vowels have particular durational values. A simple calculation of durational ratios for the regions shows that this is indeed the case: in the Randstad is /aː/ 2.2 times as long as /ɑ/; in the intermediate region this value is 2.0; 1.8 in the Southern region; and 2.1 in the Northern region.

In terms of cross-language speech perception, speakers of L1 Brazilian Portuguese exposed to Dutch have to learn to perceive a new contrast. This scenario has been extensively studied by acquisitionists and shown often to be problematic for learners (see for instance Escudero 2005 and the examples presented there). Conversely, native speakers of Dutch exposed to Brazilian Portuguese would have to unlearn a contrast. These specific *phonemic equations* (Escudero 2005, see Chapter 1 for a definition of this notion) are illustrated in Figure 2.5[1].

[1] Another possible scenario is that BP listeners map the Dutch /ɑ/ onto BP /a/ and Dutch /aː/ onto BP /ɔ/. In this case learners do not have to learn or unlearn a contrast but simply adjust their perceptual boundaries. I will return to this scenario in Chapter 4.

Figure 2.5: Illustration of the *phonemic equation* involving the low vowels of Brazilian Portuguese and Dutch.

When dealing with children being raised bilingually in Dutch and BP we have to take into account that these children are exposed to all three vowels: Dutch /ɑ/ and /aː/, and BP /a/. Each of these vowels varies in its production, both within and between speakers, possibly involving a large degree of overlap. The input these children receive is complex and in some cases ambiguous. The question remains if or how the different vowels influence each other and what the details of their sound categories are.

In sum, the main differences between the Dutch and BP vowel systems is that Dutch has a larger inventory than BP, leading to a more crowded acoustic space. Moreover, Dutch has a clear durational distinction between two groups of vowels whereas BP does not, leading to specific challenges in cross-linguistic perception, as discussed in the current section.

2.2 Methodological considerations in speech perception research

This section discusses methodological issues relevant to experimental studies on speech perception, such as the stimuli type, their phonetic context, and the different experimental tasks.

2.2.1 Stimuli

When working with speech perception, important choices must be made about stimuli, for instance the type of stimuli and the phonetic context in which they will be embedded, if any. These topics will be discussed in this section.

The issue of phonetic contexts relates to whether the stimuli are going to be presented in isolation or embedded in a larger phonetic context, for instance, a syllable, a word, or a sentence. Beddor and Gottfried (1995) point out that the most important reasons for presenting stimuli embedded within a linguistic context is because this adds to the naturalness of the task. Moreover, a larger context, like a sentence or a word, provides the listeners with extra language input. Language input is relevant in speech perception experiments to prevent participants from engaging in a non-linguistic perception mode. It has often been claimed that speech and non-speech sounds are processed differently. Most evidence for this comes from research on Categorical Perception. The Categorical Perception Hypothesis states that two distinct sounds from the same linguistic category are not (or hardly) discriminated, and that this phenomenon is unique for speech sounds (e.g., Liberman *et al.* 1961, Mattingly *et al.* 1971, Miyawaki *et al.* 1975, Liberman *et al.* 1981, Best *et al.* 1981, Remez *et al.* 1981, Whalen & Liberman 1987, Nygaard & Eimas 1990. But see e.g., Miller *et al.* 1976, Pisoni 1977, Kuhl 1981, Kuhl & Padden 1982, 1983, Fowler 1990 for counter evidence.) Another kind of evidence for specialization of speech processing comes from research on the rate at which speech and non-speech sounds can be processed: 25 to 30 phonetic segments per second, whereas processing 30 non-speech sounds per second seems to be beyond human capacity (Jusczyk & Luce 2002.)

Another reason for embedding stimuli in a larger context is because this can create a more complete representation of the sound properties. There is, for instance, significant evidence that vowel identification is influenced by spectral change patterns such as formant transition from the vowel to its neighbouring consonants (Hillenbrand *et al.* 2001). This fact favours the use of CVC chunks over vowels in isolation in vowel perception tasks.

There are however also some drawbacks to embedding stimuli within larger contexts. Firstly the contexts may function as distracters. When embedding the target vowel in a syllable, for example, the participants' attention will not be fully focused on the vowel, but on the whole chunk. Despite the fact that a syllable may give a more complete representation of the sound, the experimenter can choose to focus on specific cues, such as duration or formants, and abstract from these extra perceptual cues. In this case the best choice would be to present the target stimuli in isolation. Secondly, on a more practical note, embedding stimuli within larger contexts such as a sentence, makes an experiment last longer especially when dealing with younger participants, who already have a short concentration span, the length of the experiment is crucial. Finally, psycholinguistic studies have shown that the unit of stimuli presented triggers different processes. This means that in some cases presenting stimuli in isolation should be preferred as it makes listeners rely on their abstract representation of the stimuli involved (e.g. Strange *et al.* 2001).

Another issue to be taken into account in speech perception experiments is the type of stimulus used, wheather natural or synthetic. The most important reason for choosing natural stimuli over synthetic ones is that they provide a full representation of the speech properties. This means that the experimenter avoids the risk of failing to represent some relevant acoustic properties.

In early studies another reason for working with natural stimuli was the fact that synthetic stimuli sounded highly artificial, possibly leading listeners away from their speech perception mode, affecting the results found. Remez *et al.* 1981, for example, presented subjects with sinewave speech, which is produced by replacing the formants of syllables with frequency-modulated sinewaves. They found that listeners processed the signals differently when they were told that they were hearing speech or non-speech. This criticism is of less importance nowadays as modern speech synthesizers are able to create very natural and accurate sounds.

The main advantage of synthetic over natural stimuli is that synthetic stimuli allow for complete manipulation and control over the physical variation of the speech sound (Beddor & Gottfried 1995). When studying different acoustic properties, each of these dimensions can be manipulated separately and in equal steps. For this reason, synthetic stimuli (and to some extent, hybrid) are the best options in cue-weighting studies.

2.2.2 Tasks

Experimental tasks differ in the perceptual and cognitive challenges they offer. This section provides a brief overview of different types of perception tasks.

Many earlier studies used *imitation tasks*, in which participants hear a sound, and have to repeat it (for example Flege & Hammond 1982, Flege 1993 and Rochet 1995). The most important advantages of this task are its simplicity, naturalness and light memory load. A drawback is that it does not allow for a distinction between production and perception. In order to tease these two factors apart, an imitation task can be adapted. For instance, when eliciting English productions of /r/-/l/ contrastive words by Japanese speakers Bradlow *et al.* (1997) found it necessary to present participants with visual information in addition to auditory stimuli. By presenting a picture of the item along with the spoken stimuli, the researchers wanted to make sure the participants would know which word was being elicited even if they could not perceive the /r/ - /l/ distinction.

In *identification tasks* participants choose a response to each stimulus from a multiple but finite set of alternatives. This kind of task measures listeners' ability to linguistically label a sound. Presenting listeners with a fixed set of response alternatives has the advantage of decreasing memory load. A shortcoming is that it is not always clear which response alternatives should be offered, or how. The choice of one alternative over the other is often based on the investigator's theoretical background (Rochet 1995). Flege (1989) for example points out that the vowels of the English words *beat* and *bit* can be represented by the pairs /iː/ - /i/ or /i/ - /ɪ/, depending on whether a contrast in duration or timbre is being considered as primary. To decrease the risk of underestimating listeners' labelling ability an investigator can choose to increase the number of labels presented. The more labels, however, the more complex the task becomes.

In identification tasks researchers need to consider the form in which the response alternatives will be presented. One commonly used and very simple option is presenting orthographic representations of the sound being studied (e.g., Rochet 1994, Bradlow *et al* 1997 and Escudero 2005). When presenting response alternatives orthographically, however, listeners' responses may be influenced by orthography, as it has been shown that orthography can affect sound perception. For instance, when participants make lexical decisions or rhyme judgments about spoken words, their performance is affected by the spelling of the spoken words (e.g., Ventura *et al*. 2004, Ziegler & Ferrand 1998 and Ziegler *et al*. 2004). Instead response alternatives can be presented visually, for example in a picture of the item containing the sound. This is useful and advisable especially when working with children (e.g., Gerrits 2001 and Heeren 2006) or illiterate participants.

Identification tasks can be combined with other tasks, such as judgment of goodness, or reaction time measurements. In goodness judgments participants have to decide on the quality of the stimulus immediately after identification, i.e. how good an example the stimulus is for this category. These adaptations assess listeners' sensitivity to within-category differences and stimulus appropriateness (Beddor & Gottfried 1995).

Discrimination tasks measure listeners' ability to hear a difference between sounds. One of the most common discrimination tasks is AX, where listeners hear a pair of sounds and indicate if they are the same or different. One benefit of this task is that only two stimuli are presented, with only one interval. This means that the memory load is relatively low (e.g. Wood 1976). On the other side, AX discrimination tasks have been claimed to be very susceptible to bias as listeners tend to want to favour one answer over the other (e.g., Gerrits 2001). Response bias can be eliminated however by using signal-detection analysis on AX discrimination performance (Green & Sweets 1966).

A well-known variation of the AX task is the 4IAX discrimination task, which has been claimed to be more sensitive to acoustic differences between the stimuli than the AX task (Pisoni 1975). In this task listeners are presented with two AX pairs, and have to indicate which pair contains different sounds. A disadvantage is that due to its great number of stimuli and inter-stimulus interval this task increases the memory load.

Discrimination tasks are often combined with identification tasks, as in most Categorical Perception studies (e.g., Liberman *et al*. 1961). Heeren (2006) claims that identification without discrimination tends to overrate L2 learners' phonetic abilities.

Categorical discrimination tasks pose the question whether a stimulus belong to one or the other category. The most common categorical discrimination tasks are ABX, where listeners are presented with three sounds in a row and are asked to indicate whether sound X is identical to A or to B. Pisoni (1975) and Schouten (1987) observe that an ABX task prevents a direct comparison between successive stimuli and forces the listeners to use their internalized categories for their responses. This is the case especially if the interval between the stimuli increases. Werker and Logan (1985) show that shorter inter-stimulus intervals will trigger phonetic perception whereas longer ones trigger phonemic perception. Researchers need to be aware of what kind of perception they want to trigger and adjust their inter-stimulus interval accordingly.

One disadvantage of ABX tasks is that the time span between the target sound, X, and the possible responses, A and B, is different. It has been shown (e.g., Pastore 1987) that listeners reduce uncertainty in ABX tasks by comparing only B and X. Some studies have tried to avoid this problem by using an adapted form of ABX, namely AXB, where the target sound is presented chronologically in between the two response alternatives (e.g., Gerrits 2001.) However, van Hessen & Schouten (1999) show that the same problem may occur in an AXB, where responses are often given before the B stimulus is presented. If listeners choose to ignore the B stimulus, AXB tasks are identical to AX discrimination tasks.

The current study will adopt a variation of AXB task, namely XAB. The experimental task will be discussed in more detail in Chapter 3.

2.3 Summary

This chapter dealt with background information necessary to understand the methodological set-up used in this study. To this end, this chapter has provided the reader with a brief summary on the vowel systems of the languages involved as well as some discussion on methodological issues, including stimuli and tasks. In the next chapter, which describes the details of the experimental study, I will return to some of the points discussed here.

3 EXPERIMENTAL SET-UP

The current study was designed to address the question whether bilingualism affects speech sound categorization. To this end I conducted a cue weighting perception experiment to enable comparing simultaneously bilingual children with their monolingual peers as well as with adults. This chapter addresses issues related to the experimental set-up used in this study and is closely related to Chapter 2 in that some of the considerations mentioned will be reflected in this one.

In section 3.1 I introduce the participant groups, providing information concerning their age, and their social and linguistic background. Section 3.2 describes the perception test I used for eliciting my data, giving details of the stimulus manipulation and the experiment's general procedure. The last section of this chapter, 3.3, considers the vocabulary task, which was developed specially for this group of bilingual and monolingual children

3.1 Participants

One hundred and sixty participants took part in this study. They were divided into 6 subgroups:

a) 31 bilingual children in Dutch and Brazilian Portuguese (3;5 – 7;1 years; months old) raised in the Netherlands;
b) 33 bilingual children in Brazilian Portuguese and Dutch (4;7 – 7;1 years; months old) raised in Brazil;
c) 43 Dutch monolingual children (3;9-6;5 years; months old);
d) 14 Dutch monolingual adults (19-35 years; months old);
e) 26 Brazilian Portuguese monolingual children[2];
f) 13 Brazilian Portuguese monolingual adults (23-27 years; months old).

There are two groups of bilingual children involved in this study, one of which was raised in the Netherlands and one of which was raised in Brazil. I will refer to the children in group (a) as the Dutch bilinguals and to the children in group (b) as the Brazilian bilinguals.

All the bilingual children were exposed to both their languages from birth. There is, however, a large amount of variation in language dominance. Later in this section I will discuss the language background of the bilinguals, which will make this difference more clear.

Dutch bilinguals and monolinguals were all tested in the Netherlands whereas Brazilian bilinguals and monolinguals were all tested in Brazil. When addressing the individual groups further in this section, I will also describe in more detail the circumstances in which the participants were tested.

Bilingual and monolingual children were matched for age and all participants were matched for social background and place of residence. Sex has not been controlled for.

In Chapter 2 we have seen that there is a significant difference in the realizations of /ɑ/ and /aː/ among the various Dutch regions, even when only the standard language is taken into account. It was not possible to limit our subjects to one specific area because we wanted to include as many bilinguals as possible. In order to control for geographical variation, and to avoid differences not due to our crucial variable (namely bilingualism) the Dutch participants were carefully matched for their place of residence. Speakers of Dutch dialects other than the standard language and people who reported a high degree of exposure to these dialects were not included in this study. Figure 3.1 illustrates the geographical spread of Dutch bilingual and monolingual children and Dutch adults.

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[2] The data including the ages of the BP monolingual children have been lost. on average, however, Brazilian monolingual children were about the same age as Brazilian bilingual children, and were never older than 7 years of age or younger than 4 years of age.

Figure 3.1: Geographical spread of Dutch bilingual children, Dutch monolingual children and Dutch monolingual adults. In the figure each symbol (x, o or -) represents one participant.

For the participants in Brazil, control for geographical variation was less stringent, given the size of the country. Although bilingual children come from various areas in Brazil, the monolinguals come from two main regions: Northeast (Teresina) and Southeast (São Paulo and Campinas). This diversity, however, does not seem to pose a problem. As previously mentioned there has been little to no regional variation signalled in the literature of the target vowel (/a/) among the different regions of Brazil.

3.1.1 Dutch bilingual children

There were 31 children in this group and their ages ranged from 3;5 to 7;1 years of age. All children in this group were tested at their homes in the Netherlands.

Most of the Dutch bilingual children were recruited through *Curumin*, an online community for Brazilian parents raising their children in the Netherlands. The majority of the parents spontaneously responded to a call advertisement. Others were approached individually by the author and were asked for their collaboration.

The children in this group come mainly from mixed families in which typically the mother was Brazilian and the father was Dutch. In only two of the families both parents were Brazilians, in which case Dutch input came from the speech community, such as day-care centres, school and neighbourhood. In all other cases one parent was a native speaker of each language. In general Dutch-speaking parents had little to no knowledge of Brazilian Portuguese whereas all BP-speaking parents knew at least some Dutch. The language of interaction between the parents was often Dutch. Most of the children had access to Brazilian TV shows or books. A few children had contact with Brazilian peers, but even in these cases the language of interaction was often Dutch.

Although exposed to both languages from birth, the Dutch bilingual children were all Dutch dominant. They could all understand Portuguese, but differed greatly in proficiency. Some of them would reply only in Dutch to the bilingual researcher whilst others could perfectly carry a conversation in BP, and in doing so were apparently indistinguishable from monolingual Brazilian children.

All the children in this group came from a mid to high social background in which at least one of the parents had some kind of higher education.

3.1.2 Brazilian bilingual children

There were 33 Brazilian bilingual children in this study with an age range between 4;7 and 7;1 years. The children in this group were tested in Brazil at their school in a quiet room, with the exception of one child who was tested at home. Although their test settings differ from that of the Dutch bilingual children, I do not expect this to be a major influence. School settings are usually more formal than home settings. The schools these children attended, however, were small-scale ones with a great degree of interaction between parent and teacher and between child and teacher.

The children were recruited through 5 Dutch schools in Brazil, located in 5 different cities: Unaí (Minas Gerais), São Paulo (São Paulo), Carambeí, Arapoti and Castrolanda (Paraná). Contrary to the children in the Dutch bilingual group, the Brazilian bilingual children typically came from families where both parents were bilinguals. All the children in this group were born and brought up in Brazil.

These children all had some Dutch input at school by a native speaker, either as a Dutch Language course or (partially) as language of instruction. Additionally since many of these children were brought up in cities recently founded by Dutch immigrants, it was not uncommon for them to have some contact with Dutch speakers outside their home or school.

This group also showed great variation in language dominance, as shown by the results of their vocabulary tests in each language. Although these children were closer to being linguistically balanced than the Dutch bilinguals, they were still BP dominant.

3.1.3 Dutch monolingual children

For this study I tested 43 Dutch monolingual children whose age ranged between 3;9 and 6;5 years. All Dutch monolingual children where tested at their homes in the Netherlands.

In order to recruit Dutch monolingual children for this study I contacted several schools in the cities where the Dutch bilinguals had already been tested. All parents of potential participants received a letter about the research and were asked to contact the researcher if they wanted to take part. The children were all monolingual speakers of standard Dutch whose parents were Dutch native speakers.

Similarly to the Dutch bilingual children, the Dutch monolingual children came from families in which at least one of the parents had some higher education.

3.1.4 Dutch monolingual adults

The 14 Dutch monolingual adults in this study had an age range between 19 and 35 years and were all tested in a quiet room at Utrecht University.

There are very few true monolinguals in the Netherlands as English is an obligatory subject at schools. For the purpose of this study I consider anyone with no regular interactive exposure to any language or dialect other than standard Dutch to be monolingual. Exposure to the English language by TV, music, and books has been disregarded.

Participants in this group were university students. Students of linguistics and students of a foreign language were not included. They all lived in or around Utrecht at the time of the testing, but were of various origins within the Netherlands, so as to match the bilingual children, as explained previously (see Figure 3.1). Condition for their participation was that they had been brought up in the target area, and that they had not been living away from that area for longer than 2 years. They all considered themselves native speakers of standard Dutch.

3.1.5 Brazilian monolingual children

Out of the 26 Brazilian monolingual children, 10 come from Teresina – PI, in the Northeastern part of Brazil, and 16 come from Campinas – SP, in the Southeast. The children in Teresina were tested in their homes whereas the children in Campinas were tested in their school or daycare centers.

Testing in schools was the most efficient way of accessing the target population. Two schools took part in the study . One was the University of Campinas school / daycare center, intended for the children of employees of the university. The second was a private school / daycare center located in a middle-class neighborhood of the town. A drawback of testing in schools is that little is known about these children's background as there was no direct contact with the parents.

All children were born and raised in the place where they were tested and were not exposed to any language other than Brazilian Portuguese.

3.1.6 Brazilian Monolingual Adults

All 13 participants in this group were university students in either São Paulo (USP) or Campinas (UNICAMP). Like the Dutch adults, they all had some exposure to English, although none to a high degree. They had all been living in the place where they were tested for at least one year. Participants in this group were tested in a quiet room in the university they were attending.

3.2 Perception task

In this study, I use a perception experiment to measure the cue weighting of bilingual and monolingual children and adults. As discussed in Chapter 1, cues are very small and specific concepts, which make it possible to look into category formation in great detail. Specifically in the case of Dutch, cue weighting has been shown to develop very gradually. Gerrits (2001) shows that children up to the age of 9 years old still have not reached the adult-like cue-weighting for two consonant contrasts (/ʃ/ - /s/ and /p/ - /k/) and for the /ɑ/ - /aː/ vowel contrast. This allows researchers to work with relatively old children, who can easily perform perceptual tasks while we are still able to follow their development.

In this section I give a detailed description of the perception experiment used to tap participants' cue weighting. Firstly I will present the stimuli and their manipulation (Section 3.2.1), followed by a description of the procedure used (Section 3.2.2).

3.2.1 Stimuli

The stimuli used in this experiment are 12 synthesized vowels, manipulated in two dimensions, a spectral one (F1 and F2) and a durational one. The vowels are synthesized in such a way as to range from the Dutch /ɑ/ to the Dutch /aː/ using some of the acoustic space reserved for the BP /a/.

Flege et al (1997) have operationalized the use of multiple cues in speech perception research by manipulating vowel contrasts in different acoustic dimensions, in their case, specifically vowel spectrum and duration. A series of three vowel continua were created for the English *beat* - *bit* (/i/ - /ɪ/) and *bat* - *bet* (/æ/ - /ɛ/) contrasts. For each contrast they developed three continua in which spectrum was manipulated in 11 steps by means of linear interpolation of the endpoints of the continua. Each of these three continua had different vowel durations. Following Bohn (1995) one continuum contained 11 relatively short vowels (138 ms); one continuum contained 11 vowels with an intermediate length (190 ms); and one continuum contained 11 relatively long vowels (233 ms). These continua were presented to native speakers of English, German, Spanish, Mandarin, and Korean. All non-native speakers of English were L2 learners of this language. To compare the different groups, Flege *et al.* calculated what they called a *spectral effect* and a *duration effect* for all groups based on their response to the continua. For the calculation of s*pectral effect* they subtracted the percentage of *beat* (or *bat*) responses given to the /ɪ/ (or /ɛ/) endpoints from the percentage of *beat* (or *bat*) responses given to the /i/ (or /æ/) endpoints.

This value was averaged over the three vowel durations. Similarly for calculating *temporal effects* the percentage of *beat* (or *bat*) responses given to the vowels with short duration was subtracted from the percentage of *beat* (or *bat*) responses given to the vowels with long duration. This value was then averaged over the 11 spectral steps. This procedure allows for a quantification of the use of different cues involved in one contrast. One should note, however, that in this method only the responses at the edges of the continua (and thus not the full matrix) are taken into account.

Escudero & Boersma (2004) used the same procedure to calculate what they called *cue reliance* (in this case, *duration reliance* and *spectral reliance*). Escudero & Boersma however chose to manipulate duration and spectrum in equal steps. It had been previously suggested that in designs like the one used by Flege et al (1997) where one dimension is manipulated in more steps than another dimension, listeners could rely more strongly on the cue which is varied the least (Bohn 1995).

The procedures used by Flege *et al.* (1997) and by Escudero & Boersma (2004) have been criticized by Morrison (2005). Morrison claims that when calculating these variables using only the responses at the edges of the continua, valuable information is lost. He then suggests an alternative method, using complete matrices to calculate logistic regression coefficients. Consequently the number of stimuli (and information) is increased. In a reply to Morrison, however, Boersma & Escudero (2005) show that, although logistic regression is a very good method and slightly more accurate, the previously used 'edges difference ratio' method does not present any real problem. Both methods revealed namely very similar results.

In this study I have chosen to work with an incomplete matrix in a fashion similar to that of Flege *et al.* (1997) and Escudero & Boersma (2004). Although an incomplete matrix might provide slightly less accurate results than a complete matrix would, it has the great advantage of reducing the number of stimuli. Working with a small number of stimuli is particularly important when testing children, since they have a short concentration span. In the next paragraph I will explain how the stimuli were manipulated in order to achieve the (incomplete) matrix used in this study.

Stimulus manipulation

To choose the beginning and end points of the continua, i.e. the typical Dutch vowels, a series of 37 vowels were synthesized based on the acoustic values presented by Adank *et al.* (2004). The synthesis was made through a Praat script (Boersma & Weenink 2006), similar to the one that would create the final stimuli, where spectrum and duration were manipulated. More detail about the script is given later in this section. These 37 vowels were presented to 10 native speakers of Standard Dutch, students of Utrecht University in an identification task, combined with a judgment of goodness experiment, in a 5-point scale. The exemplars with the highest score in correctly identified tokens were chosen as the prototype vowels /ɑ/ and /aː/ that would serve as the beginning and end points of the continua. Table 3.1 shows duration, F1 and F2 for all 12 vowels used in the experiment. Figure 3.2 shows the 12 vowels inserted within an F1 x duration space.

F1/F2 (Hz)	*Stimuli*			
687/1099	ɑ	2	3	4
725/1168	5	-	-	6
763/1236	7	-	-	8
801/1308	9	10	11	aː
Duration (ms):	*96*	*123*	*158*	*203*

Table 3.1: Duration, F1 and F2 values for the 12 synthesized vowels used in the perception experiment.

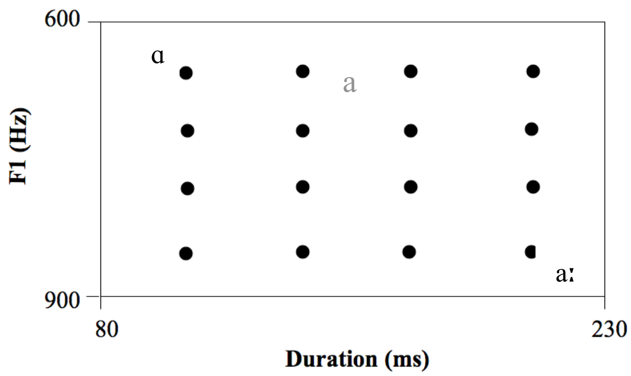

Figure 3.2: The 12 synthetic vowels used in this experiment in comparison to the Dutch and BP low vowels on an F1 x Duration plot. Values for Dutch vowels are the ones used in the current study. Values for BP vowel (grey in the figure) are taken from Rauber (2006).

The stimuli were synthesized using a Praat (Boersma and Weenink 2006) script, where duration and spectrum vary in 4 equal steps. Duration ranges from 96 ms to 203 ms; F1 ranges from 687 Hz to 801 Hz; and F2 from 1099 Hz to 1308 Hz. In order to create stimuli that sound as natural as possible, there is a gradual F0 drop in all stimuli going from 150 Hz at the beginning to 100 Hz at the end. F3 co-varies as a function of F2; F4 co-varies as a function of F3, etc. Amplitude was kept constant. A copy of the script is given in Appendix A. Figure 3.3 shows the spectrogram of the two end points of the continua /ɑ/ and /aː/.

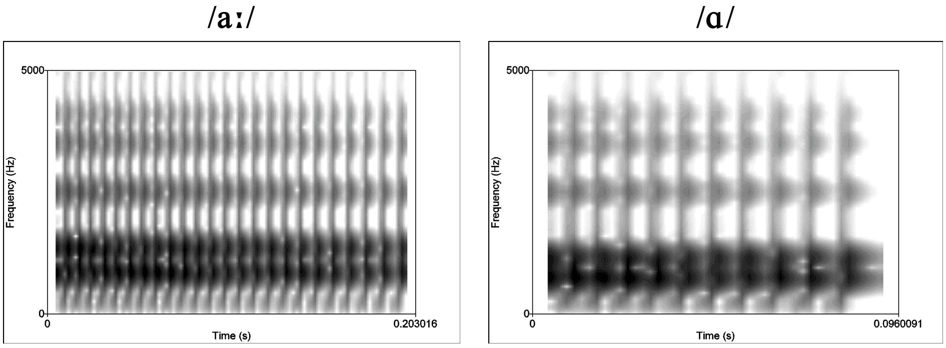

Figure 3.3: Spectrogram of the end points of the synthetic stimuli used in this study .

3.2.2 General procedure

Bilinguals and monolinguals participated in an XAB experiment. They were presented with three tokens in a row (X, A, and B) and had to decide whether the first token (X) matched the second (A) or the third sound (B). X was any of the 12 tokens shown in Figure 3.2. A and B were each of the end points of the continuum, i.e. one of the two Dutch vowels (marked in Table 3.1 as /ɑ/ and /aː/).

Generally speaking, the cognitive load of an XAB[3] experiment (or AXB for that matter, as they are basically the same task) is too high for children in the age group tested. For this reason, I have adapted the task in such a way as to make it resemble a computer game.

The game features 3 characters, the Teacher / Master (*de Meester*), Danny and Donny. The participants were first introduced to the three characters. Subsequently they were told that the Teacher (who, in the XAB experiment, produces the X sounds) would speak and Danny (A) and Donny (B) would try to repeat what he had said. The characters' lips would move when a sound was played. The participant's task was to decide who had repeated the sound that the teacher had produced correctly. Adults simply clicked on either Danny or Donny with the mouse. Children could choose to either manipulate the mouse themselves or to point at the screen. The children who wanted to use the mouse themselves, but nevertheless showed clear difficulties in its manipulation, were asked to point to their answers. In this case, the experimenter would operate the mouse. If pointing, the child was asked to do it in such a way as to (nearly) touch the screen in order to avoid an experimenter bias. Figure 3.4 presents a screen shot of the task / computer game.

[3] The choice for XAB over ABX or AXB was made to make the task less abstract for children.

Figure 3.4: Screen shot of XAB perception task used in this experiment.

As there were different experimenters and different locations, instructions for experimenters and parents / teachers were standardized and are presented respectively in Appendix B and Appendix C.

Before the test actually started, there was a short training period, using spectrally different synthetic vowels: /i/ and /u/. These vowels were synthesized with the same Praat script but with values for these two vowels. Duration was not manipulated. During the training, X was identical to either A or B, which means that there was actually a right or wrong answer. Children and adults received feedback for their answers only during the training. The training trial was repeated for as many times as necessary for the child to give the right answer twice consecutively. For the adults only one training trial was necessary as the methodology was very easy and the vowels used were clearly distinct from each other.

For the actual experiment, each of the 12 target stimuli was presented four times in four blocks. After every trial the child received a word of encouragement (for instance, "very good!" or "well done!"), which was pre-recorded and part of the game. This was done in order to keep providing the children with naturally produced speech input during the experiment.

There was an interval of 1500 milliseconds between the stimuli in order to access participants' phonemic perception as opposed to their phonetic perception (Werker & Logan 1985). The intervals between the trials were not timed, and in the case of the children, the experimenter was the one to decide when the next trial should come. Usually that would be immediately after the child gave her answer and heard the word of encouragement.

At the beginning of the test, children received a card with four empty slots. The children were told that they were to receive one sticker four times if they got all the answers correct, one for every empty slot, and that once their card was full they would receive a small gift. There were three reasons for this. First of all to keep the children motivated to respond as accurately as possible. The second reason was to provide them with something to do during the break and avoid giving them time to get tired or bored. Finally, once more, this was done to maintain steady natural language input during the experiment. The adults received neither a card nor stickers. They were encouraged to take breaks between the blocks, but could go straight on if they wished.

One test session including training would take between 10 and 15 minutes for adults and between 20 to 35 minutes for the children.

The test was done using a Macintosh laptop, either an iBook, a Powerbook or a MacBook. We used a Fostex PH-50 amplifier, which was plugged into the computer, and two Beyerdynamic DT250/80 headphones, one for the child and one for the experimenter. Our pilots had shown that the children felt less motivated during the test if there was no one to "play the game" with them. For adult participants only one headphone was plugged into the amplifier as they performed the test single-handed.

The tests were conducted in different locations. In the case of Dutch children (bilingual and monolingual) and Brazilian monolingual children, they were tested at either their own homes or in a few cases, the home of one of their friends. Brazilian bilingual children were tested at their schools / day-care centres and adults at the university. Some of the test locations were quieter than others, but always as quiet as possible, usually in a living room where only the child and the experimenter were present. None of the participant groups were tested in a soundproof room.

Bilingual children and Dutch monolingual children and adults performed the same perception task under three different settings. The setting manipulation was done so as to affect the bilinguals' Language Mode through careful control of the researcher (always a native speaker of one language or the other) and the language being used by the experimenter and the test. Although monolinguals are not expected to show a Language Mode effect their test setting was manipulated as well in order to keep bilingual and monolingual testing situations as similar as possible. I will discuss the details of this manipulation in Chapter 6 where I address the Language Mode issue.

3.3 Vocabulary test

In addition to the perception task, bilingual and monolingual children took a vocabulary test. As discussed in the previous chapter, it has been suggested that vocabulary size affects sound categorization (Werker *et al*. 2002.) Additionally the test has been used for the bilingual children as a way to estimate their language dominance, as they answered the test in both of their languages.

The basis for the test was the Dutch *Taaltoets alle kinderen* (TAK, Verhoeven & Vermeer 2001), a language test used for assessing Dutch language proficiency in native and foreign children. The bilingual population targeted by the TAK however is mainly that of Arabic background, since this is the most important immigrant group in the Netherlands. A careful analysis of the TAK reveals that it was not suitable for the purpose of the current study. The vocabulary test I used was then developed especially for this study bearing in mind the specific groups to be tested, namely bilingual children in Dutch and Brazilian Portuguese. It was designed in such a way as to avoid words that sounded similar in both languages in order to avoid triggering effects. I also excluded words that lacked a one-to-one correspondence between the languages.

It has long been claimed in the literature that bilinguals often differ on their proficiency / dominance of each of their languages in the different domains (e.g Fishman 1965). This is closely related to the setting where each of the languages is learnt. So in the traditional home / school language context it is to be expected that children will be more proficient in one language in home related vocabulary, and in their other language in school related vocabulary. Therefore the words used in this test have been carefully controlled to include a range of difference domains (school, home, food/drink, animals, and residual). Each of these domains includes 10 words varying in their frequency. The frequency has been measured based on the Dutch spoken corpus (*Corpus Gesproken Nederlands,* Piepenbrock 2000).

A first version of the vocabulary test included 80 items and was piloted among 60 children (5;0 - 7;12) and 8 adults. Out of the original 80 items, 40 items were selected. The selection of the items was based on their reliability. The final test including the 40 items reached a reliability of 0.9. Appendix D shows the answer sheet used by the experimenters to note participants' answers.

3.4 Summary

In this chapter I described the details of the experiment used in the current study such as the participant groups, their background, and the procedure and stimuli / items used for both the perception experiment and the vocabulary task. In the next series of chapters I will present the results of these tests, relating them to the research questions which have been stated in Chapter 1. The next chapter (Chapter 4) addresses the question whether bilingualism plays any role in the representation of phonological categories by comparing the perception of bilingual children to that of monolingual children and adults, addressing the language dominance issue.

4 PHONETIC DETAIL IN BILINGUALS' PERCEPTUAL CATEGORIES

This chapter aims at answering questions concerning the phonetic detail in bilingual children's sound categories. To this end I compare bilingual children's perception to that of monolingual children and adults. The two groups of children have been carefully matched and only differ from each other in terms of bilingualism. This way we can observe two similar groups of developing children and what is assumed to be their end state, the adults. A second issue addressed in the current chapter concerns the role played by language dominance in bilinguals' sound categorization. I also compare bilinguals to each other. Specifically I investigate differences and similarities in the perceptual behaviour of two groups of bilingual children, who differ from each other in terms of the language they are dominant in.

All participants have been tested using the same methodology and the same stimuli, namely the Dutch /ɑ/ - /aː/ contrast. In order to reach adult-like perception of this contrast, Dutch infants must acquire the acoustic cues involved in the contrast and learn to adjust the correct weight of each of them. This task is supposedly more complex for bilingual children due to their dual language exposure and possible interaction between their languages. It is therefore possible that bilingual children need a more extensive period of time than monolingual children in order to acquire adult-like perception. This is especially true in the case of the bilinguals who are non-dominant in Dutch since their input is reduced.

In the first section of this chapter (Section 4.1) I discuss the perception of the /ɑ/ - /aː/ contrast by Dutch children (Section 4.4.1), focusing on the use of spectral and durational cues, which allows me to make some predictions concerning bilinguals' perception (Section 4.4.2). In 4.2 I return to the general question I try to answer in the current chapter, as well as more specific ones, regarding discrimination abilities (Section 4.2.1) and phonetic detail (Section 4.2.2) in bilingual and monolingual children. Although the details of the experimental methodology have been described in the previous chapter, I summarize it here (Section 4.3) to allow the reader to better understand the way results were computed and analyzed. In Section 4.4 I present the results and discussion involving the contrast discrimination. Section 4.5 deals with the extent to which participants rely on spectral and durational cues in the perception of the contrast, allowing us to quantify the phonetic information in their categories. In Section 4.6 I give a general discussion, combining issues which had been addressed in the previous sections. The chapter is closed with a brief summary of the main findings (Section 4.7)

4.1 Perceptual acquisition of the /ɑ/ - /aː/ Dutch contrast

Numerous phonetic studies have shown that the vowels of the Dutch /ɑ/ - /aː/ contrast differ in terms of spectrum as well as duration (e.g. Nooteboom 1972) and that Dutch listeners use both these cues in their perception (e.g. Nooteboom & Cohen 1995, van Heuven, van Houten & de Vries 1986). Van Heuven *et al.*, however, show that although both cues are used, Dutch listeners weight spectral information more heavily than durational information. Moreover, Nooteboom & Cohen notice an asymmetry in the perception of the contrast when only their duration is manipulated: synthetically shortening /aː/ leads to the perception of /ɑ/; conversely, synthetically lengthening /ɑ/ does not lead to the perception of /aː/, but to a long version of the short vowel /ɑ/. These results suggest that durational cues alone are not sufficient information for the perception of the contrast.

In terms of development this means that to acquire the /ɑ/ - /aː/ contrast in an adult-like fashion, Dutch children must acquire both acoustic cues involved, spectrum and duration. Moreover, they need to acquire the correct weight for both cues, so as not to over- or under-use each of them.

In the next section I briefly discuss the literature on the acquisition of durational and spectral cues by Dutch children, with a particular focus on the acquisition of durational cues, since this cue presents more controversial results. Importantly, all languages of the world use spectral cues to differentiate their vowels. This is not true for duration and in this respect vowel duration is a marked cue.

4.1.1 Native acquisition of durational and spectral cues

Numerous studies show that infants are aware of spectral differences between the vowels of their native language from a very early age (e.g. Werker & Tees 1984)[4]. Results concerning the age at which durational cues are acquired are less straightforward. Some studies suggest that children as young as 18 months of age are aware of the use of duration to cue contrast in their language (Dietrich, Swingley & Werker 2007); other studies show that children up to 5 years of age still do not have the durational cue in place (Heeren 2006). In the next paragraphs I will address these studies and their contradictory findings.

Despite the marked nature of durational cues, Dutch-acquiring children seem to be aware of the relevance of this cue in contrasts of their native language at a very young age. Dietrich *et al*. (2007) tested 18-month-old Dutch and Canadian-English (CE) children on their perception of a series of /tVm/ syllables. They used a word-learning task, where vowel duration varied in a ratio of 2:1. All groups of infants were presented with three different types of stimuli: (1) Dutch-sounding stimuli varying in duration (‘t[ɑ]m’ vs. ‘t[ɑː]m’); (2) CE-sounding stimuli varying in duration (‘t[æ]m’ vs. ‘t[æː]m’); and (3) native vowel quality contrasts (‘t[ɑ]m’ vs.

[4] In fact, most of the studies discussed in Chapter 1 regarding the perceptual acquisition of vowels were done with vowels that differ from one other spectrally.

't[ɛ]m' for Dutch and 't[æ]m' vs. 't[ɛ]m' for CE). Only Dutch children showed an effect of duration. This was the case for the Dutch sounding-syllables as well as for the CE-sounding syllables. When tested on spectral contrasts (set 3 of stimuli) the two language groups showed effects of similar magnitude in differentiating the syllables. Their results suggest that only Dutch children were able to use durational cues in word learning. This is especially interesting considering that CE infants *are* able to discriminate vowels varying in duration (Dietrich *et al.* refer to R. Mutigani, F. Pons, C. Dietrich, J. Werker, and S. Amano's unpublished data). These children just do not seem to be able to use this discrimination ability in word learning. Dutch children on the other hand have no problem with the task.

Dietrich *et al.* discuss two possible explanations for this difference between Dutch and Canadian children. The first one is a vocabulary-driven cue-acquisition hypothesis. According to this hypothesis the presence of minimal-pairs in the vocabulary of Dutch children would lead their attention to the importance of duration in contrasting meaning in their native language. Dutch child picture books routinely contain pictures of highly frequent nouns such as *man* (m[aː]n) 'man' and *maan* (m[ɑ]n) 'moon', suggesting that children will be used to the contrast from a very early age onwards. Apart from, perhaps the 'm[aː]n' – 'm[ɑ]n', however, eighteen-month-old children have nearly no minimal pairs in their productive vocabulary containing the /ɑ/ - /aː/ contrast, as shown in two different databases, the Dutch version of the MacArthur-Bates Communicative Development Inventory (CDI, Fenson, Dale, Reznick, Bates, Thal & Pethick 1994, Swingley 2003) and the Levelt-Fikkert database (Fikkert 1994, Levelt 1994). This gap in children's vocabulary renders the vocabulary-driven hypothesis very unlikely.

The second explanation Dietrich *et al.* entertain is related to distributional learning. Maye *et al.* (2002) have shown that infants are able to observe the frequency with which the sounds of the language around them are produced, and use this ability in category formation. Exposure to a bimodal distribution of tokens varying in duration by Dutch (but not Canadian) children, would lead them to the formation of two durational categories, long and short. Dietrich *et al.* point out, however, that child-directed speech reveal a great deal of overlap in durational properties between different productions of the Dutch /ɑ/ and /aː/, resembling a unimodal distribution. The nearly unimodal distribution of durational properties of the Dutch vowels also makes this second hypothesis as questionable as the first one.

The ability of 18-month-old Dutch children to use durational cues in word learning was left unexplained by Dietrich *et al.* The evidence strongly supports the idea that it is a linguistic fact, since the language these children were exposed to (Dutch or English) was a relevant variable. Somehow these Dutch children pick up the information provided by their input language that duration is a relevant acoustic cue in their language, and use that information to learn new words. They are able to use duration only to split the acoustic continuum into two categories. The details of what provides these children with that kind of information, however, are still uncertain.

Interestingly the pattern shown by the Dutch children tested by Dietrich *et al.* differs from that of Dutch adults. Dutch adult listeners do not perceive a lengthened [ɑ] as [aː] (although they do perceive a shortened [aː] as [ɑ], Nooteboom & Cohen 1995), as the children in Dietrich *et al.*'s studies do. Moreover, many cue integration studies have shown that Dutch adults do not commonly use duration only to cue the /ɑ/ - /aː/ contrast. Typically they integrate durational and spectral cues in the perception of the contrast (see e.g. Brasileiro 2004, Gerrits 2001, Nooteboom 1972). Only under certain circumstances are Dutch adults able to use duration only to cue this contrast. The Dutch adults (but not all children) in Heeren's (2006) study, for instance, were able to perceive the /ɑ/ - /aː/ contrast based solely on duration when presented with spectrally ambiguous vowels. It seems then that the role of durational cues will be especially important when the primary cue for the contrast, spectrum, is ambiguous.

Cue-weighting studies have suggested that children are more consistent in their responses when multiple cues are congruently integrated than when a single cue is manipulated (Hazan & Barrett 2000). Along these lines, Van Alphen, de Bree, Gerrits, de Jong, Wilsenach & Wijnen (2004) found that the 4-year-old children in their study are able to consistently classify the /ɑ/ - /aː/ continuum when both spectral and durational cues are manipulated. Studies using stimuli where both cues are simultaneously manipulated, however, are not able to tell us how children integrate these cues. For this we need cue-weighting studies where cues are individually manipulated, such as those performed by Gerrits (2001) and Heeren (2006), which will be discussed in the next paragraph.

Gerrits (2001) compared the perception of the Dutch /ɑ/ - /aː/ contrast by Dutch children in three age groups (4, 6, and 9 years old) to that of adults. Her results showed that the younger children, 4- and 6-years old, weighted spectral information less heavily than adults did. There was however no difference between children and adults in their use of durational cues. Gerrits interpreted this finding as meaning that the cue weighting of duration had already been acquired by all three groups of children. Heeren (2006) however points out that in Gerrits's stimuli, formant frequencies varied along a 7-step continuum whereas duration was binarily distributed, either short or long. This difference in the number of steps for each cue may have led participants to treat the stimuli differently (similar claims were previously made by, for instance, Bohn 1995 and Escudero & Boersma 2004). The very exposure to the stimuli during the experiment may have led participants to form two durational categories, considering that durational cues were bimodally distributed, contrary to spectral cues. Consequently, one cannot conclude that children classified the duration dimension in the same fashion as adults did.

A more direct investigation of the acquisition of durational cues in the /ɑ/ - /aː/ contrast was carried out by Heeren (2006). In her experiments Heeren used a continuum with ambiguous spectral characteristics where duration was manipulated in 7 steps. Heeren tested two groups of children (5- and 7-year-olds) as well as adults. The adults and the 7-year-old children in Heeren's study were able to disambiguate the spectral cue and identify the /ɑ/ - /aː/ contrast on the basis of duration only. About half of the 5-year-olds however were not able to comply with the task as they reported always hearing the short vowel (/ɑ/) even for the longest end point of the continuum. This suggests that the youngest group of children were not using durational cues in an adult-like way. The same 5-year-old children who had not been able to use duration only to perceive the /ɑ/ - /aː/ contrast were tested once again 9 months later. Heeren found that more children were able to identify the contrast (15 out of 22 as opposed to 12 out of 22 on the same test 9 months earlier) and that children became more consistent in their responses with age. However still 7 out of 22 children had not mastered the use of duration in an adult-like fashion when identifying the contrast. These results are not in line with Gerrits' finding that by 6 years of age children are already adult-like in their use of durational cues. These contradictory findings are probably related to the difference in stimulus manipulation, as previously discussed. Comparing the two studies, Heeren (2006) suggests that young children may pay more attention to spectral than to durational information, as the young listeners in Gerrits' study were able to classify the continuum, which varied in 7 spectral steps and 2 durational ones. This is in line with the results for adult Dutch listeners, who weight spectral cues more heavily than duration cues (van Heuven *et al.* 1986). Heeren concludes that the youngest children in her study might have had difficulties in classifying her stimuli as their attention was directed to the more prominent spectral cues, which were ambiguous in her study.

Additional evidence for late acquisition of durational cues in the /ɑ/ - /aː/ contrast comes from production studies. In Clement & Wijnen's (1994) study, 4-year-old children's productions of [aː] vowels were about 1.54 times longer than their short counterpart [ɑ], whereas in adults the ratio was 1.75. Similarly, Kuijpers (1993) found that Dutch children increase the duration difference between the short and the long vowel, as they grow older.

Interestingly, older children seem to have problems with the perception of the /ɑ/ - /aː/ contrast when only durational cues are manipulated (compare the 5-year-olds in Heeren's study with the 18-month-old children in Dietrich *et al.*'s study). There are three possible explanations for this discrepancy. The first one is related to the lexicon. The response options in Heeren's study were existing words (namely *m*[*ɑ*]*n* 'man' and *m*[*aː*]*n* 'moon') whereas Dietrich *et al.* worked with non-words. Possibly the children in Heeren's study were accessing lexical information, which is already phonetically specified, even if its details are still under development. The young children in Dietrich *et al.*'s study, on the other hand, were dealing with non-words and hence did not have to deal with any lexical effect. Secondly there was a task difference between the studies: Heeren tested her children with an identification task while the children in Dietrich *et al.*'s study were tested on their discrimination. Task difference has been shown to yield different results for similar groups (see the discussion in Chapter 2, section 2.2.2 on this subject). A third possible explanation is an age effect. Language exposure has a facilitative effect in perception which is still active throughout childhood (Sundara *et al.* 2006). We can assume that the phonetic details of 18-month-old children categories are less specified than those of 5-year-old children, which allows for more flexibility in the perception the former group. This is similar to Werker *et al.* (1981) and Werker & Tees' (1994) findings for infants' cross-linguistic perception: very young infants are able to perceive non-native contrasts whereas older ones are not. Werker and colleagues suggest that this loss of perceptual sensitivity is related to infants' tuning to their native language. Similarly, it is possible that younger children, although aware of the use of duration for word forming, allow for more cue variation than older children, since they are still at the beginning of the acquisition process.

In sum, studies investigating the perception of the /ɑ/ - /aː/ continuum are somewhat inconclusive. The two studies involving the perception of the /ɑ/ - /aː/ contrast by children in which single cues are manipulated (Heeren 2006 and Gerrits 2001) have contradictory results. Gerrits suggests that children acquire adult-like use of spectrum between the ages of 6 and 9 and adult-like use of duration before age 4. Heeren shows that by 5 years of age most children are not able to use durational information, even in spectrally ambiguous stimuli. The two studies however differ crucially in their stimuli. Gerrits presented her participants with two continua of unambiguous duration where spectrum varied in 7 steps; Heeren uses one continuum of ambiguous spectrum where duration varies in 7 steps. Bohn (1995) has suggested that in an experimental set, participants are likely to pay greater attention to the cue which is least varied: in Gerrits' study that was duration; in Heeren's study that was spectrum. This might explain why the children in Gerrits' study used more durational cues than the children in Heeren's study. In the design of the current study special attention was paid to this issue, and both spectral and durational cues were varied in an equal number of steps, avoiding possible effects of the type noticed by Bohn (1995). Similar designs were used in, for instance, Brasileiro (2004) and Escudero (2005).

4.1.2 Predicting bilingual acquisition of durational cues

To my knowledge no study has directly investigated the perceptual acquisition of durational cues in simultaneous bilinguals. There is however some evidence pointing to a late bilingual acquisition of durational cues from a production study by Kehoe (2002). Kehoe investigated the vowel production of German-Spanish bilingual children and their monolingual peers. Like Dutch, German has a distinction between short and long vowels whereas Spanish (like Portuguese) does not. The bilingual children in Kehoe's study were less consistent in their production of the length contrast than the monolingual children. Kehoe's findings are somewhat in line with perceptual studies of bilinguals, suggesting a later acquisition of speech sounds in bilingual as compared to monolinguals (Bosch & *Sebastián-Gallés* 2003, Sundara *et al.* 2006).

In the first chapter of this dissertation (Section 1.4.3) I have discussed the issue of bilingual perceptual acquisition. One of the points I made there is that bilinguals' input is more complex than that of monolinguals, given that they have to deal with more variability in the input with less exposure. Bilinguals' input is more variable because they have to deal with variability within each language and between the languages, considering a certain degree of overlap between the sounds of both languages. Bilinguals' exposure is lessened since exposure to more than one language usually means less exposure in each language. Possibly this extra complexity leads bilinguals to need a longer period of time to acquire the sounds of their languages. This extra complexity might lead bilinguals to be somewhat later in the acquisition of durational cues than monolinguals. I will return to the issue of bilingual delayed acquisition of speech sounds further in Chapter 5 of this dissertation.

4.2 Research questions

In the current chapter I look into the phonetic detail of bilinguals' and monolinguals' sound categories. The carefully manipulated design allows me to compare bilinguals' categories to those of monolinguals' as well as children's categories to those of adults'. To this end, I tested the perception of the /ɑ/ - /aː/ Dutch contrast in a cue-weighting design by Dutch-Brazilian Portuguese (BP) bilingual children as well as by adults and children who are monolingual speakers of Dutch and BP. The ultimate question I try to answer here is the following: *do bilingual children develop similar perceptual categories to those of monolingual children?*

In order to draw the complete picture, I will compare bilingual and monolingual children in two levels of analysis: firstly in their ability to discriminate the contrast and secondly in their use of acoustic cues, or cue reliance, when perceiving the contrast. Additionally to a comparison between bilingual and monolingual children, I will also investigate the differences and similarities between monolingual Dutch children and adults. Although monolingual children do not form the main research group of my study, it is crucial to know how they will perform in this task in order to understand the results of the bilingual children. Specifically, to be able to draw any conclusion about a possible effect of bilingualism, any difference found between bilingual children and monolingual adults has to be ruled out as being a consequence of the fact that their acquisition is still in progress. Another reason to test monolingual children is that Gerrits's (2001) and Heeren's (2006) studies were left inconclusive concerning children's use of durational cues due to differences in methodology, as previously discussed. The current study might shed some light on this issue. A third group to be taken into account in this study is that of the monolingual BP listeners. Knowing what these listeners do with the foreign sounds /ɑ/ and /aː/ will possibly help us better understand bilinguals' behaviour.

In the following sections, sections 4.2.1 and 4.2.2, I will dissect the general question stated above into more specific ones, each followed by a prediction of what the findings might be. The questions addressed here are related to the discrimination of the contrast as well as to bilinguals' and monolinguals' specific use of durational and spectral cues.

4.2.1 Differences and similarities in the discrimination of the /ɑ/ - /aː/ contrast

The first topic I address concerns participants' abilities to discriminate the /ɑ/ - /aː/ contrast. Specifically, I investigate possible differences between bilinguals and monolinguals and between children and adults on the accuracy of their responses to the end points of the continuum (average /ɑ/ and /aː/, see Figure 3.1 for reference). The specific questions are spelled out below.

Do children differ from adults in their discrimination abilities?

Overall Dutch native participants are expected to have no trouble discriminating between the sounds, including the monolingual and bilingual children. For one thing, children in this study are on average 5;5 years old (the youngest is 3;5) and at this age they have already acquired many lexical items containing the contrast. Words like /mɑn/ 'man' and /maːn/ 'moon' are very frequent input for normally developing children (see for instance the study by Heeren 2006 who used these words to elicit children's responses). Moreover the acoustic differences between the stimuli used in this study are fairly prominent, which should enhance discrimination.

Although all native Dutch listeners are likely to be good discriminators, the literature suggests possible differences between the groups. As thoroughly discussed in the literature (see Chapter 1 for a review) language exposure plays a crucial role in phonetic perception. Hence, we expect monolingual Dutch adults to show a better discrimination of the contrast than children, whether monolingual or bilingual.

Are bilingual and monolingual children equally good discriminators?

Previous studies on the discrimination of sound contrasts by bilingual children have pointed to a possible bilingual delay (Sundara *et al.* 2006). Therefore it is possible that monolingual children in this study are in a more advanced stage in their perceptual acquisition than the bilingual children. We should consider that part of the input bilinguals are receiving (their BP input) does not have the contrast being investigated, which is a Dutch native contrast. This means that bilinguals' exposure to the contrast is lessened when compared to that of monolinguals. This difference is even greater for the bilingual children being raised in Brazil since their exposure to Dutch is reduced. Consequently we expect monolinguals to outperform the bilinguals on their discrimination abilities. This difference should be even stronger between the Brazilian bilinguals and the Dutch monolinguals.

Are monolingual BP listeners able to accurately discriminate the Dutch foreign contrast?

There are different predictions one can make about the discrimination abilities of monolingual BP listeners depending on how they categorize the Dutch vowels. The Perceptual Assimilation Model (PAM, Best 1995) distinguishes three possibilities for processing non-native sounds: (1) they can be assimilated by one of the native categories, possibly differing in the degree to which they deviate from the category they have been assimilated to; (2) they can be assimilated as non-categorized sounds; or (3) they can remain unassimilated, i.e. not perceived as speech.

For each of these possible patterns the model predicts a degree of discriminability as presented in Table 4.1 below (adapted from Best 1995).

Type of assimilation	**Description**	**Discrimination**
1. Two-category assimilation	Each of the foreign sounds is assimilated to a different native category	Excellent
2. Difference in degree of deviation from native category	Both foreign sounds are assimilated by the same category but differ in the degree of deviation	Reasonable - very good
3. One-category assimilation	Both foreign sounds are assimilated by the same native category and equally deviate from it	Poor
4. Uncategorized	Both sounds are left uncategorized	Poor - very good
5. Categorized and uncategorized	One of the sounds is assimilated as a native category and the other is left uncategorized	Very good
6. Unassimilated	Sounds are not perceived as speech	Good - very good

Table 4.1 – Predictions of the *Perceptual Assimilation Model* (Best 1995) on the degree of discriminability between foreign sounds.

Despite these very specific predictions made by the PAM it is not possible to predict exactly how well monolingual BP listeners will discriminate the contrast, as we do not know how they will categorize the Dutch sounds. Considering the vowel inventory of both languages one possible strategy is to assimilate the Dutch /aː/ to the native BP /a/ and the Dutch /ɑ/ to the native BP /ɔ/. This would be a case of two-category assimilation and the discrimination of the foreign sound would be perfect. Another possible strategy is that both Dutch vowels are assimilated by the same BP vowel (/a/) and both sounds deviate from the BP vowel or, more probably, one of the vowels (/aː/) is considered a better exemplar than the other. In the former case discrimination would be poor and in the latter discrimination would be good.

Since we do not know how BP monolinguals categorize the Dutch vowels, no prediction can be made regarding their degree of discriminability. I will return to this issue in section 4.3.1 when discussing the results for discrimination.

4.2.2 Differences and similarities in cue reliance in the perception of the /ɑ/ - /aː/ contrast

Bilingual and monolingual children and adults were studied on their use of acoustic cues for the perception of the Dutch /ɑ/ - /aː/ contrast, and how much they rely on each kind of cue: spectral or durational ones. Investigating participants' use of spectrum- and duration reliance in their perception allows us to look into the phonetic detail of their sound categories.

Have 5;6 year-old children reached adult like spectrum- and duration reliance?

The previously mentioned studies by Gerrits and Heeren point to a possible difference between children and adults in their use of acoustic cues. It was suggested that up to the age of 6 children had not yet acquired spectral (Gerrits) or durational reliance (Heeren) in an adult-like fashion. Considering these findings, it is likely that children's categories are not yet phonetically specified to the same level of detail as that found in adults' categories. Specifically this predicts that children and adults will differ in their spectrum reliance as well as their duration reliance.

Are there differences between monolingual and bilingual children in their use of spectral and durational cues?

Making predictions for bilinguals' perceptual performance in this specific case is tricky as there have been no cue-weighting studies investigating the perception of simultaneous bilinguals. One possible outcome of this study is that bilinguals' and monolinguals' categories qualitatively differ from each other as the consequence of interaction between the bilinguals' two native languages. There is however a strong body of evidence suggesting that bilinguals' languages develop autonomously (see e.g., Genesee 2001, de Houwer 1990, 2005 and Meisel 2001 for reviews), rendering this possibility unlikely.

Moreover, most studies on bilingual perceptual development suggest that bilinguals may be delayed when compared to monolinguals (Bosch & Sebastián-Gallés 2003, Sundara *et al.* 2006), but eventually catch up. Considering this proposed bilingual delay, one of the possible outcomes of the current study is that bilingual children's spectrum and duration reliance will differ from monolingual children in that they deviate even more from monolingual Dutch adults than monolingual Dutch children do.

In production, bilingual children have been shown to be delayed specifically in the use of the cue which is not present in one of their languages (Kehoe 2002). Dutch-BP bilinguals lack durational cues in part of their language input since BP does not use duration to cue phonemic contrasts. Therefore it is possible that the deviation in bilingual children's categories when compared to monolingual adults will be greater for durational cues than in the perception of spectral cues.

Following this reasoning we might also make a specific prediction for the results concerning the bilingual children being brought up in Brazil. If lack of positive evidence leads to delay in the perception of durational cues in bilingual children, this effect is likely to be stronger in the bilingual children growing up in Brazil than in the ones growing up in the Netherlands since the former children receive more BP and less Dutch input than the latter.

Are monolingual BP listeners able to use spectral and durational cues in their perception of the Dutch contrast?

One of the most important findings of cross-language perception research is that speech sound perception is modulated by the native phonological inventory. Similarly I expect monolingual BP listeners to process Dutch vowels based on the BP vowel inventory.

As previously discussed, we cannot be sure about how exactly BP monolingual listeners categorize the Dutch vowels. The two proposed possibilities were the 'two-category assimilation' and the 'one-category assimilation' (Best 1995). The 'two-category assimilation' path would lead BP monolinguals to overuse spectral information to perceive the Dutch /ɑ/ - /aː/ contrast since vowel duration is not used phonemically in their language. In the 'one-category assimilation' scenario it is unclear how BP listeners would make the contrast, what cues they would use and how much of each. It is, however, probable that in this situation BP listeners might use some durational cues to perceive the contrast, since spectral information only would not be enough to disambiguate the vowels.

4.3 A brief description of the experimental procedure

This section briefly summarizes the methodology used in the current study. For a more detailed description the reader is referred to Chapter 3.

Monolingual and bilingual children and adults were tested on their perception of the Dutch /ɑ/ - /aː/ contrast. They participated in an XAB categorical discrimination task where X could be each of 12 synthesized vowels ranging in spectrum and duration from /ɑ/ to /aː/. A and B were the end points of the continuum, which correspond to average tokens of each of the two vowels.

Six different groups were tested, for a total of 130 participants:

1. 43 Dutch monolingual children;
2. 31 bilingual children in Dutch and Brazilian Portuguese raised in the Netherlands, so-called Dutch bilinguals;
3. 33 bilingual children in Brazilian Portuguese and Dutch raised in Brazil, so-called Brazilian bilinguals;
4. 26 Brazilian Portuguese monolingual children;
5. 14 Dutch monolingual adults;
6. 13 Brazilian Portuguese monolingual adults.

Only participants who had a minimum of 75% correct answers to stimuli at the end points of the continuum (/ɑ/ and /aː/) were considered in the analysis[5]. This is one objective way of disregarding participants who were not attentive during the test or who could not perceive the contrast accurately. This meant that the following number of children were dropped from further analysis: 10 Dutch monolingual children (out of 43, or 23%); 7 Dutch bilingual children (out of 31, or 22%), 15 Brazilian bilingual children (out of 33, or 45%) and 11 BP monolingual children (out of 26, or 42%). All adults reached the criteria and thus none had to be dropped.

These new groups of children are overall older than the ones including all the children. The age means for each group of children before and after application of the 75% criterion are given in Table 4.2.

	Before 75% criterion		**After 75% criterion**	
	N	**Age mean**	**N**	**Age mean**
Dutch monolingual	43	5;2	33	5;4
Dutch bilingual	31	5;4	24	5;7
Brazilian bilingual	33	6;0	18	6;8
BP monolingual[6]	26	-	15	-

Table 4.2 – Number of participants and mean age per group of children before and after applying the 75% criterion. The 75% criterion means that only children who gave a minimum of 75% accurate responses to stimuli at the end points of the continuum were considered for the analyses.

In Table 4.2 we can see that both the bilingual and the monolingual Brazilian children have a much higher drop-out rate than the Dutch bilingual and monolingual children. Moreover we see that the Brazilian bilingual group is also older than the Dutch children. The age difference is a statistically significant one ($F_{2,69} = 6.164$; $p < 0.01$) and will be taken into account in the analysis of the data.

For a more detailed and extensive description of the experimental design see Chapter 3 in this dissertation.

4.4 The discrimination of the /ɑ/ – /aː/ contrast

To measure possible differences between the groups we have computed an A' (or A-Prime) score for each individual based on their responses to stimulus 1 (average Dutch /ɑ/) and to stimulus 12 (average Dutch /aː/, see Table 3.1 for reference). A' is an index of sensitivity representing participants' *hit* rate as a function of their *false-*

[5] Studies on cue weighting acquisition usually choose an arbitrary criterion of 80% accuracy (e.g. Nittrouer 1996). Given the number of stimuli in this study (8) I have approximated this criterion down to 75%, which means 2 innacurate answers.

[6] The data including the age of the BP monolingual children have been lost. On average however they were about the same age as the bilingual BP children.

alarm rate (Grier 1971)[7], which means that participants' answers are corrected for bias. A-Prime values range from 0 to 1, where 1 represents an ideal score and 0.5 is chance. Calculating A-Prime scores allows me to make a more direct comparison between the results in this study and results in other studies involving bilingual children, such as that of Sundara *et al.* (2006), which also used A-Prime.[8]

The average A-Prime value per group is displayed in Figure 4.1, yielding perfect scores for both groups of adults, and nearly perfect scores for the groups of bilingual and monolingual children[9].

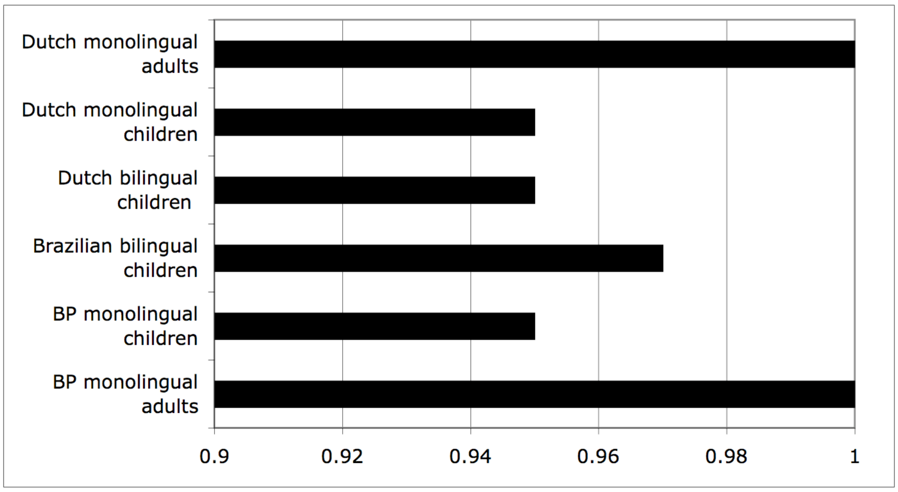

Figure 4.1 – Average A-Prime score of all groups of participants.

The A-Prime scores were analyzed with a one-way ANOVA, revealing a significant group effect ($F_{5,125} = 5.03$, $p < 0.001$). Subsequent analyses (Tukey HSD) show that BP and Dutch adults do not differ from each other, and all 4 groups of children were clustered together in one subset.

To further investigate which factors play a role in participants' discrimination of the contrast, I ran a regression analysis with the following dummy variables: (1) Child (child / adult); (2) Bilingualism (bilingual / monolingual); (3) Nativeness (Dutch native / Dutch non-native); and (4) Raised in the Netherlands (raised in the Netherlands / raised in Brazil). The model including these 4 variables was

[7] In this study, a hit (H) was the proportion of /ɑ/ answers to stimulus 1 and a false-alarm (FA) was the proportion of /A/ answers to stimulus 12. The formula used was A'=0.5+[H-FA)(1+H-FA)/(4H(1-FA))].
[8] I am aware of the fact that the XAB task used in the current study is a not a discrimination task. Nonetheless I have chosen to take a first look at the data in this way in order to make my results comparable to those reported on other bilingualism studies. The strongest conclusions taken in this chapter, however, are not based on the results for discrimination.
[9] The reader should remember that only participants who gave at least 75% accurate responses to the end points of the continua were included, which led to these high discrimination rates.

significant ($F_{4,126}$ = 6.337, p = 0.00, R Square = 0.167). The coefficient of each variable is presented below in table in Table 4.3.

	Unstandardized Coefficients		
Model	**β**	**Std. Error**	**Sig.**
(Constant)	0.982	0.019	0.000
Child	-0.050	0.010	0.000
Bilingualism	0.005	0.013	0.672
Nativeness	0.016	0.019	0.406
Raised in the Netherlands	0.014	0.015	0.359

Table 4.3 – Coefficients of regression analysis with A-Prime as dependent variable.

As we can read from the table, the only significant factor in the model is the child factor ($p < 0.001$). Children have an overall lower A-Prime score than adults. Importantly bilingualism is not a relevant factor and there is no difference between bilingual and monolingual children.

4.4.1 Discussion

There are three important conclusions to be drawn from these results, concerning the BP monolinguals, the children, as compared to adults, and the bilinguals, as compared to monolinguals. I will discuss each of these issues separately, relating them to the questions proposed in section 4.2.1.

Discrimination of a Dutch contrast by BP monolingual listeners

The results of the BP monolingual listeners seem at first to be a surprise. We see BP adult listeners very accurately perceiving the contrast, just as accurately as Dutch adults; and we see BP monolingual children patterning with Dutch children. Accurate perception in this case however is one of the possibilities clearly predicted by the PAM's (Best 1995) two-category assimilation scenario (see Table 4.1). Many BP monolinguals, children as well as adults, reported hearing /a/s and /ɔ/s during the task. The discrimination of the contrast is in this case predicted to be excellent as each of the foreign sounds is assimilated by a different native category. This was however not the case for all participants. About one-third of the BP monolingual children reported that the two vowels (/ɑ/ and /aː/) were exactly the same and could not discriminate between them. Importantly, none of the Dutch native children (bilingual or monolingual) showed this pattern. These responses showed by this one-third of the BP children suggest a case of one-category assimilation, predicted by the PAM to lead to poor discriminability. The results of these children were not included in the analysis as they were not able to perform the task. This means that the results presented in Figure 4.1 overestimate the discriminatory abilities of BP children. Therefore the claim that there are no differences between BP monolingual children and native Dutch children should be carefully interpreted.

Although no BP adult has explicitly reported patterns of one-category assimilation (i.e. none report not perceiving the contrast), if it is found in the children, it is likely to have been found in the adults as well, in which case they would develop another strategy to deal with the task. I will return to this issue further in this chapter, after discussing the cue reliance results.

Differences between children and adults

Monolingual and bilingual children of about 5;5 years of age are not able to discriminate the Dutch /ɑ/ - /aː/ contrast as accurately as adults. This might come as a surprise considering that vowels are usually acquired very early in life, which should lead to early adult-like discrimination. The children in this study had indeed acquired the vowels being tested and knew numerous lexical items containing each of them, as shown by their results in the vocabulary test. But the question here was about their perception when omitting lexical information. In this case children were not able to perform as well on the task as adults did.

Although very young infants have been shown to be able to discriminate contrasts in their native language (e.g. Werker *et al.* 1981), results showing an increase in discrimination abilities as a function of age have been found in a number of studies (e.g. Kuhl & Meltzoff 1996, Sundara *et al.* 2006), suggesting that language exposure plays a facilitative effect throughout childhood. A linguistic explanation for this difference is that children are less sensitive to small changes in the speech signal than adults are, as suggested by Hazan & Barrett (2000). This means that they will pick up less information from the acoustic signal. I will return to this issue in the next section (4.5), when discussing the cue reliance results.

There are, however, a number of extra-linguistic factors that could explain why children performed worse than adults. For instance it might be claimed that some of the children in the study simply did not understand the task and were aimlessly clicking buttons. This is very unlikely since the children were carefully instructed prior to the actual task and would only proceed if they had been able to correctly perform it with vowels that clearly differ from each other (/i/ and /u/). Only when it was unmistakable that the children had understood the task would the experiment proceed using the target contrast. Another factor that is more likely to have played a role in these results is the difference in concentration span between children and adults. Although the task was not excessively long and most children seemed to actually enjoy it, it is possible that some of the children lost their concentration part way through the task, which would lead to less accurate results. This problem is however inherent in studies comparing children and adults on their performance of any task. Although this factor probably has played a role, it is not likely to have been overwhelming, considering, as previously mentioned, that most children seemed to pay attention to the task. Moreover, to filter out a possible interference from differences in concentration span, only participants who accurately identified at least 75% of the end points of the continua were considered in the analysis. Any effect of the extra-linguistic factors discussed here has been reduced to the minimum and hence the suggestion that the differences in discrimination abilities between children and adults are a linguistic reality still holds.

The role of bilingualism in contrast discrimination

Most perception studies done with simultaneous bilinguals suggested that bilingual children lag behind monolingual children in the acquisition of discrimination abilities in their native contrast. In this study however bilingual and monolingual children showed similar patterns. Even the bilinguals who were brought up in Brazil and were dominant in BP showed no signs of perceptual delay in the discrimination of the contrast as compared to monolingual children. Sundara *et al.*'s (2006) findings on bilingual delay are not confirmed in my results. It is always difficult, however, to trace direct parallels between different studies as they differ in methodology, stimuli (consonants vs. vowels), etc. This is especially true in studies involving bilinguals, considering the great heterogeneity in this population. A very important difference between the current studies and that of Sundara *et al.* concerns the vowels under investigation and their distributional properties in each language, a factor shown to play a crucial role in contrast discrimination (Meye *et al.* 2002). I will return to this in the general discussion, at the end of this chapter.

Moreover it is possible that the lack of difference in discrimination abilities between bilingual and monolingual children in this specific case is the consequence of the vowel inventories of the bilinguals' languages, Dutch and BP. We have seen that BP monolingual adults and children are able to accurately perceive the contrast, patterning respectively with Dutch adults and children. There is indeed quite a large group of Brazilian monolingual children unable to discriminate the contrast, but the ones who did discriminate it, performed similarly to Dutch children. In the next section I suggest that these BP monolingual children are using different strategies than Dutch children to perceive the contrast. It is then possible that bilingual children are taking a 'side track' similarly to BP children, achieving the same end through a different path.

4.5 Cue reliance

To calculate the perceptual reliance on spectrum and duration, I followed the same analysis as used in Bohn (1995), Flege *et al.* (1997) and Escudero & Boersma (2004). I calculated participants' reliance on spectral differences to perceive the vowel contrast, i.e. *spectrum reliance*, by subtracting the percentage of /ɑ/ responses of the top horizontal edge of the continuum from the percentage of /ɑ/ responses of the bottom horizontal edge (see Figure 3.1 in Chapter 3 for reference). The value was then averaged across the number of tokens in each row (4 in this case). Similarly, *duration reliance* was computed by subtracting the percentage of /ɑ/ responses of the right vertical edge of the continuum from the percentage of the left vertical edge. This value was also averaged across the number of tokens in each column (4). Figure 4.2 displays the means of spectrum reliance and duration reliance for all 6 groups.

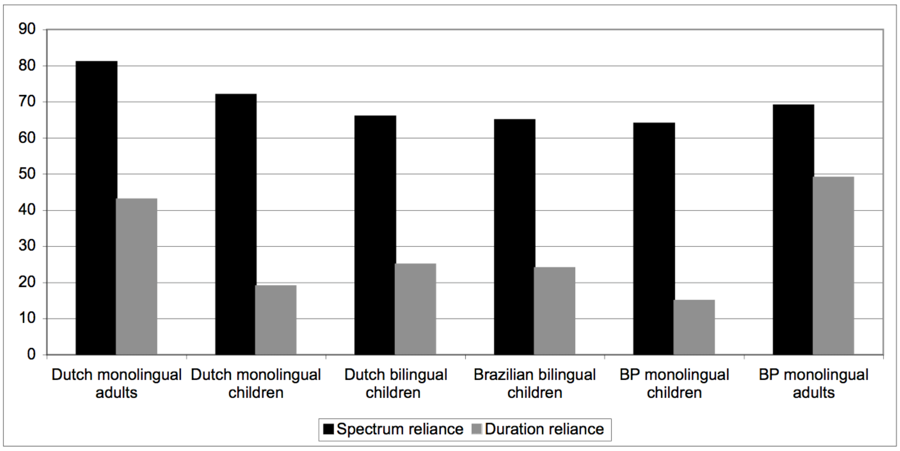

Figure 4.2 – Average spectrum reliance and duration reliance of all groups of participants.

Spectrum reliance and duration reliance were analyzed with the GLM Repeated measures procedure of SPSS. There was one within-subject factor (cue) with two levels (spectrum and duration), and one between-subject factor (group) with six levels (bilingual children in Brazil, bilingual children in the Netherlands, monolingual Dutch children, monolingual BP children, monolingual Dutch adults and monolingual BP adults).

The results reveal a significant effect of the "cue" factor ($F_{1,125} = 112.826$; $p = 0.00$; MSE = 856.064). A Tukey HSD post hoc test shows two homogeneous subsets, one formed by the bilingual and monolingual children and another one formed by the Dutch and BP adults. This suggests that children, regardless of whether they are bilingual or monolingual, make less use of speech cues to perceive vowel contrasts than adults do. There was no interaction between cues and groups.

The monolingual BP adults and children reveal interesting results as they seem to pattern with Dutch adults and Dutch children respectively even though they have never had any contact with the Dutch language or the contrast being tested. There are however crucial differences between the way the Dutch natives and the BP monolinguals process the contrast. In the next section (4.5.1) I will specifically address the perception of the BP monolinguals.

4.5.1 Cue reliance of BP Monolinguals

The results for cue reliance in Figure 4.2 reveal another interesting issue. When comparing all groups, we notice that BP monolinguals show a relatively high use of spectrum, which is similar to what Dutch adults do, even though they have never been exposed to any Dutch. On the other hand, we also see BP adults making more use of duration in absolute values than Dutch adults, even though duration is not used as a phonological cue in that language.

To better understand how BP monolingual listeners categorize the Dutch foreign sounds, I look at a similar study done with second language learners. Brasileiro & Escudero (2006) tested 22 Brazilian L2 learners of Dutch using the same methodology and stimuli as the ones used in the current study. Their results show that compared to Dutch natives, L2 learners overuse durational cues, using even more durational than spectral cues in their perception of the /ɑ/ - /aː/ contrast. To illustrate the differences between the groups the results presented in Figure 4.2 are repeated below in Figure 4.3 including for comparison the results of the L2 learners.

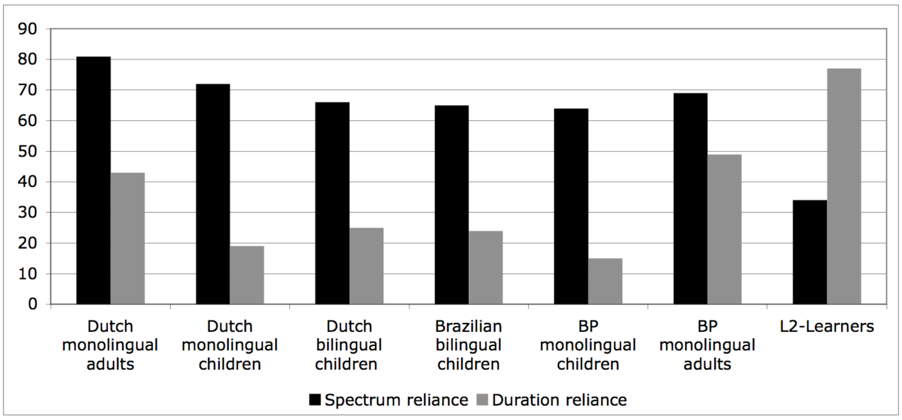

Figure 4.3– Average spectrum reliance and duration reliance (as shown in Figure 4.2) including the averages of Brazilian L2-Learners of Dutch for comparison (Brasileiro & Escudero 2006).

The most striking difference is that L2 learners show inverse use of the cues: whereas all groups tested in this study (even the BP monolinguals) rely more on spectrum than on duration to perceive the contrast, the L2-learners rely more on duration than on spectrum. An Analysis of Variance (ANOVA) reveals a difference between the groups for both variables: spectrum reliance ($F_{6,145} = 7.627$; $p = 0.00$) and duration reliance ($F_{6,145} = 19.561$; $p = 0.00$). A Tukey HSD post-hoc test confirms that the L2 learners differ both in spectrum and duration reliance from the Dutch and BP monolingual adults. Additionally they do not pattern with either child group, suggesting that their development towards the Dutch adult norm is behind that of the Dutch-acquiring children.

The overuse of durational cues by the Brazilian L2-learners of Dutch could not be straightforwardly traced back to their L1 because, as we have seen, Brazilian Portuguese does not use duration to cue contrasts. In fact, the monolingual BP listeners who participated in the current study, both children and adults, still use more spectral than durational cues when perceiving the contrast, which is closer to the Dutch adult norm than what the L2-learners are doing. This could actually lead one to assume that contrast perception is regressing as a function of language exposure. Brasileiro & Escudero, however, explain the difference between the L2 learners and the monolingual Dutch and the similarity between BP monolinguals and Dutch monolinguals by assuming different categorization strategies, along the lines proposed in Escudero (2005). The two strategies depend on how the vowels are being assimilated (as discussed in 4.2.1, when making predictions about BP listeners' discrimination abilities) and are illustrated below in Figure 4.4.

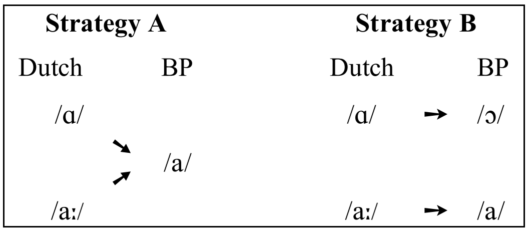

Figure 4.4 – Categorization strategies where two Dutch vowels are either mapped onto one (Strategy A) or two BP vowels (Strategy B).

In categorization strategy A, the two Dutch vowels /ɑ/ and /aː/ are both mapped onto one single BP vowel, the acoustically close /a/. In this case, participants will have to rely on durational differences between the vowels to perceive the contrast. Further in this section I will argue that this reliance on duration is an extra-linguistic, (semi-) conscious skill. In strategy B, the two Dutch vowels are mapped onto two distinct vowels, /aː/ to /a/ and /ɑ/ to /ɔ/. In this case the contrast spectrum reliance is enough to efficiently perceive the contrast.

Duration reliance in BP monolinguals

The fact that BP monolingual listeners relied so strongly on duration is an interesting issue that needs further explanation. This reliance cannot be directly traced back to their native language because Brazilian Portuguese does not use duration to cue vowel contrasts.

It has been suggested that the fact that BP adults are able to use duration in the perception of the foreign Dutch contrast is not an extra-linguistic strategy, but possibly a consequence of a training effect: exposure to durational variation during the experiment would lead them to set categories apart on the basis of duration (Escudero, personal communication). As a whole however the distribution of the stimuli was more compatible with a unimodal distribution than a bimodal one, since the entire continuum was presented in exactly the same frequency. A unimodal distribution of the sounds would lead participants not to perceive the contrast instead of facilitating it (Maye *et al.* 2002).

It is possible, however, that a few participants did have a more bimodal distribution of the stimuli at the beginning of the experiment, since the order of stimuli presentation was random. To control for this, I have compared the answers to stimulus 4 and stimulus 9 on the first and on the second half of the experiment for each participant (see Table 3.1 for reference). Stimulus 4 is spectrally equal to /ɑ/ but with duration values compatible with /aː/; conversely, stimulus 9 has the same spectral values as /aː/ and the same duration values as /ɑ/. If exposure to the stimuli during the experiment were to play a role in facilitating duration use, we would expect participants to give more /aː/ answers to stimulus 4 on the second half of the experiment than they did on the first half; similarly we would expect participants to give more /ɑ/ answers to stimulus 9 on the first half of the experiment than on the second half. This was not the case, however, and participants' responses were virtually identical on the both halves of the experiment.

Bohn (1995) suggests that the duration reliance by non-native listeners is the consequence of a general speech perception strategy. In this view listeners will use durational cues whenever spectral cues do not provide sufficient information. If we were to assume duration reliance in BP listeners to be a general speech perception strategy, however, we would have to explain why so many BP children were not able to do that and failed to comply with the task. Conversely I suggest that duration reliance in BP listeners is an extra-linguistic skill and that BP monolingual children, due to general cognitive constraints, do not have that skill and hence could only perform the task under strategy B.

The suggestion of differences in perceptual strategies as illustrated in Figure 4.4 and the use of duration reliance as an extra-linguistic skill account not only for the data presented in Figure 4.2 but also for the great number of BP children who dropped out of the experiment, reporting that they always heard the same vowel. Recall that about one-third of the BP monolingual children tested in the /ɑ/ - /aː/ showed this pattern. I suggest that these children were mapping both Dutch vowels onto their native /a/ (strategy A) and were not able to pick up on durational information, since duration is not a cue used in BP to contrast sounds. Even among the children who did perform the task, a large number had problems perceiving the contrast accurately, as shown by a high proportion of children who did not reach the 75% accuracy criterion: compare the 23% and 22% of drop-out rates among respectively the Dutch monolingual children and the Dutch bilingual children to the 42% among the BP monolingual children; the case of the Dutch bilinguals will be discussed in Section 4.6.1 and that of the Brazilian bilinguals, who also show a high drop-out rate, will be discussed in Section 4.6.2.

It could be hypothesized that the reason why BP monolinguals use duration is an experimental artefact: since the durational differences between the two vowels being tested were so great (2:1) this could lead participants to start using durational information simply because the information was prominently available. To investigate this, BP monolinguals have been tested on a native contrast where duration was manipulated.

Testing monolingual BP listeners on a native contrast

Adult and child monolingual speakers of BP were tested on the BP native contrast /ɔ/ - /o/. The methodology used was identical to the one used in the rest of this study (see Chapter 3 and / or section 4.3 in this chapter). Also the stimuli were synthesized in a similar fashion. Firstly 10 vowels were synthesized with acoustic values (F1 and F2) presented in the literature for BP /ɔ/ and BP /o/ (Fails & Clegg 1992). These vowels were used in an identification plus judgment of goodness task. Ten BP monolingual adults, students of the University of Campinas participated in this study. The tokens with the highest score for correct identification for /ɔ/ and for /o/ were chosen as the end points of the continuum.

For the main experiment a series of 12 stimuli were synthesized where spectrum and duration were manipulated in 4 equal steps ranging from the average /ɔ/ to the average /o/. For the synthesis I used the same Praat script as had been used for the /ɑ/ - /aː/ manipulation (see Chapter 3 for a more detailed description of the script). Although BP does not use duration phonemically I introduced an artificial length distinction between the vowels so as to simulate the /ɑ/ - /aː/ Dutch contrast. In this experiment /o/ was twice as long as /ɔ/.

These new stimuli were inserted into the same task used with the /ɑ/ -/aː/ contrast. Nineteen Brazilian children and 12 Brazilian adults were tested. Their spectrum and duration reliance on the perception of the native /ɔ/ - /o/ contrast was computed similarly to the /ɑ/ -/ aː/ contrast. Their results are illustrated in Figure 4.5.

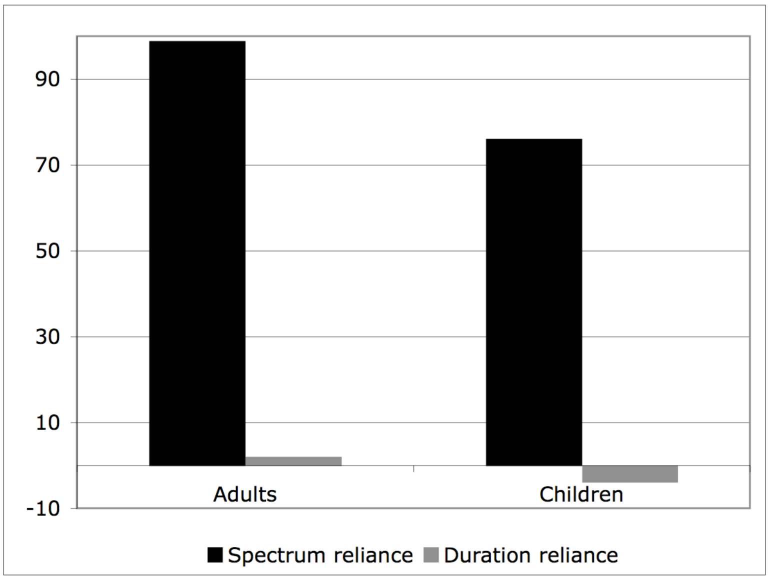

Figure 4.5 – Mean Spectrum reliance and duration reliance for Brazilian monolingual adults and children on their perception of the /ɔ/ - /o/ native contrast where one of the vowels (/o/) was lengthened.

The data illustrated in Figure 4.5 clearly show that BP monolinguals make virtually no use of durational cues when tested on a native contrast. When spectral information is unambiguous, i.e., when there is a perfect spectral match between the foreign and the native vowels, BP monolinguals will rely solely on this cue to perceive the contrast. This means that at least to some listeners, the /ɑ/ - /aː/ contrast was spectrally ambiguous, in which case they used duration to make the contrast. Many BP children were not able to disambiguate the /ɑ/ - /aː/ contrast by using duration and had to be dropped from the experiment (these were the children who reported hearing /ɑ/ and /aː/ as the same vowel). The adults however had no problems with it.

Discussion

The results presented in the current section suggest that BP monolingual children and adults use different strategies when perceiving the Dutch foreign sounds. There is no perfect acoustic match between the stimuli used in the task and their native vowel inventory. Consequently we find a number of listeners using durational cues, an acoustic cue not used in their native language, in order to sort out the ambiguity in the contrast. Importantly, it is only in this kind of situation that BP listeners rely on duration. When tested with contrasts that spectrally match their categories, they make no use of durational cues I have suggested that duration reliance in BP listeners is a (semi-)conscious strategy, which requires some degree of cognitive development still lacking in many children.

In an alternative account, adult Brazilian listeners might be relying on duration because vowel duration is a relevant cue in BP. Escudero, Boersma, Rauber & Bion (under review) analysed the acoustic characteristics of BP's 7 oral vowels as produced by 20 native speakers, 10 males and 10 females, from São Paulo. All vowels were produced in stressed position in dissyllabic words. Their results show that duration significantly differs between the vowels, in that low vowels are longer than high vowels. The effect of height in vowel duration is a widespread phenomenon (see for instance Lehiste 1970) but seems to be even stronger in BP, leading Escudero *et al.* to suggest that BP might have phonologized vowel duration. Their results, however, present no direct evidence for this claim. Nonetheless, it is possible that this intrinsic difference in duration put BP listeners on the right track when perceiving the Dutch vowels. If we assume a one-way category assimilation scenario (Best 1995; see also categorization strategy B described above) the fact that BP /a/ is longer than BP /ɔ/ might trigger the use of duration.

In the next sections, the use of spectral and durational cues will be analyzed separately so that we can take a more detailed look into the differences and similarities between the groups. BP monolinguals have been excluded from the analysis but I will refer to the findings discussed here when necessary.

4.5.2 Spectrum reliance: results from monolingual and bilingual native speakers of Dutch

Mean spectrum reliance for monolingual and bilingual native speakers of Dutch is repeated below in Figure 4.6[10].

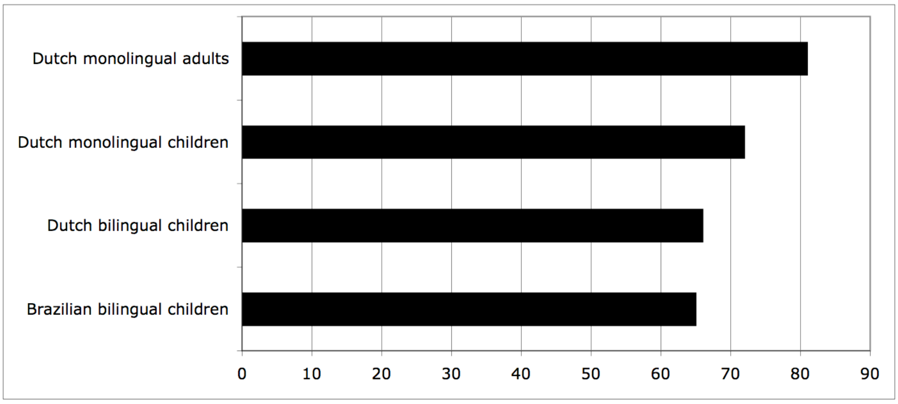

Figure 4.6 – Average spectrum reliance of monolingual Dutch adults, monolingual Dutch children, bilingual Dutch children and bilingual Brazilian children.

An analysis of variance reveals that spectrum reliance does not differ significantly between the groups, but there is a certain tendency for deviation ($F_{3,99} = 2.29$; $p = 0.08$).

To identify the factors behind the variation between the groups found in spectrum reliance a regression analysis was carried out, including 3 of the dummy variables described previously ('Child', 'Bilingualism', and 'Raised in the Netherlands'[11]) as well as different combinations of these factors: 'Child raised in the Netherlands', 'Bilingual raised in the Netherlands' and 'Bilingual Child'. Since the previous analysis suggests that age plays a relevant role in cue reliance (as we have seen that adults have an overall higher cue reliance than children) we have included the variable 'age' in the model. To account for different age effects between the groups, age has been specified per group.

Table 4.4 displays the coefficients of the variables included in the model ($F_{7,86} = 3.82$, $p = 0.001$, R Square = 0.236). 'Bilingualism' and 'Bilingual Child' were automatically discarded from the model, which means that being a bilingual, or more specifically, being a bilingual child, does not add to the variation in spectrum reliance. Also the variable 'Child Raised in the Netherlands' was automatically excluded, suggesting that children raised in the Netherlands do not necessarily have higher spectrum reliance than children raised in Brazil.

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[10] The results displayed in Figure 4.6 are a subset of the results in Figure 4.2.
[11] Dummy variable 'Nativeness' was excluded since all groups analyzed were native speakers of Dutch.

	Unstandardized Coefficients		
Model	**β**	**Std. Error**	**Sig.**
(Constant)	-9,656	39,818	0,809
Raised in NL	78,063	46,038	0,094
Child	-57,682	31,291	0,069
Bilingual raised in NL	31,087	32,291	0,355
Age in children	0,884	0,333	0,009
Age in bilinguals	-0,591	0,477	0,219
Age of participants raised in NL	-0,581	0,615	0,347
Age	0,65	0,621	0,298

Table 4.4 – Coefficients of regression analysis with spectrum reliance as dependent variable.

Out of the 7 factors included in the model, the only significant one is children's age ($p < 0.01$). It is noteworthy that age is only a relevant factor within the groups of children: the older a child is, the higher the spectrum reliance. This correlation does not hold for the adults. These results suggest a development in the use of spectrum reliance, which is still taking place within the groups of children. Moreover, the data suggest a tendency for children overall to use spectrum less than adults ($p = 0.069$) regardless of whether they were monolingual or bilingual, raised in Brazil or in the Netherlands[12].

Discussion

The data illustrated in Figure 4.5 suggest a trend within the group of children that did not reach significance level in the ANOVA. Specifically we see that spectrum reliance decreases as a function of estimated amount of Dutch input: the children that are expected to have the most Dutch input, the Dutch monolingual children, have the highest spectrum reliance among the children. Following the monolingual children we have the two groups of bilingual children, very close to each other. The children with the least Dutch input, the Brazilian bilingual children, have the lowest values for spectrum reliance, slightly lower than those of the Dutch bilinguals. Amount of input has not been quantified in this study so we cannot directly address questions concerning the role of this factor.

Investigating the role of input

To indirectly investigate the relation between spectrum reliance and amount of Dutch input, I specifically consider the children's results for spectrum reliance. A new regression analysis was carried out including the following factors: 'Age', 'Bilingualism', 'Raised in the Netherlands', 'age', 'Vocabulary in Dutch',

[12] The possible tendency of 'Raised in the Netherlands' on participants' spectrum reliance will be discussed in Section 4.5.5.

'Vocabulary in BP'. Vocabulary in Dutch and vocabulary in BP are the results of the vocabulary test described in Chapter 3. We added the results of the vocabulary tests in the model as an implicit control for proficiency. The model was significant ($F_{5,67} = 2.47$; $p < 0.05$, R Square = 0.116) and all variables were included. The coefficients are presented in Table 4.5.

	Unstandardized Coefficients		
Model	**B**	**Std. Error**	**Sig.**
(Constant)	5.926	22.584	0.794
Bilingualism	-17.797	9.524	0.066
Raised in NL	25.913	9.524	0.107
Age	0.767	0.293	0.011
Vocabulary in Dutch	-0.315	0.537	0.560
Vocabulary in BP	0.692	0.519	0.118

Table 4.5 – Coefficients of regression analysis of children's spectrum reliance.

The figures presented in Table 4.5 reveal age to be the only significant factor ($p = 0.01$). From the previous analysis, including the adult participants, it had already become clear that age is a relevant factor predicting children's spectrum reliance. This is confirmed here. Our implicit measure for amount of Dutch input, Vocabulary size was not a relevant factor. Moreover bilingualism shows a nearly significant effect ($p = 0.06$). Overall, bilingual children tend to have lower spectrum reliance than monolingual children. There is, however, no difference between the children raised in the Netherlands and the children raised in Brazil (all bilingual), which was to be expected if the amount of Dutch input played a very significant role in their spectrum reliance. We should however bear in mind that the bilingual children in Brazil are significantly older than the children raised in the Netherlands. Since age is a significant factor in predicting spectrum reliance, it is possible that this factor is covering group differences. I will return to this issue further, in this section 4.5.5.

4.5.3 Duration reliance: results from monolingual and bilingual native speakers of Dutch

Mean duration reliance for each of the four Dutch native groups is displayed in Figure 4.7[13].

[13] Figure 4.7 shows a subset of the data in Figure 4.2.

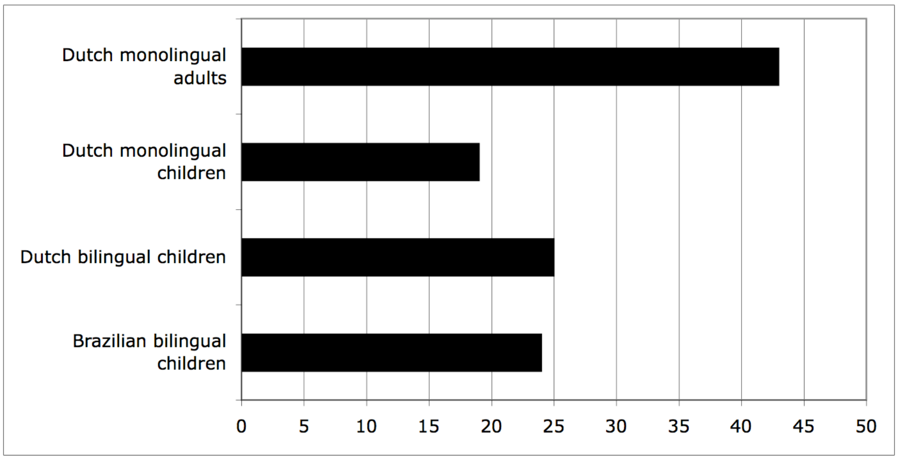

Figure 4.7 – Average duration reliance of monolingual Dutch adults, monolingual Dutch children, bilingual Dutch children and bilingual Brazilian children. The scale displayed in this figure differs from the scale displayed in Figure 3.3 for spectrum reliance.

To investigate the differences in duration reliance between the groups, I carried out a one-way ANOVA, which reveals a significant difference between the groups ($F_{3,99}$ = 6.12; p = 0.001). Additional post hoc comparisons (Tukey HSD) revealed two subsets in the data, one with the three groups of children (Dutch monolinguals, Dutch bilinguals and Brazilian bilinguals) and one with the Dutch monolingual adults. This means that monolingual children and both groups of bilingual children do not differ in duration reliance. They do all, however, differ from the Dutch adults.

A regression analysis including the same variables as for spectrum revealed no significant model. Contrary to spectrum reliance, duration reliance was not influenced by age, which suggests that no development is taking place in this variable.

4.5.4 Summary: cue reliance by monolingual and bilingual native speakers of Dutch

The results from spectrum reliance and duration reliance both show that children have lower cue reliance than adults. A relevant factor in explaining the variation found between the groups in their spectrum reliance is age, but this is only true for the children. Specifically, the older the child, the more spectrum they use in the perception of the /ɑ/ - /aː/ contrast. This finding suggests that spectrum reliance is still under development among the children. The three groups of children also have lower duration reliance than adults, but age does not play a role in this case. This suggests that difference in duration reliance is not a developmental issue. This is a somewhat paradoxical statement because since children rely less on duration than adults, development must play some role. I will return to this issue in 4.6.1

When considering the children's results, we find a tendency for bilingual children to have lower spectrum reliance than monolingual children. I had hypothesized that amount of input could be playing a crucial role in these differences. This means that spectrum reliance would increase as a function of amount of Dutch input and Dutch monolingual children would have higher spectrum reliance than Dutch bilingual children and Dutch bilingual children would have higher spectrum reliance than Brazilian bilingual children. Contrary to these expectations, the difference between the two groups of bilingual children, whether raised in Brazil or in the Netherlands, did not reach significance. There is, however, a crucial difference between these two groups in addition to the obvious difference between the places where they were brought up, namely age. Bilingual children raised in Brazil are significantly older than bilingual children raised in the Netherlands. As we have seen that children's age is a crucial factor when predicting spectrum reliance, the differences in age might act as a confounding variable, obscuring possible differences between children raised in Brazil and children raised in the Netherlands. In order to minimize the age difference between the groups, the next section focuses on a subset of the data, namely that of the older children.

4.5.5 Results from older participants

To filter out a possible interference from the age difference between the groups of children, I levelled up this difference by selecting per group the oldest children. The oldest group was that of the Brazilian bilinguals (mean 6;6 years old). As this group was also the smallest one with 18 participants, I selected the 18 oldest participants for each of the other groups[14]. Table 4.6 gives an overview of the age means per group before and after the selection of the oldest 18.

	All Children		**Older children**	
	N	**Age mean**	**N**	**Age mean**
Dutch monolinguals	33	5;4	18	6;1
Dutch bilinguals	24	5;7	18	6;1
Brazilian bilinguals	18	6;6	18	6;6

Table 4.6 – Number of participants and mean age per group of children. The first column includes all children and the second column, the 18 oldest children per group (in the group of Brazilian bilinguals this includes all the children).

Even when only the oldest children are taken into account there is still a 5 month difference between the Brazilian bilinguals on the one hand and the Dutch monolinguals and bilinguals on the other. This difference, however, is not a significant one ($F_{2,49} = 1.032$; $p > 0.1$)

[14]Since the aim was to achieving equal group sizes, I also selected the oldest 18 adult participants. There were, however, no significant age differences within this group.

The average spectrum reliance for the groups formed by the 18 oldest children is displayed in Figure 4.8.

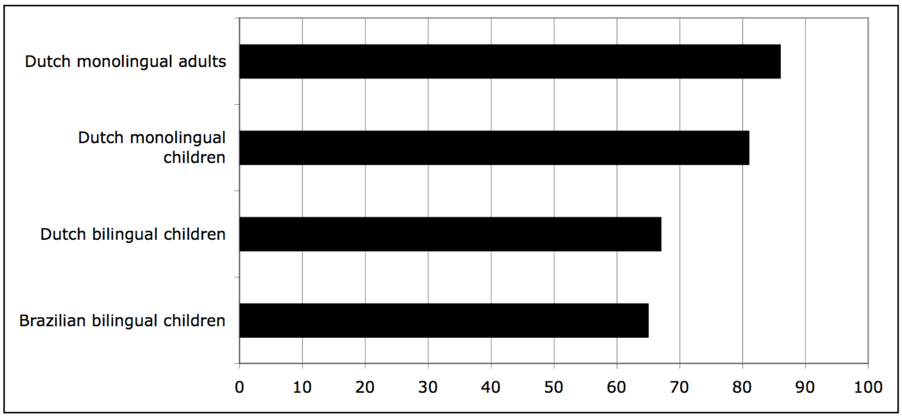

Figure 4.8 – Average spectrum reliance of 18 oldest participants in the groups of monolingual Dutch adults, monolingual Dutch children, bilingual Dutch children and bilingual Brazilian children.

An analysis of variance (one-way ANOVA) reveals a significant group effect regarding spectrum reliance ($F_{3,68} = 3.73$; $p < 0.05$). Successive Tukey HSD post-hoc tests reveal two subsets in the data: one formed by the three groups of children (Brazilian bilinguals, Dutch bilinguals, and Dutch monolingual children) and one formed by the three Dutch groups (Dutch bilingual children, Dutch monolingual children, and Dutch monolingual adults). Importantly, the only group that significantly differs from the Dutch monolingual adults is that of the Brazilian bilinguals.

The fact that spectrum reliance in the two groups of bilinguals are closer together than the two groups of monolinguals might lead one to suspect that bilingualism is playing a role in the variation found in spectrum reliance. To control for this I carried out a regression analysis in the same fashion as described in the previous sections, including the dummy variables 'Child', 'Bilingualism' and 'Raised in the Netherlands' and combinations of these factors: 'Bilingual child', 'Child raised in the Netherlands', and 'Bilingual raised in the Netherlands'. The model was significant at the 0.05 level ($F_{3,68} = 3.73$; $p < 0.05$; R Square = 0.142). The variables 'Bilingualism', 'Bilingual child' and 'Child raised in the Netherlands' were discarded from the model. The coefficients of the remaining variables ('Child', 'Raised in the Netherlands' and 'Bilingual raised in the Netherlands') are given in Table 4.7.

	Unstandardized Coefficients		
Model	**B**	**Std. Error**	**Sig.**
(Constant)	69.792	9.285	0.000
Child	-4.861	7.581	0.524
Raised in NL	16.319	7.581	0.035
Bilingual raised in NL	-13.889	7.581	0.071

Table 4.7 – Coefficients of regression analysis of spectrum reliance in older children.

As we can read from Table 4.7 the only significant factor in the model is 'Raised in Netherlands' ($p < 0.05$). Participants who were raised in the Netherlands have on average higher spectrum reliance than participants who were raised in Brazil. There is a tendency among bilinguals raised in the Netherlands towards lower cue reliance ($p = 0.071$), which could indicate a slight delay among bilinguals in the acquisition of spectrum reliance.

Mean duration reliance for the groups formed by the 18 oldest children is shown in Figure 4.9.

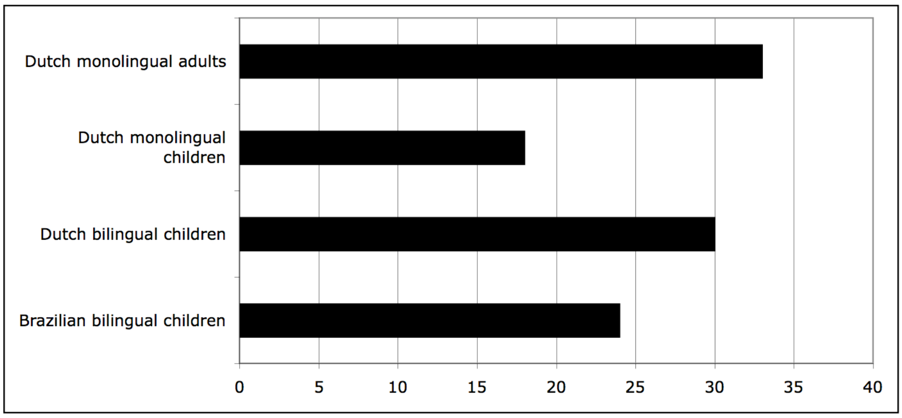

Figure 4.9 – Average duration reliance of 18 oldest participants in the groups of monolingual Dutch adults, monolingual Dutch children, bilingual Dutch children and bilingual Brazilian children.

An analysis of variance (one-way ANOVA) showed no significant differences in duration reliance between the groups. Moreover, significance levels were also not reached by a regression-model including the 6 dummy variables 'Child', 'Bilingualism', 'Raised in the Netherlands', 'Bilingual child', 'Child raised in the Netherlands', and 'Bilingual raised in the Netherlands'.

Discussion

The analysis carried out here reveals that there were no significant differences between the groups in their duration reliance, suggesting that 6.5-year-old children have already acquired adult-like duration reliance. Moreover, the analysis of participants' spectrum reliance reveals that at 6.5 years of age the only group of children that has not yet attained an adult-like level is that of the Brazilian bilinguals. A regression analysis confirms this finding as the only relevant factor in predicting the variance found in the data is the place where participants were raised, whether in the Netherlands or in Brazil. The bilingual children raised in Brazil are delayed in their acquisition of spectrum reliance when compared to children (and adults) raised in the Netherlands. It is important to note that the Brazilian bilingual children are also the ones with the least input in Dutch. The delay found here for these children is not related to bilingualism, since Dutch bilingual children did not differ from monolingual Dutch children, but a matter of amount of input.

In the next section, when analyzing participants' cue integration, I will look at individual results, allowing for a more complete understanding of the data.

4.5.6 Cue integration

Relative cue integration is the extent to which a listener uses one dimension more than the other to perceptually differentiate between the vowels. It can be expressed by the *ratio* between duration reliance and spectrum reliance, which Escudero & Boersma (2004) call the *reliance ratio*. The reliance ratio determines the relative use of the auditory dimensions at hand. The higher the ratio, the more a listener or group of listeners relies on durational cues as compared to spectral cues to identify the contrast. Escudero & Boersma show that it is possible to estimate the slope of a listener's perceptual category based on their reliance ratio. They propose 6 possible patterns: a ratio with values higher than 4 means that a listener used only durational cues to perceive the /ɑ/-/aː/ contrast; values between 4 and 2 mean that a listener used mainly durational cues to perceive the contrast, spectral cues being used as well, but to a small degree; values between 2 and 1 reveal a boundary where both durational- and spectral cues are used, durational cues counting somewhat more heavily; ratios with values between 1 and 0.5 form a mirror image of the category boundary previously described, meaning that both cues are used, but spectral cues weight somewhat more heavily than durational cues; values between 0.5 and 0.25 mean that listeners use considerably more spectral cues than durational cues in the perception of the /ɑ/ -/ aː/ contrast; finally, listeners who have a ratio with values below 0.25 use only spectral cues. These 6 patterns and their estimated category slopes are illustrated below in Figure 4.10.

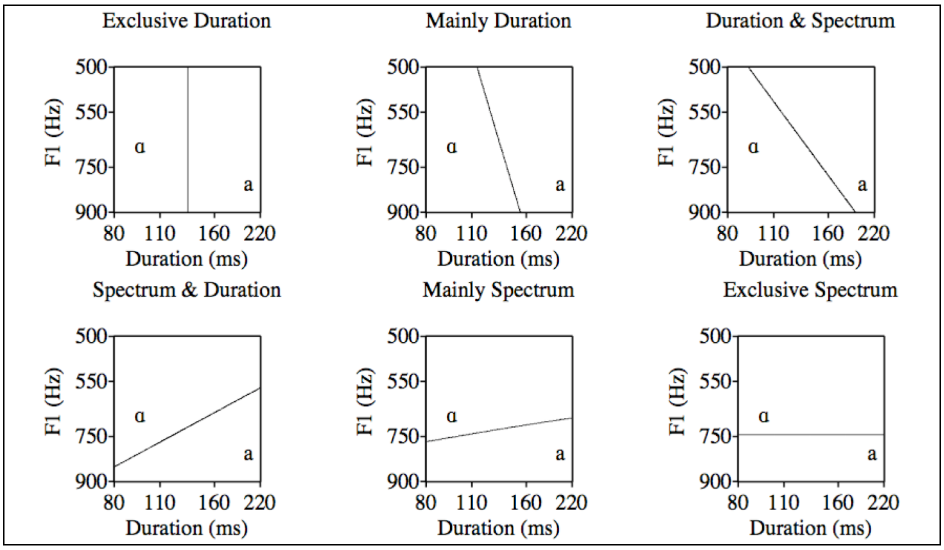

Figure 4.10 – Category boundary illustration for 6 possible perceptual patterns based on listeners' use of durational and spectral cues in their perception of the /ɑ/ - /aː/ Dutch contrast.

To analyse the results monolingual and bilingual participants were divided according to their perceptual pattern. Table 4.8 presents the six possible patterns proposed by Escudero & Boersma (2004), which range from the use of duration only, on the top, to the use of spectrum only, on the bottom. The number of participants presenting each of these patterns is displayed in the columns.

	Ratio values	**Dutch mono. adults**	**Dutch mono. children**	**Dutch bil. children**	**Brazilian bil. children**
Excl. dur.	*x>4*	-	-	-	-
Mainly dur.	*4≥x>2*	2	-	-	1
Dur. & spec	*2≥x>1*	3	1	3	1
Spec. & dur.	*1≥x>½*	7	5	2	5
Mainly spec.	*½≥x>¼*	6	9	8	4
Excl. spec.	*x≤¼*	9	18	11	7
% of participants integrating cues		*66.7%*	*45.5%*	*54.2%*	*61.1%*

Table 4.8 – Participants divided according to their cue integration pattern and the percentage of participants per group who integrate durational and spectral cues.

As illustrated in Table 4.8, most listeners rely more heavily on spectral than on durational cues to perceive the /ɑ/ - /aː/ contrast, and this is true for all groups of participants. Most of the Dutch adults (18 out of 27, or 66.7%) integrate both cues. A minority of them, however, are able to perceive the contrast using spectral cues only. Among the Dutch monolingual children, less than the half of the participants integrate spectral and durational cues (15 out of 33, or 45.5%) whereas the majority of them rely solely on spectrum. The group of Dutch bilingual children show a pattern similar to that of the Dutch monolingual children with a high proportion of participants integrating durational and spectral cues (13 out of 24, or 54.2%). Among the Brazilian bilingual listeners there is a relatively large number of participants integrating both acoustic cues (11 out of 18, or 61.1%), a pattern more similar to that of the Dutch adults.

The numeric difference between the groups was analyzed by a General Loglinear model and revealed no significant results, perhaps due to the great deal of variation within each group.

Discussion

The statistical analysis of the data showed no significant difference between the groups on the number of participants showing each perceptual pattern. This is possibly due to the large variation even within the group of adults, where we would expect some uniformity. What causes such variation? One possible answer to this question is related to the degree of variability found in the Dutch language. As previously discussed in Chapter 2, there is wide variation in how the vowels are produced in different places in the Netherlands, even when only taking the standard language into account. This variation is found in spectrum, as well as in duration. In my data participants cannot be straightforwardly traced back to one specific geographical region according to their perceptual pattern, i.e. it is not the case that, for example, both Dutch adults relying mainly on duration come from the same part of the country. Geographical variation was, however, not the focus of this study. The experimental design used here does not allow for any in-depth conclusions on the topic since there is no balanced distribution of participants among the different regions. In sum, it is possible that geographical spreading played an important role in the variation found in the data, but it is not possible to identify its details in this investigation.

Among the Dutch adults, the acoustic cue varying most is vowel duration (compare the standard deviation for spectrum reliance, 18.7 to that for duration reliance, 29.6), possibly because it is less important for the perception of the contrast and hence allows for greater variation. This is, however, not the case for the children, where in all three groups, spectrum reliance varies more than duration reliance. This might be related to the fact that children are still in the process of acquiring that cue.

4.6 General discussion

Bilingual and monolingual listeners have been analyzed on their ability to accurately perceive the contrast, on their cue reliance, and on their patterns of cue integration. In this section I bring these three issues together, discussing two main findings, namely that of age and that of bilingualism effects.

4.6.1 Age effects

Children have been shown to differ from adults regarding spectrum reliance as well as duration reliance. This is in line with the studies by Gerrits (2001) and Heeren (2006). Overall children make less use of speech cues when perceiving the contrast than adults do, which might explain why their discrimination of the contrast is less accurate than that of adults.

More specifically the age of the children is a significant factor in explaining the variation found in spectrum reliance. Generally speaking, the older the child, the more use of spectral cues in the perception of the /ɑ/ - /aː/ contrast. This is true for all children, whether bilingual or monolingual. This age effect is not found within the Dutch adults. These findings can be interpreted in terms of development: whereas Dutch adults have already acquired spectral cues and their use has stabilized, children are still in the process of acquiring it.

The case of duration reliance differs from that of spectrum reliance in that there is no clear age effect. Although children use duration less than adults, there is no positive correlation between the use of durational cues and age within the child group, ruling out an account related to development. This is a puzzling finding since on the one hand, the fact that children differ from adults suggests that development might play a role, and on the other hand, age turns out not to play any relevant role.

It is possible that duration actually develops as a function of age but I have not been able to tap this development due to the great variation within the group of children. The longitudinal data in Chapter 5 will shed some light on this discussion since it eliminates individual variation. I will return to the issue of duration development there.

4.6.2 Bilingualism effects

The three studies previous to this one investigating the perceptual abilities of bilingual children (that of Bosch & Sebastián-Gallés 2003, Burns *et al.* 2003 and Sundara *et al.* 2006) all led us to suspect that bilinguals would lag behind monolinguals in the perception of the contrast. This was however not the case in any of the variables studied here. All differences found between bilingual children and Dutch adults have been shown to be a matter of development instead of bilingualism. Crucially bilingual children do not differ from monolingual Dutch children.

In a more recent study, Sundara, Polka & Molnar (2008) show that bilinguals' development of contrast perception is similar to that of monolinguals when the tokens involved are highly frequent. Even when there is a high degree of acoustic overlap in the production across the languages, bilinguals are able to cope with this challenge if they are given enough input, i.e., if the tokens in question have a high frequency of occurrence. The vowels involved in this study are highly frequent in both languages: in Dutch /ɑ/ and /aː/ are the two most frequently occurring vowels after schwa, responsible for about 8% and 9% of all vowel productions respectively (CELEX data base); these values rise to 12% and 14% if we disregard the schwa. In BP /a/ is also the most frequently occurring vowel and represents 32% of all oral vowel productions (CetenFolha database, e.g. Albano 2007). The fact that the vowels in this study form a significant part of bilinguals' input is enough to allow bilinguals to develop their perceptual abilities in the same time course as monolinguals.

The distributional properties of the Dutch /ɑ/ and /aː/ and the BP /a/ are similar to the Catalan /ɛ/ and /e/ and Spanish /e/ studied by Bosch & Sebastián-Gallés (2003). In both cases, the three vowels form an acoustic continuum and the vowel that is acoustically in the middle is more frequent than the other two. This means that if both languages are taken together bilinguals are provided with a unimodal distribution of the sounds. This was the explanation offered by Bosch & Sebastián-Gallés to deal with the delay found among their bilingual infants. There is however no delay in the bilinguals in the current study. Importantly Bosch & Sebastián-Gallés also claim that infants' vocabulary acquisition would trigger language differentiation. Once bilinguals' languages are stored in two split files, they would no longer trace token frequencies across their two languages but would look into each language separately. Bilinguals in the current study are well beyond the stage referred to by Bosch & Sebastián-Gallés and we can assume that, in their view, they already have two separated files for each language and are not tracing frequencies across both their languages.

One group which has been found to deviate from the Dutch monolingual children is that of Brazilian bilingual children, who have lower spectrum reliance when compared with age-matched Dutch monolingual and bilingual children. We have also seen that the proportion of children who did not reach the 75% criterion is much greater in Brazilian bilinguals (0.45) than in Dutch monolinguals (0.23) or Dutch bilinguals (0.22). This does not seem to be due to an overall lag of Brazilian children since the rate of Brazilian children performing in a native contrast (/ɔ/ - /o/) that did not reach the 75% criterion was much lower (0.21). This is comparable to that of Dutch children tested on the /ɑ/ - /aː/ Dutch contrast. It is important to consider, however, that Brazilian bilinguals have poorer Dutch input than those raised in the Netherlands, suggesting that the crucial factor here is amount / quality of input and not a matter of bilingualism.

4.7 Summary

In this chapter I compared bilinguals and monolinguals sound categories. To this end I have analyzed them on their ability to discriminate the /ɑ/ - /aː/ contrast and on the extent to which they use spectral and durational information to perceive the vowels. The data discussed here does not present any evidence for a difference between bilingual and monolingual categories. All the variation found was explained to be a matter of either development or amount of input. Specifically, children have lower spectrum and duration reliance than adults, and Brazilian bilinguals have lower spectrum reliance than Dutch bilingual and monolingual children. Among the children, spectrum reliance correlated positively with age, suggesting that this cue is still under development in this group.

Importantly, the developmental path presented here is merely an estimate based on cross-sectional data. In Chapter 5 I present the longitudinal results for some of these children. I will return to the question regarding the development of spectrum and duration reliance there.

5 THE PERCEPTUAL DEVELOPMENT OF BILINGUAL AND MONOLINGUAL CHILDREN

The question this chapter addresses concerns the perceptual development of bilingual children as compared to that of monolingual children. I addressed the topic of development in the previous chapter, when discussing cross-sectional data. To fully answer questions concerning development, however, longitudinal studies are the ideal solution, since they allow us to investigate perceptual development and at the same time filter out the role of individual variation. The current chapter thus complements the previous one (Chapter 4) in that it answers some of the questions left open and investigates in detail some of the suggestions made.

In the current study I have carried out a longitudinal investigation of the perception of bilingual and monolingual children and monolingual adults. The children were tested three times in a period of three years with an interval of about one year between the tests. Their results were compared to the results of the adults and to each other.

The bilingualism literature suggests that the interaction between the languages of bilinguals can take three forms: transfer, delay and acceleration (Paradis & Genesee 1996). Concerning the *development* of perception, delay is the most commonly attested pattern (e.g. Bosch & Sebastián-Galles, Sundara *et al.* 2006). Reasons for delay are often related to the bilinguals' input, either amount of input or, more specifically, their distributional properties. From studies with monolinguals, we know that infants are able to track statistical properties of their languages, and use their distribution to form their sound categories (Maye *et al.* 2002). Bilingual infants act similarly but have the extra challenge of disentangling the overlap within each of their languages as well as between them.

I will deal with the issue of bilingual delay and acceleration in the first section of this chapter (Section 5.1) discussing the scarce literature on the topic and presenting some evidence for both delay and acceleration in bilingual phonological / phonetic acquisition. Section 5.2 presents the research question addressed in the current chapter, followed by a summary of the experimental set-up used in the current study, providing details about the number of participants and their age (Section 5.3). The results found are discussed in Section 5.4, separately for spectrum reliance (Section 5.4.1) and duration reliance (Section 5.4.2), followed by a discussion (Section 5.4). Finally section 5.5 presents a summary of the current chapter.

5.1 Delay and acceleration in bilingual speech development

There are different ways in which the languages of a bilingual may interact with each other. Paradis & Genesee (1996) mention three: *transfer*, *delay*, and *acceleration*. One speaks of *transfer* when grammatical properties from one of the bilinguals' languages are integrated into the other language. *Acceleration* happens when a grammatical structure emerges in the speech of bilingual children earlier than in that of monolingual children. Conversely, when a specific structure is acquired by bilingual children later than by monolingual children, one speaks of *delay*, or *deceleration*. Examples of transfer abound in the bilingualism literature, in virtually every aspect of linguistic competence (see for instance Müller & Hulk 2001 and Yip & Matthews 2000 for syntactic transfer, and Fabiano & Goldstein 2005 and Mack 1990 for phonological / phonetic transfer). The other two patterns, delay and acceleration, are less attested in the modern literature[15], most specifically in the field of phonology / phonetics.

In this section I will discuss some of the studies which have addressed delay and acceleration in bilinguals sound acquisition, in this way sketching the state of the art in the field. Firstly I will present cases of bilingual delay in both production and perception, followed by a discussion of the possible reasons for this alleged delay; I will then discuss the very scarce literature on bilingual phonological acceleration.

A few studies have reported delays in sound acquisition by bilinguals in production (e.g. Kehoe 2002 and Kehoe, Lleó & Rakow 2004) and perception (e.g. Bosch & Sebastián-Gallés 2003 and Sundara *et al*. 2006) of consonants and vowels.

In consonant production Kehoe *et al*. (2004) point out that bilingual children are delayed in their realization of VOT cues in comparison to monolingual children. They compared VOT measures as produced by German-Spanish bilingual children to that of Spanish and German monolingual children. Their findings show that 2 out of the 4 bilingual children studied were delayed in their acquisition of German long lag stops. Importantly this study shows that some, but not all bilinguals were delayed in their VOT production, suggesting that delay is not a necessary consequence of bilingualism. The Japanese-English children in Johnson & Wilson's (2002) study also seemed to have a late acquisition of VOT cues, failing to pre-voice their Japanese voiced consonants. The children did have distinct VOT realizations in their production of English and Japanese consonants, showing that they had separate systems. The phonetic detail in their Japanese voicing system, however, was not adult-like at the age tested (around 3 and 5 years), suggesting a delay when compared to monolingual Japanese children.

Also in vowel production bilingual children have been found to lag behind monolingual children. Kehoe (2002) analyzed the production of vowels by 3

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[15] As discussed in Chapter 1, cases of bilingual delay were very commonly reported in the early literature on bilingualism, but since these studies were so full of flaws in their methodologies and interpretation they will be disregarded here.

German-Spanish bilingual children and their monolingual counterparts, 2 Spanish and 3 German children. The vowel systems of German and Spanish differ in that German has a significantly larger inventory than Spanish, the languages having 13 and 5 vowels respectively. Moreover, German has a distinction between short and long vowels whereas Spanish does not. The children in Kehoe's study were followed from the beginning of the word production stage (around 1 year of age) until around the age of 3. Analyses of the children's vowel production showed that the Spanish vowels produced by the bilingual children were identical to those of Spanish monolingual children. In their production of the German vowels, however, bilingual children failed to make the length contrast consistently, even though German was the majority language. Only in their production of dissyllabic words, and never in monosyllabic ones, did two out of the three bilinguals produce some length contrast at the last measurement (around the age of 2;5). All three monolingual children, on the other hand, consistently produced longer and shorter vowels in both mono- and dissyllabic words from around the age of 1;7. The differences between monolingual and bilingual children suggest a bilingual delay in the production of the German length contrast.

There have been only a few studies in phonetic *perception* involving simultaneous bilinguals. These studies seem to suggest that exposure to dual language leads to a difference in the time course with which phonetic discrimination is achieved (Bosch & Sebastián-Gallés 2003, Sundara *et al*. 2006). Bilingual delay has been found for infants and for children in their perception of vowels as well as consonants.

Bosch & Sebastián-Gallés (2003) tested vowel perception in Catalan-Spanish bilingual infants and their monolingual peers. The two languages are similar but differ crucially in their vowel inventories. The Catalan 7-vowel system is identical to the Spanish 5-vowel system (a, e, i, o, u) plus two mid-peripheral vowels /ɛ/ and /ɔ/. Bosch and Sebastián-Gallés tested bilingual and monolingual infants on their perception of the /e/ - /ɛ/ contrast which is present in Catalan but not in Spanish. There were three age groups: 4-, 8-, and 12-month-old. As expected the monolingual Catalan infants discriminated their native contrast at all ages. Among the monolingual Spanish infants only the youngest group (4-month-old) were able to discriminate the Catalan contrast, a result commonly found in infant cross-language perception studies. Interestingly the bilingual infants were able to discriminate the Catalan contrast at 4 and at 12 months of age but not at the age of 8 months. These results suggest that the development of sound contrast in bilinguals may differ from that of monolinguals. These bilingual children acquired the discrimination of the contrast at the age of 12 months but it took them 4 months longer than it took the monolingual children.

Although the bilingual infants in the Bosch & Sebastián-Gallés study caught up with their monolingual peers within a few months, bilingual delay can last longer, entering school years, as shown by Sundara *et al*.'s (2006) study. Sundara *et al*. used a modified version of the conditioned head turn paradigm to test the perception of 4-year-old monolingual children acquiring either English or French and bilingual children acquiring both languages simultaneously. Three groups of adults, monolinguals of each language and bilinguals, were included in the study in order to observe age effects. Children and adults were tested on the English /d/ -/ ð/ contrast, which is absent in French. French has the dental voiced plosive /d/ but lacks the interdental voiced fricative /ð/. French also lacks the voiceless fricative /θ/, but this consonant was not investigated in Sundara *et al.*'s study. The results of the 4-year-old children were compared to those of the monolingual French and English infants tested by Polka *et al.* (2001), who tested the same contrast using a similar methodology. Their results show that English monolingual children outperform French monolingual children on their discrimination of the native English contrast, a pattern commonly attested in the literature. Less well attested is the pattern they found for the bilingual children. The bilingual children in their study were found to behave similarly to the French monolinguals, which means that their discrimination of the English contrast was less accurate than that of English monolingual children. Sundara *et al.*, however, found no differences between the bilingual and monolingual adults. These results show that discrimination of native sounds can be affected by bilingualism, suggesting that dual language exposure delays the positive effect of language experience in discrimination ability. This delay is temporary, however, since there was no difference between bilingual and monolingual adults suggesting that somewhere between 4 years of age and adulthood this facilitation has taken place.

There are a number of possible explanations to account for this suggested bilingual delay. One of them is related to the extra complexity in the bilingual input combined with their diminished exposure to each of their languages. Bilingual children have to face the same acquisition issues monolingual children do (see Section 1.4.2 in Chapter 1 for a discussion on the topic) with additional challenges specific to their bilingual situation, such as potential overlap between their two languages. Moreover, considering their dual exposure, bilingual children receive less input in each of their languages. As a consequence of these two factors collectively, bilinguals need a longer period of exposure to their languages. Kehoe (2002) for instance attributes the delay in duration production in short-long contrast in German vowels by bilinguals to the amount of input of the feature in question. Bilingual children received reduced positive evidence on short-long vowel contrasts, since this type of contrast is absent in part of the input they receive (i.e. in their Spanish), hence the bilingual late acquisition of the feature.

In addition to *quantity* of input, *quality* of input can also be claimed to play a role in the bilingual "delay". In Khattab's (2002) study the English speech of English-Arabic bilingual children was influenced by the accented speech they were exposed to. Exposure to accented speech may cause bilingual children to form sound categories that deviate from those of monolinguals. Specifically, bilingual children can incorporate features of their accented input into their categories. As a consequence of this deviating category, bilinguals may perform differently from monolinguals in experimental settings, when faced with monolingual-like stimuli, leading to conclusions of bilingual 'delay'. These categories may be adjusted to monolingual norms as the result of increasing exposure to non-accented speech and their performance in experimental tasks will be more monolingual-like, leading to the conclusion that bilinguals are 'catching up' with monolinguals.

Moreover, accented speech may affect the distributional properties of the sounds being acquired. Considering that if a specific sound contrast forms two extremes of a bimodally distributed acoustic continuum, mispronunciations may result in tokens falling in between the contrast continuum, turning the continuum into a unimodally distributed one. Maye *et al.* (2002) have shown that in an artificial language learning task infants exposed to a unimodal distribution of the stimuli were not able to discriminate between the two end points of the continua. In this sense, mispronunciations could lead to bilingual delay.

In many cases, however, it is very difficult to disentangle the effects of accented speech from the effects of interaction between the bilinguals' linguistic systems. In both cases there is some sort of interaction between the two languages involved. In accented speech the speaker's second language is (usually) effected by his / her first language. In the case of bilinguals, the languages are acquired simultaneously, and if they are to affect each other it is possible that this effect leads to similar outputs to those in situations of accented speech.

Bosch & Sebastián-Gallés (2003) account for bilingual delay in terms of the acoustic distribution of the sounds of the contrast. The variable affecting the distribution in bilinguals is in their explanation however not mispronunciations but cross-linguistic interference, which would be a result of initially shared representation systems. They suggest that young bilingual infants have a shared representation system for both languages, in which case the acoustic and distributional properties of the languages being acquired will play a crucial role. This explanation was particularly suitable for the languages and the contrast they studied. Their Spanish-Catalan bilinguals were delayed on the perception of the /e/ - /ɛ/ Catalan contrast when compared to Catalan monolingual infants. Acoustically speaking, however, the two Catalan vowels [e] and [ɛ] and the Spanish vowel [e] nearly form a continuum, with the Spanish vowel in the middle. Furthermore, the relative frequency of each vowel differs greatly. The Spanish vowel accounts for 25% of the vowel tokens in Spanish whereas the two Catalan vowels put together only account for 9% of the Catalan vowels. This means that the input bilingual children are receiving is more similar to a unimodal distribution than to a bimodal distribution, leading bilingual children to be delayed in their perception.

Finally, Burns *et al*. (2003) point out that differences between bilingual and monolingual perception can be the result of differences in language dominance. The bilingual infants in their study showed signs of being dominant in one of their languages or, conversely, being (nearly) perfectly balanced. The group results pointed to a bilingual delay. Analysis of the individual data, however, revealed that half of the bilinguals were behaving like monolinguals of either language and could only discriminate the contrast that was relevant in that language; conversely the other half of their bilinguals could discriminate the contrast in both languages. These results point to the risk of premature conclusions about delay when analyzing bilingual data as a group, which may be covering different patterns within heterogeneous populations.

To my knowledge the only systematic evidence of bilingual acceleration in phonological / phonetic acquisition was presented by Lleó, Kuchenbrandt, Kehoe & Trujillo (2003). Their study shows that children simultaneously exposed to German and Spanish were faster than Spanish monolingual children in the acquisition of syllable codas in Spanish. German has a more complex coda system, allowing many consonants and consonant clusters to appear in that position. Spanish on the other hand is much more restrictive. Despite the more marked nature of the German system, monolingual German children have been shown to acquire codas earlier than monolingual Spanish children (see e.g. Grijzenhout & Joppen 1999 for German data and Garlant 2001 for Spanish data). This early acquisition of coda in German was explained by Lleó *et al.* in terms of frequency of input, since German children have a higher exposure to codas than Spanish children. A second explanation was related to the highly functionality of codas in German's phonology. In the case of the bilingual children in their study, their early acquisition of codas in Spanish would be the consequence of a facilitative effect of German. Specifically, bilinguals' high exposure to German codas triggered their early acquisition and, due to interaction between their two languages, this ability was transferred to their Spanish.

In fact Genesee (2003) points out that the most likely candidates for acceleration in bilingual acquisition are features that are acquired earlier in one language than in the other. It is well attested that in normally developing children the same feature can be acquired earlier in some languages than in others (Allen 1996). This is the case for codas, acquired earlier in German than Spanish, leading to accelerated coda acquisition in bilingual children's Spanish.

5.2 Research questions

In this chapter, I look into the development of bilingual children when compared to monolinguals in more detail. The question I attempt to answer is whether bilingual children show the same perceptual development as monolingual children.

In Chapter 4 I made some suggestions concerning bilingual and monolingual development based on cross-sectional comparison between the groups. There is a risk however in making inferences about development based on comparison between different groups. This is especially true in the case of bilingual children, considering the great heterogeneity in this population. The longitudinal data discussed here will then shed some light on the suggestion made there.

The two questions I address in this chapter are the following:

1 *Do monolingual children develop their cue weighting as a function of age in order to acquire adult-like perception?*

2 *Do bilingual and monolingual children follow similar developmental paths?*

In Chapter 4, we saw that when perceiving the Dutch /ɑ/ - /aː/ contrast children of around 5;5 years of age still had not acquired adult-like cue weighting. Specifically we saw that both their spectrum reliance and their duration reliance were lower than those of adults. Moreover we saw that age had a positive effect on spectrum reliance. Although no effect of age could be shown for duration reliance, the most obvious prediction is that monolingual children will increase both their spectrum reliance and their duration reliance as a function of age in order to match those of the adults' perception.

Concerning bilingual development there are two possible patterns proposed in the literature: delay or acceleration[16]. A third possibility would be that bilinguals and monolinguals do not differ in their development. The latter is in fact what the results found in Chapter 3 suggest. Based on the literature of phonetic perception in bilinguals, however, delay has been the most attested case.

5.3 Methods: testing children longitudinally

In this section I briefly describe the experimental procedure used in this study. For a more detailed description the reader is referred to Chapter 3.

Sixty-three children and adults participated in this study. Participants formed three different groups: bilingual children (N = 22), monolingual Dutch children (N = 25) and monolingual Dutch adults (N = 15). The bilingual children discussed in this chapter were all brought up in the Netherlands and were referred to as "Dutch bilinguals" in Chapters 3 and 4.

The groups were tested with an XAB task on their perception of the Dutch /ɑ/ - /aː/ contrast. In the task, X could be any of 12 synthesized vowels ranging in spectral and durational continua between average values of the Dutch /ɑ/ and /aː/. A and B were either of the average tokens. A more elaborated description of the experimental task and stimuli was given in Chapter 3 of this dissertation.

Participants performed the same task at three different points in time. For the children there is an interval of about one year between the measurements, as we wanted to tap their perceptual development; for the adults there was an interval of about one month, as no great developmental shifts were expected. Table 5.1 shows the means for age per group per measure point.

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[16] The third pattern of interaction between the bilinguals' languages as proposed by Paradis & Genesee (1996) would be *transfer*. Transfer however does not directly refer to developmental questions, as it is a synchronic phenomenon. For this reason it is not taken into account here.

	1		2		3	
	Age	**N**	**Age**	**N**	**Age**	**N**
Adults	23;3	15	23;4	15	23;5	15
Monolingual children	5;3	16	5;11	21	7;4	23
Bilingual children	5;5	16	6;4	20	7;8	20

Table 5.1: Number of participants (N) and mean age for bilingual children, monolingual children and adults at the three points in time at which they were tested. Each point in time is shown in the table as 1, 2 and 3.

The means presented in Table 5.1 show that there is a slight difference in the interval between the tests if we compare bilingual and monolingual children. This is not an issue, however, since the analysis used here (I will discuss the analysis in Section 5.4) takes these differences into account. Moreover the data presented in the table shows that the number of participants in both groups of children increases in later observations as compared to earlier ones. This is a consequence of the fact that only results of participants who gave a minimum of 75% accurate answers to the end points of the continuum were analyzed. As children grew older they were more likely to give accurate responses. Hence, in many cases the children's results were disregarded in the first observation, but not on the second or third[17] ones. Moreover, some children only joined the experiment in the second year of the test. Importantly there are at least two observations per child.

There is a great deal of overlap between the participants analysed here and the ones whose results were reported in the previous chapter, as participants who were followed longitudinally form a subset of the ones reported in Chapter 4. The first reason for this is that some participants were tested only once. The second reason is that in some cases participants, although measured 2 or 3 times, only gave accurate results in one of their measurements, most often the later measurements, as they grew older. In these cases their results were included in the analysis of Chapter 4 but not in the current analysis.

5.4 Results

Adults and children were analyzed on their cue reliance. For each observation participants' spectrum reliance and duration reliance were computed. The procedure used for computing participants' cue reliance was explained in detail in Chapter 4. Importantly, a subset of the children in this study only participated in two of the three measure points. This was the case for 5 bilingual children (out of 22) and 8 monolingual children (out of 25).

The group means for spectrum and duration reliance in each of the three measures are illustrated in Figure 5.1.

[17] In a few cases a child gave accurate responses on the first and on the third measure. This was the case for 2 bilingual and 4 monolingual children.

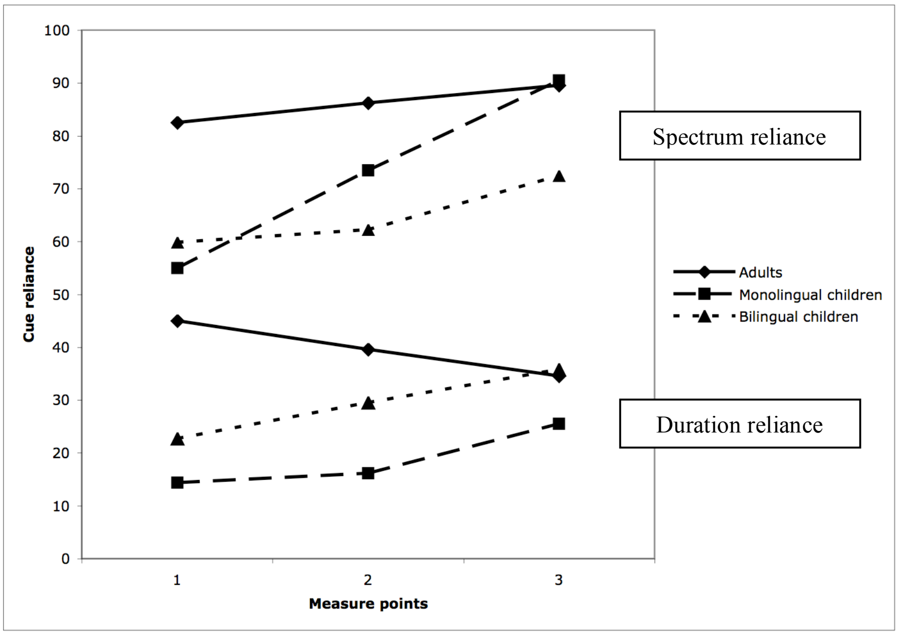

Figure 5.1: Mean spectrum reliance (on the top) and duration reliance (on the bottom) for bilingual children, monolingual children, and adults at three different points in time (shown as 1, 2 and 3 in the X bar). For the children there is an interval of about one year between the measures; for the adults the interval is of around one month.

The data were analyzed with a multi-level regression model in MLwiN, a piece of statistics software for the Windows operating system. Hox (1995) explains that multi-level regression models are basically multilevel versions of the more familiar multiple regression model. In multi-level models (MLM), the data structure is hierarchical, as variables are nested within each other. In longitudinal studies this means that different observations are nested within individuals.

One important advantage of multilevel regression analysis over the more standard analysis of variance when analyzing longitudinal data is that MLM does not require complete data sets (Quené & van den Bergh 2004). It is not unusual for longitudinal studies to have missing data, cases where a set of individuals did not participate in all observations. This is also the case in the present study. In an analysis of variance empty cells would imply disregarding all other observations of this set of individuals, losing the information they would potentially provide. Hence the power of the statistical analysis is diminished. Moreover, MLM analyses are more conservative and the chances of unjustifiably rejecting the null-hypothesis are lower than in conventional analysis of variance.

For the reasons briefly summarized above, the longitudinal data in this study were analyzed with an MLM. In the analysis, age in children was centralized around the group mean, which was 76 months (6;4 years of age). The results for spectrum reliance and duration reliance will be discussed separately in Sections 5.4.1 and 5.4.2 respectively.

5.4.1 Results for spectrum reliance

The results of the multi-level regression analysis for spectrum reliance are given in Table 5.2.

	Fixed Parameters		**Variances**	
	Const (SE)	**β * Age† (SE)**	$S^2_{between}$	S^2_{within}
Bilingual children	63.1 (4.12)	0.60 (.22)	130.5	686.4
Monolingual children	78.2 (3.67)	1.06 (.18)	192.0	329.4
Adults	93.2 (5.16)	-0.01 (.02)	19.4	37.9

†: Age is centralized for children, hence age is rescaled as (Age – 76)

Table 5.2: Results of multilevel regression analysis for spectrum reliance. The fixed parameters (constant and age) and the variances between and within the groups are given.

As illustrated in Table 5.2 in the fixed parameter data, at an age of 76 months (6;4 years) spectrum reliance in bilingual children equals 63.1, whereas that of monolingual children equals 78.2. There is a significant difference between the groups at this age ($\chi^2 = 7.48$; df =1; p = 0.006). Hence at 6;4 years of age bilingual children rely less on spectrum than monolingual children. Both groups of children at the age of 76 months clearly rely less on spectrum than adults ($\chi^2 > 5.62$; df = 1; p < 0.02 in both cases).

Moreover the results in Table 5.2 show that for both bilingual and monolingual children there is a significant relation with the age at which they are measured (for bilingual children β/SE[18] = 2.72; p = 0.006; for monolingual children β/SE = 5.88, p < 0.001). For bilingual children spectrum reliance increases with an average of 0.6 for every month above 76 months of age. So at an age of 86 months their spectrum reliance has increased to 69.1. Conversely, for every month under 76 months of age, their spectrum reliance decreases with 0.6. So at an age of 66 months their expected score for spectrum reliance would be 57.1. Also monolingual children show a significant effect of age in their spectrum reliance. Specifically, they increase or decrease 1.06 in their spectrum reliance for every month over or under 76 months of age. So at an age of 86 months, monolingual children's spectrum reliance has increased to 88.8 and at an age of 66 months, their spectrum reliance has decreased to 67.6. The effect of age on the spectrum reliance, however, does not differentiate between bilingual and monolingual children ($\chi^2 = 2.62$; df = 1; p = 0.106).

[18] β/SE is the formula for z-score.

No relation between age and spectrum reliance could be assessed for adults (β/SE = 0.05; p = 0.96) suggesting that their spectrum reliance in the perception of the contrast is stable over time[19]. Figure 5.2 illustrates the MLM estimated development for bilingual and monolingual children as a function of age. The results for adults were added to the figure for comparison but, importantly, these results do not correspond to the age given on the X-axis.

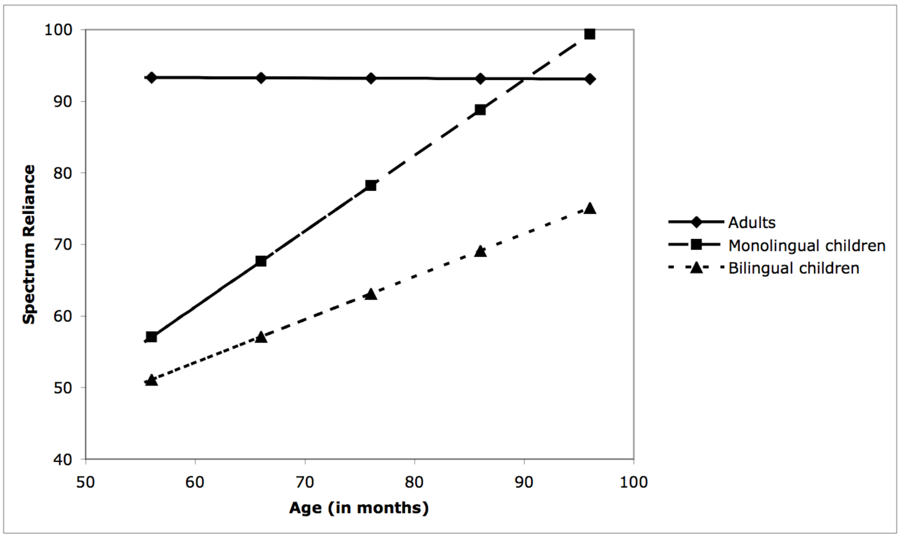

Figure 5.2: Multi-level regression estimate for spectrum reliance development in bilingual children and monolingual children. Results for adults are given for comparison.

Next to the fixed parameters the variance between participants and the variance within participants is also estimated (see table 5.2). It is remarkable that differences among bilingual and differences among monolingual children are much larger than differences among adults (χ^2 = 3.13; df =1; p = 0.03 one-sided, for both groups of children), while the variance within bilingual children does not differ from that of monolingual children (χ^2 = 0.15; df = 1; p = 0.35 one-sided). So, adults are much more homogeneous than either group of children. The homogeneity (or heterogeneity, in the case of the children) within the groups is illustrated in Figure 5.3 for the adults, in Figure 5.4 for the monolingual children, and in Figure 5.5 for the bilingual children.

[19] Although there was only an interval of one month between the tests with the adults, the model also takes into account the age differences within the groups.

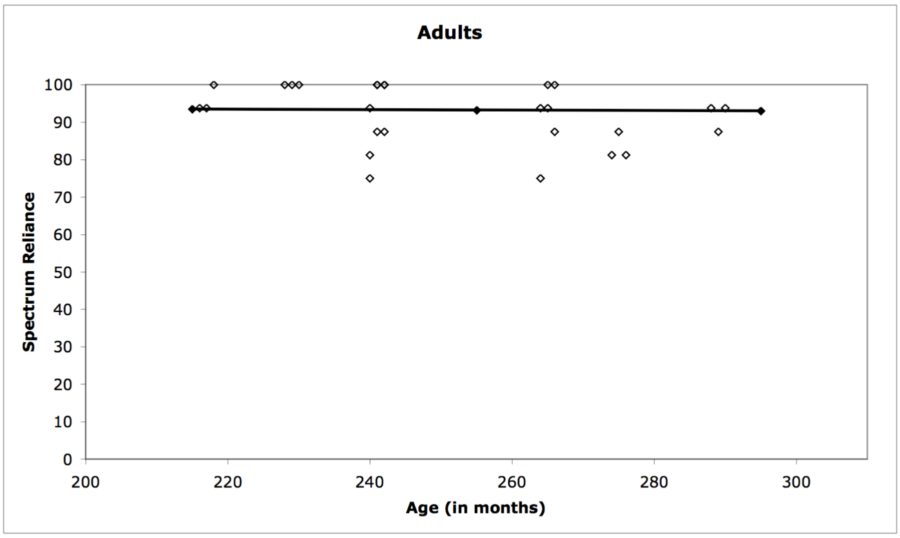

Figure 5.3: Spectrum reliance as a function of age (in months) for Dutch adults. The line and full diamonds illustrate the MLM estimates; the empty diamonds are the actual data.

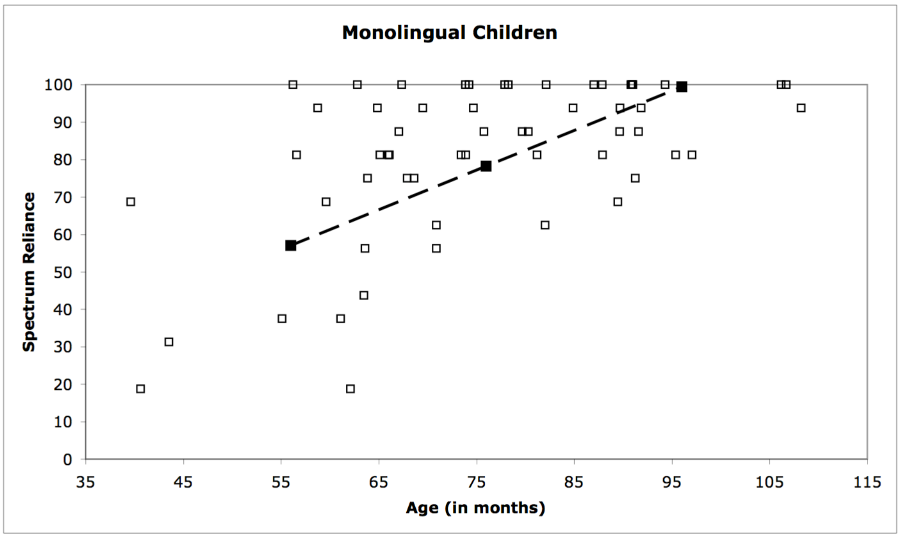

Figure 5.4: Spectrum reliance as a function of age (in months) for Dutch monolingual children. The line and full squares illustrate the MLM estimates; the empty squares are the actual data.

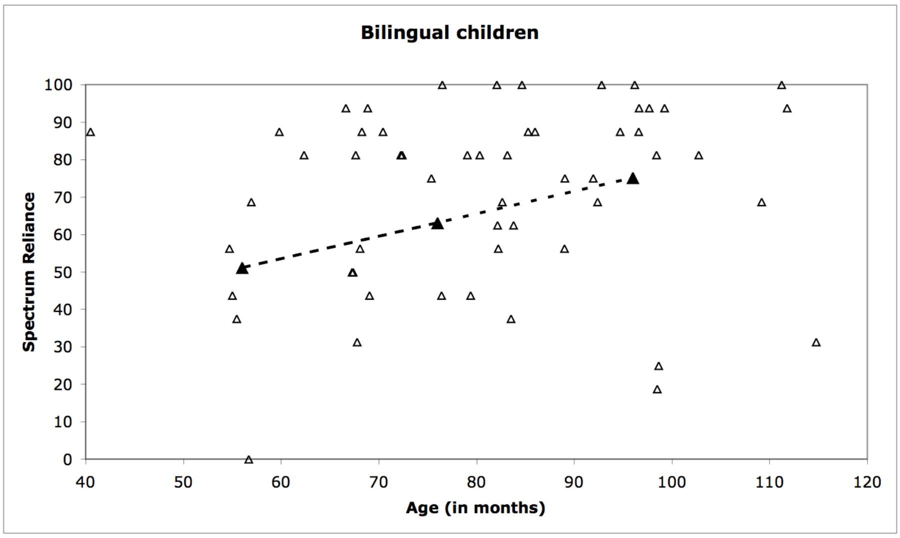

Figure 5.5: Spectrum reliance as a function of age (in months) for Dutch-BP bilingual children. The line and full triangles illustrate the MLM estimates; the empty triangles are the actual data.

As we can see in Figure 5.3, the adults form a very homogeneous group. There is much larger variation within both groups of children as we can see in Figure 5.4 for the monolingual children and in Figure 5.5 for the bilingual children. In these groups we see large deviations between the individual measures and the estimated line.

This is not only the case for the differences between respondents, but hold as well for the differences within participants. We also see that adults are significantly more stable than either group of children in their spectrum reliance across the 3 measurements (χ^2 = 29.95; df = 1; p < 0.001). This shows that children (both bilingual and monolingual) are less predictable, and that their reliance on spectrum differs more from one measure to the other than that of adults.

5.4.2 Results for duration reliance

Table 5.3 shows the results of the multi-level regression analysis of duration reliance for adults, monolingual children and bilingual children.

	Fixed Parameters		Variances	
	Cons (SE)	**β * Age† (SE)**	**$S^2_{between}$**	**S^2_{within}**
Bilingual children	28.3 (2.59)	0.48 (.14)	49.4	278.5
Monolingual children	19.7 (2.56)	0.23 (.14)	49.4	278.5
Adults	47.8 (12.73)	-0.08 (.06)	137.8	171.0

†: Age is centralized for children, hence age is rescaled as (Age – 76).

Table 5.3: Results of multilevel regression analysis for duration reliance. The fixed parameters (constant and age) and the variances between and within the groups are given.

The values for fixed parameters in Table 5.3 show that at the age of 76-month-old bilingual children have a duration reliance of 28.3 whereas that of monolingual children is 19.7. This difference is a significant one ($\chi^2 = 5.34$ df = 1; p = 0.02). This means that at 76 months of age (6;4 years) bilingual children have higher duration reliance than monolingual children. Moreover, the data in Table 5.3 reveal that at an age of 76 months bilingual children do not differ from adults in duration reliance ($\chi^2 = 2.25$; df = 1; p = 0.13) whereas monolingual children do ($\chi^2 = 4.62$; df =1; p = 0.03).

In addition to the constant effect, the data in Table 5.3 show a significant age effect for bilingual children (β/SE = 3.42; $p < 0.001$). Bilingual children's duration reliance increases by 0.48 for every month over 76 months of age. Likewise their duration reliance decreases by 0.48 for every month under 76 months of age. At 86 months of age bilingual duration reliance is estimated to equal 33.1; and at 66 months of age their duration reliance is estimated to equal 23.5.

The age effect is not significant for monolingual children (β/SE = 1.64; p = 0.10) or for adults (β/SE = 0.134; p = 0.17), although it is reasonable to speak of a certain trend for the monolingual children. The MLM estimated development of duration reliance for bilingual and monolingual children is illustrated in Figure 5.6.The values found for adults are displayed in the picture for comparison, but do not correspond to the age given in the X-axis.

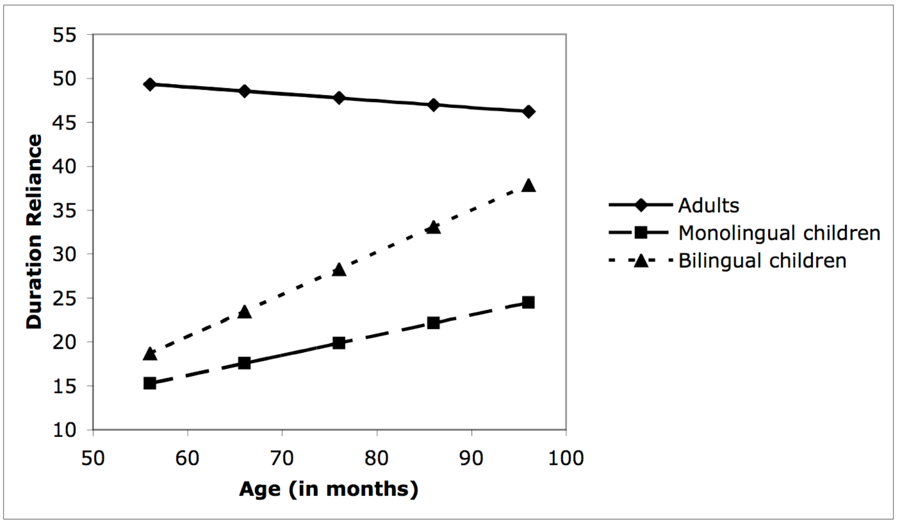

Figure 5.6: Multi-level regression estimate for duration reliance development in bilingual children and monolingual children. Results for adults are given for comparison.

An analysis of the estimated variance between participants within one group (see table 5.3) reveals no difference between children and adults ($\chi^2 = 0.92$; df = 1; p = 0.17). Also the variances within participants do not significantly differentiate children from adults ($\chi^2 = 2.51$; df = 1; p = 0.057), although the trend suggests that the variation between measure points is larger in children than in adults. The homogeneity within the groups can be visualized in Figure 5.7 for the adults, in Figure 5.8 for the monolingual children, and in Figure 5.9 for the bilingual children.

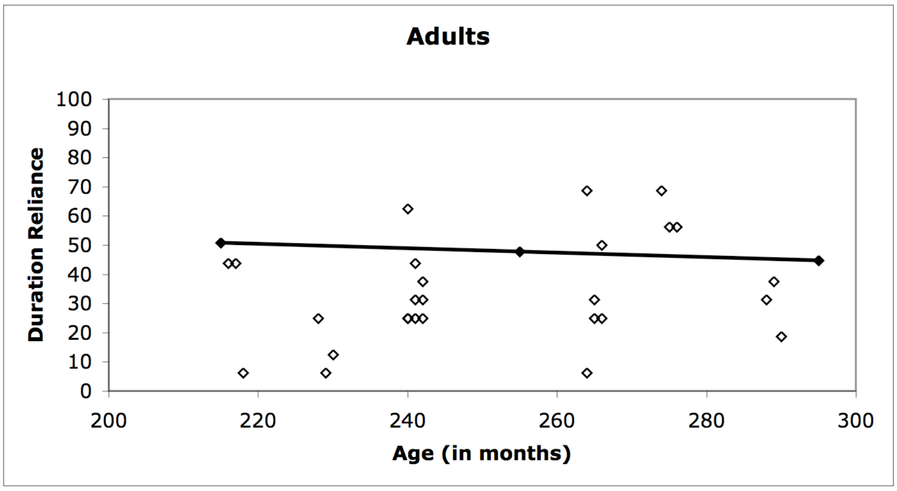

Figure 5.7: Duration reliance as a function of age (in months) for Dutch adults. The line and full diamonds illustrate the MLM estimates; the empty diamonds are the real data.

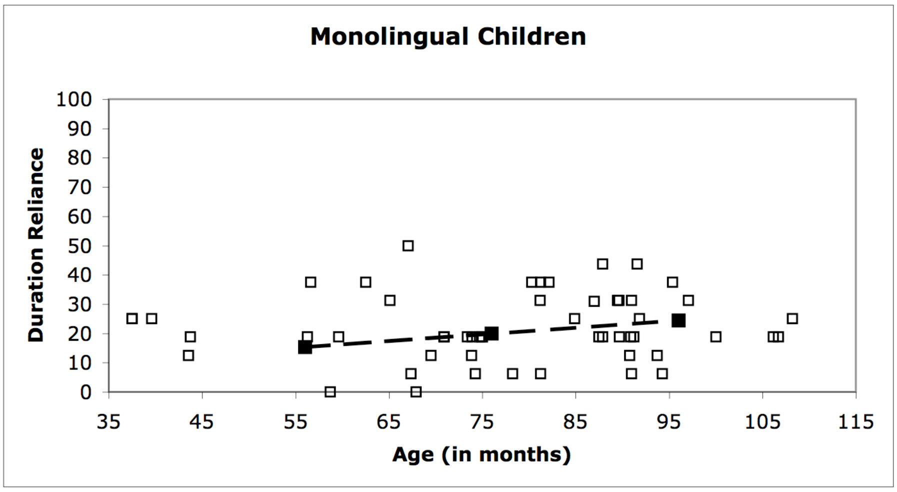

Figure 5.8: Duration reliance as a function of age (in months) for Dutch monolingual children. The line and full squares illustrate the MLM estimates; the empty squares are the real data.

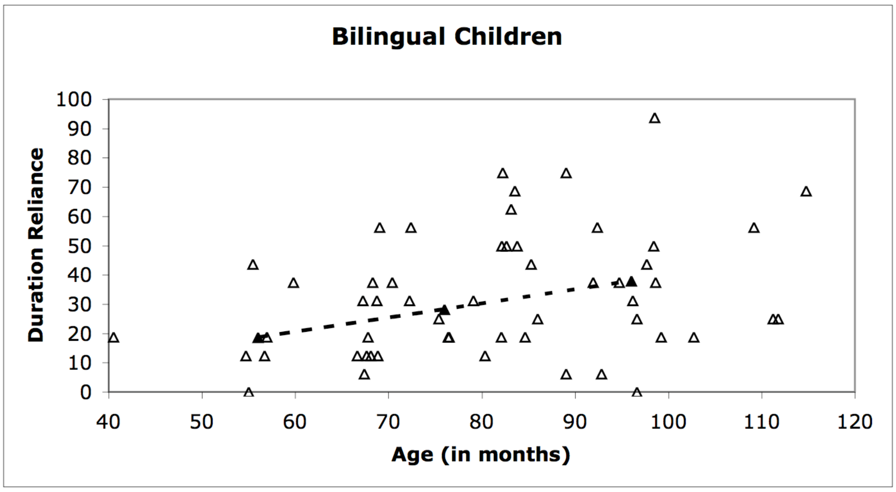

Figure 5.9: Duration reliance as a function of age (in months) for Dutch-BP bilingual children. The line and full triangles illustrate the MLM estimates; the empty squares are the real data.

As we can see in Figures 5.7 through 5.9, there is a large variation among all three groups, adults, monolingual children and bilingual children. In all groups we see a fairly large deviation from the individual measures to the estimate line.

5.5 Discussion

The results presented in the previous section raise interesting issues. Firstly, the results show age effects, given the differences found between adults and children. Secondly, the results show differences with respect to the factor most relevant to the purpose of this dissertation, namely differences between bilingual and monolingual children's perceptual development.

In the next sections I will discuss the results for spectrum reliance (Section 5.5.1) and duration reliance (Section 5.5.2) separately, combining them both in Section 5.5.3, when discussing an alternative way of looking at the data.

5.5.1 Spectrum reliance

The results for spectrum reliance reveal that at the average age of 76 months (6;4 years) both bilingual and monolingual children differ from adults. More importantly the results show a positive effect of age for children. This suggests that the use of this cue is still under development in both groups of children. No age effect could be found for the adults suggesting that this cue is stable through time within this group.

Moreover, the results discussed here show that at 6;4 years of age bilingual children differ from monolingual children in that they have a lower spectrum reliance. In the next paragraphs I will address this issue and discuss reasons for this delay.

Bilingual delay?

The scarce literature on perceptual development in bilingual children had previously suggested a possible delay by bilingual children as compared to monolingual children in their discrimination abilities (e.g. Bosch & Sebastián-Gallés 2003; Sundara *et al*. 2006). Bosch & Sebastián-Gallés explain the delay found in their infants in terms of the distributional properties of the vowels involved in the contrast. Sundara *et al*. (2006) take a similar approach, suggesting that the distributional peculiarities of the sounds they investigate might make it necessary for children to need extensive exposure to the contrast before their discrimination abilities can improve. In a more recent study, however, Sundara *et al* (2008) show that bilingual infants and monolingual infants do not differ in their discrimination abilities if the contrast investigated is frequent enough, even if their distribution is overlapping.

In the current study the sounds involved (Dutch /ɑ/ and /aː/ and BP /a/ and possibly /ɔ/) may have overlapping distribution across languages (see Section 2.1.3 in Chapter 2 of this dissertation) but are all very frequent sounds (see Section 4.6.2 in Chapter 4 of this dissertation). This would lead bilingual and monolingual children to have similar development in the light of the findings presented by Sundara *et al*. (2008). This, however, was not the case here, as we see bilingual children lagging somewhat behind monolingual children in their acquisition of spectrum reliance. Moreover since all vowels are about equally frequent but the bilinguals discussed here have a higher exposure to Dutch than to BP we can assume that the distribution of the vowels in their input is more compatible with a bimodal distribution than with a unimodal one. The exposure to a bimodal distribution should trigger the formation of two categories. Indeed, bilinguals in this study do show evidence of having two categories (recall from Chapter 4 that they had no problem discriminating the contrast) but the phonetic detail of their categories is not acquired at the same pace as in monolingual children.

How do the bilinguals in the current study differ from those discussed by Sundara *et al*. (2008)? One important difference between the current study and that of Sundara *et al* (2006 and 2008) is the variable studied. Whereas Sundara *et al.* study participants' discrimination abilities, I focus on their cue reliance. Adult-like cue reliance presumably leads to adult-like discrimination, given that adult-like cue reliance indicates adult-like categories. The reverse is not true, as adult-like discrimination does not necessarily mean adult-like cue weighting (see for instance Escudero, Benders & Lipski, submitted, for similar findings regarding L2 learners). Children may be accurately discriminating a contrast using different strategies, or based on different acoustic cues. It is then possible that the bilingual children in Sundara *et al*. (2008) have adult-like discrimination but not yet adult-like cue reliance. It is possible that children need an even greater amount of input to acquire adult-like cue reliance because it is an even finer ability than contrast discrimination.

Indeed even the monolingual children in this study have not yet reached adult-like cue reliance. Their spectrum reliance is developing towards the adult norm the more input they receive, as shown by the positive effect of age in their spectrum reliance, but they have not yet reached an adult-like state.

The bilingual delay found here can then be explained by a combination of increased complexity and reduced amount of input. Bilingual children's input is more complex in that their spectral space is more crowded, comprising vowels of both languages. Moreover compared to monolingual children, bilingual children's exposure to Dutch, or more specifically to the /ɑ/ - /aː/ contrast being studied here, is reduced, as part of their input is Brazilian Portuguese. This possibly implies that bilingual children need a more extensive period of time in order to acquire the correct weighting of cues.

5.5.2 Duration reliance

The results for duration reliance reveal that at the age of 76 months bilingual children have already mastered duration reliance in an adult-like fashion whereas monolingual children have not. Moreover a significant age effect was found for the bilingual children but not for the monolingual children suggesting that only bilingual children are developing their durational reliance to match that of the adults.

Bilingual acceleration?

These results suggest a case of bilingual acceleration in the perceptual development of duration reliance. This comes as a surprise considering the literature on the topic, which suggests that bilinguals are delayed when the cue to be acquired is only available in one of their languages but not the other. This was the case in the present situation since duration as a cue for vowel contrast is available in Dutch, but not in BP. Bilinguals were, however, found to be faster than monolingual children in their development of duration reliance. Here I will entertain three possible explanations for this finding.

Firstly it is possible that exposure to BP triggered the use of duration in Dutch. This hypothesis would seem very unlikely considering that BP does not use vowel duration to cue vowel contrasts. Moreover, in the previous chapter we have seen that BP monolingual children do not strongly rely on duration in the perception of the Dutch contrast. This suggests that exposure to BP in itself is not enough to stimulate duration reliance. It is however possible that the *combination* of BP and Dutch is what causes the acceleration. Dutch would work as the trigger, by making children "aware" of the possible use of duration to cue vowel contrasts whereas BP would work as the accelerator. Although there is no phonological vowel duration in BP, Escudero *et al.* (under review) have shown that the intrinsic durational difference between low and high vowels is very prominent in BP. Moreover BP strongly relies on duration to cue stress. Specifically stressed vowels have been shown to be at least twice as long as unstressed vowels. Results from experimental work revealed a ratio of 3:5:2 or 3:4:2 in the syllable duration of trisyllabic paroxytones (Major 1992). This prominent use of duration may work as an accelerator in bilinguals' acquisition of duration reliance. Part of this explanation implies that children have the ability to transfer the use of acoustic cues from one context (stress) into another one (vowel contrasts).

Another hypothesis about why bilingual children could be accelerated in their duration reliance as compared to monolingual children is related to their exposure to accented speech. Recall that Brazilian L2-learners of Dutch overuse duration in their perception. These listeners even rely more strongly on durational than on spectral cues, an inverse pattern compared to the Dutch natives (see Figure 4.3 for reference). It is possible that this perceptual pattern is reflected in their production, which would mean that these L2 learners produce exaggeratedly long [aː]s or exaggeratedly short [ɑ]s, or use Dutch native length with little to no use of spectral cues. Most, if not all, children being raised bilingually in Dutch and BP are exposed to this kind of accented speech, which might lead them to rely more strongly on duration than Dutch native children.

Thirdly it is possible that bilingual children rely on duration earlier than monolingual children because this cue is more relevant for this group. We should recall that there is a greater spectral overlap in the input these children receive, considering the two different vowel systems plus eventual mispronunciation. Once spectral cues lead to ambiguity, bilingual children use durational cues to disambiguate the more prominent, primary spectral cues.

Monolingual child development

Another interesting issue suggested by the results presented in Section 5.6 is the lack of development in duration reliance by monolingual children. Specifically our results found no effect of age for the monolingual children suggesting that there is no development for duration reliance in this group. This pattern had already been suggested in the previous chapter, when discussing the synchronic data. I will discuss here three possible explanations for this finding. The first one is related to the fuzziness in the input monolingual children receive, in combination with the nature of the contrast. The data for the Dutch adults concerning duration reliance was very fuzzy and variable, which is very surprising considering adults' great homogeneity in spectrum reliance. This finding suggests that duration reliance, although greatly used in production as well as perception, is of less importance than spectrum reliance and allows for more variance. As a secondary cue, its importance for the accurate perception of the contrast is not very great. Moreover the variation found in perception has also been found in production. Diettrich *et al*. (2007) points out that there is a great deal of overlap in durational properties when we compare different productions of Dutch /ɑ/ and /aː/, affecting for instance its bimodal distribution. Hence monolingual children possibly need an extensive period of time to acquire adult-like use of duration.

This fuzziness in the adult data should allegedly affect bilingual children as well as monolingual children. This does not seem to happen as we found bilingual children developing duration reliance. It is, however, possible that the different explanations I have previously entertained when discussing bilingual acceleration interact. It is possible, for instance, that bilingual children are aided by clearer use of duration to cue BP stress, or that duration is for this group a more necessary cue considering their crowded spectral space.

A second explanation for differences between monolingual children and adults in duration reliance is related to language change between the generations. Many sociolinguistic studies (e.g. Labov 1972) compare language production of participants of different ages as a way to access language change in progress. Although these studies are not done with language perception there is no reason why perception should not present the same evidence for language change. More simply put, we cannot be certain that the adult perception is the target of these monolingual children. Although this is generally a well-accepted assumption, I leave open the possibility that it is not the most accurate.

Finally, it is also possible that the age differences within the monolingual children group interact with other factors, such as geographical variation among the participants, making the age-factor insignificant. Since some varieties of Dutch use more duration than others (see e.g. Adank *et al.* 2007) it is possible that this might have influenced children's perception of the contrast. Although we aimed for an equal spread of bilingual and monolingual children and adults throughout the Netherlands, this was not perfectly achieved. Specifically, after selecting participants based on the accuracy of their answers to the end points of the continua we had an unbalanced design in terms of geographical distribution. Although this is also true for the bilinguals, they might have been affected differently.

5.5.3 General discussion: quantitative or qualitative differences between bilingual and monolingual children?

The results presented in this chapter show that monolingual and bilingual children differ in their perceptual development of spectral and durational cues. Specifically we found that monolinguals outperformed bilinguals in spectrum reliance and conversely bilinguals outperformed monolinguals in duration reliance.

In the previous two sections I have interpreted these findings in terms of delay and acceleration, two developmental patterns suggested for bilingual acquisition. This merely implies a quantitative difference between bilingual and monolingual children, as they show similar developmental paths within different time spans. It is, however, possible to interpret these results by assuming that monolingual and bilingual children use different strategies in the development of their perception. This view leads to different developmental paths and hence a qualitative difference between bilingual and monolingual children. In the next paragraph I describe these two hypothetical strategies, firstly for monolingual children and secondly for bilingual children.

The results of the monolingual children show that they quickly develop spectral cues and by 6;4 years of age they are adult-like in their perception. We found no evidence, however, for development in their durational reliance. Monolingual children might acquire one cue at a time, a path similar to that found in Escudero (2005), who proposed that children acquire acoustic cues separately and only later learn to integrate them. In the scenario described here monolingual children would firstly acquire the more prominent, or most important cue. In the case of the /ɑ/ - /a:/ Dutch contrast that is spectrum. Only once this cue is in place will they focus on the secondary cue (i.e. duration). Conversely, the results of the bilingual children show evidence for development in both spectral and durational cues. Bilingual development for spectral cues was however slower than that of monolinguals. These results suggest that bilingual children acquire both cues at the same time. In this view, bilingual 'delay' in spectrum reliance is a consequence of this strategy: since they are acquiring both cues simultaneously, they acquire them both slowly due to general cognitive limitations. Contrary to bilingual children, monolingual children focus all their efforts into acquiring the more essential cue, i.e. spectrum reliance, and hence outperform bilinguals in the development of this cue. In this view, bilinguals are not *delayed* or *accelerated* when compared to monolinguals, but simply take different paths to achieve the same endpoint.

To consider this hypothesis a plausible one we would firstly need to explain what would lead bilingual and monolingual children to different developmental paths if both groups of children are exposed to input where both spectral and durational cues are available. The best answer to this question would probably be a combination of the different factors discussed in the two previous sections, when explaining the quantitative differences between bilinguals and monolinguals. We could consider the monolingual children's strategy, focusing on the more relevant cue, to be the default strategy. The crowded spectral input bilinguals receive plus the facilitative role of BP could possibly trigger the acquisition of durational cues in this group, leading to a different acquisition strategy.

Importantly, it is not possible to disentangle quantitative from qualitative explanations in this data. These are two possible ways of interpreting it. There is in the general bilingualism literature, however, no reason to assume qualitative differences between bilingual and monolingual children, so the interpretation in terms of quantitative differences is the most probable explanation, and should be preferred.

5.6 Summary

The current chapter investigated whether bilingual and monolingual children follow the same developmental path in their perception of contrast. The present results found some differences between them. Specifically it was found that monolingual children were faster at acquiring spectrum reliance, the primary cue for the contrast, whereas bilingual children were faster at acquiring duration reliance, the secondary cue for the contrast. Interestingly no evidence for development of duration reliance was found within the group of monolingual children.

I have dealt with these differences in terms of quantitative (i.e. delay and acceleration) as well as qualitative differences between bilinguals and monolinguals. When discussing the data in terms of quantitative differences I suggested that monolingual children outperform bilingual children in the development of spectrum reliance due to their greater positive evidence. Bilingual children have reduced input for the contrast because part of their input is in another language (BP), and therefore, lacks the contrast under investigation. Moreover, the input received by bilingual children is spectrally more crowded, since there is an overlap between the vowels within each language, and between the vowels of the bilinguals' two languages, as well as a large number of mispronounced vowels (i.e. accented speech). On the other hand I discussed three ways in which bilingual input could cause accelerated development of duration reliance. Firstly it is possible that BP works as an accelerator since the durational differences in BP are highly prominent between high and low vowels and as a cue to stress. Secondly it is possible that the accented speech bilingual children are exposed to, where durational cues are exaggerated, facilitates the use of this cue. Thirdly duration might be necessary in order to disambiguate spectral cues.

When discussing the data in terms of qualitative differences between bilingual and monolingual children, I suggest that these children differ in how they acquire their perceptual cue weighting for this vowel contrast. Monolingual children might focus on the acquisition of the primary cue first and focus on the secondary cue once the primary cue is in place. Bilingual children, on the other hand, seem to acquire both cues at the same time, which might lead to some delay on the acquisition of the primary cue. The reason why bilingual and monolingual children would hypothetically use different strategies was related to input, in the same fashion as that proposed in the discussion on quantitative differences.

Finally it should be noted that it is not possible to separate quantitative from qualitative differences in this case. Considering the literature, however, quantitative explanation should be preferred.

Having established that bilingual and monolingual children differ in their cue weighting, in the next chapter I address the question of the role played by external factors in bilinguals' sound perception.

6 LANGUAGE MODE AND BILINGUAL PERCEPTION

In this chapter I address the fourth research question presented in Chapter 1, namely, *do bilinguals change their perception of vowel contrasts as a result of the relative activation of each of their languages (i.e. is there a Language Mode effect)*? The Language Mode Hypothesis claims that bilinguals' language systems are more likely to interact when bilinguals have both their languages activated, i.e. when they are in a so-called bilingual mode. An effect of language mode can then be interpreted as evidence for bilinguals' intact representation and adjustable performance, varying as a function of the language mode they are in.

To investigate a possible Language Mode effect I focus on bilinguals' perception of the /ɑ/ - /aː/ Dutch contrast. The main prediction of the Language Mode Hypothesis is that when tested in a monolingual mode, bilinguals and monolinguals show similar perception due to their similar perceptual representations. In a bilingual mode, however, bilinguals' and monolinguals' perception differs as a consequence of a language mode effect on bilinguals' perceptual performance. In the current study, participants' language mode was manipulated in three steps, ranging from a monolingual mode to a bilingual mode. Bilingual and monolingual participants took part in the same perceptual task as described in Chapter 3 under these three conditions. The results however do not support the Language Mode Hypothesis.

The first section of this chapter (Section 6.1) discusses the topic of bilingual representation, namely, the separate vs. common storage controversy. Section 6.2 introduces the Language Mode variable, providing its definition and a literature review on speech perception and Language Mode. In Section 6.3 I return to the research question addressed in this chapter, followed by a discussion of my hypothesis. Section 6.4 briefly describes the methods used in the current study and considers the ways in which the test settings have been manipulated in order to set participants in the desired language mode. The results discussed in Section 6.5 lead to a more precise hypothesis concerning the effect of language mode on bilingual's perception. This hypothesis is described in Section 6.6 followed by an alternative analysis and its results (Section 6.7). Section 6.8 provides an overall discussion of these results, relating them to relevant issues such as experimental design and language dominance. The chapter concludes with a summary in Section 6.9.

6.1 Bilingual's linguistic representation

The question of whether children raised bilingually have one or two linguistic systems has long been the subject of debates in the literature. Extreme views propose either completely shared systems or absolute separation, where no room is left for interaction between the two linguistic systems.

Between these extreme theories, there is a range of intermediate views concerning bilingual's languages representation. One of the most influential theories among them is Volterra & Taeschner's (1978) Unitary Language System Hypothesis. Volterra & Taeschner support the idea that initially bilingual children go through a stage where their two languages are part of a single system. This single system will however differentiate into two systems as a result of development sometime before the age of 3. More specifically, the Unitary Language System Hypothesis claims that at the first stage of acquisition, bilingual children start with a single language system, combining words and grammatical rules of both languages. As acquisition progresses, these bilingual children reach a second stage where the lexicons of the two languages are differentiated but not the grammatical rules. At the third and final stage of their linguistic acquisition bilingual children differentiate the grammatical rules of the languages they are acquiring and can be said to have two separated linguistic systems.

Alternatives to the unitary view are for example the Dual Language System Hypothesis (Genesee 1989) or the Separate Development Hypothesis (de Houwer 1994). According to these hypotheses, children acquiring two languages from birth develop two separated linguistic systems consistently with each of their input languages.

Arguments supporting either unitary or dual systems come from various types of linguistic evidence, such as vocabulary, syntax and phonology. In the following paragraphs I will briefly address each of these three fields. The case of phonology will be discussed in more detail considering its relevance for the present study.

6.1.1 Vocabulary

Vocabulary acquisition has often been claimed to support the theory of shared representation in young bilinguals. Volterra & Taeschner strongly base their hypothesis of an initial unitary language system on an alleged lack of translation equivalents in the vocabularies of young bilinguals. They claim that bilingual children create lexical labels on a one-to-one basis and avoid having two labels for the same object, even if these labels came from two different languages. This means that if a concept already had a label in one of the languages, it would not receive a label from the other language. In this view, translation equivalents could be considered evidence for two vocabularies, and hence two separate linguistic systems.

Contrary to Volterra & Taeschner's findings, a number of studies have found translation equivalents to be very common in young bilinguals' vocabulary, such as

Nicoladis & Genesee (1996), Nicoladis & Secco (2000), Pearson, Fernández & Oller (1993) and Quay (1995). One of the most in depth studies involving bilingual children's vocabulary acquisition is that of Pearson *et al*. 1993. In their large-scale study involving 25 Spanish-English bilingual children, Pearson *et al*. found that, despite a great number of translation equivalents, still a large part of bilingual's lexicon consists of *singlets*, i.e. words without a translation equivalent. The percentage of singlets however changes over time as bilinguals develop.

One might raise the question why bilingual children have such a large number of singlets in their vocabulary. The most important reason for this seems to be related to the concept of *domains of language use*, informally defined as 'who speaks what language to whom and when' (Fishman 2000). In a bilingual setting it is often the case that different languages are associated with different domains. Children acquire the vocabulary of their language according to the setting in which it is learnt, and they may not duplicate every experience in both languages. In a typical home-school bilingual situation, where a child speaks language A at home, and language B at school or the day-care centre, this child is likely to learn more family-related words in language A, and more school-related words in language B. Consequently, even very fluent (adult) bilinguals have gaps in their vocabulary.

In addition to differences in the language domains, bilinguals' early vocabulary acquisition may be constrained by general cognition issues such as memory limitations (Pearson *et al*. 1993).

6.1.2 Syntax

Syntax plays a prominent role in the discussion of bilinguals' language representations as many of the studies directly addressing this question come from this field. Moreover, syntax is also the field that has offered the strongest criticism against Volterra and Taeschner's three-stage hypothesis (e.g. Genesee 1989, Meisel 1989, De Houwer 1990, Döpke 1993). One of the main arguments for the criticism is the fact that young children are able to differentiate their two input languages despite some degree of mixing (Döpke 1997). If young bilingual children were to have a shared system for their lexicon one would expect them to frequently mix words, independently of the conversation setting and partners, or even to form sentences using grammatical rules of one language with words of the other language. This kind of data is not typically found in the bilingualism literature.

Recent studies in bilingual syntax acquisition often show that from a very early age bilingual children acquire language-specific structures of their languages exhibiting patterns similar to monolingual children (see e.g. Genesee 2001, de Houwer 1990, 2005 and Meisel 2001 for reviews). A large number of studies show that as early as their first word combinations, children can have two separate grammars. For instance, Paradis, Nicoladis, and Genesee (2000) observed negative markers in the production of 15 French-English bilingual children between the ages of 2 and 4 years. In French, the negative marker *pas* is placed after the main verb, whereas in English *not* it is placed between the main verb and the auxiliary (such as *can*, *do*, or *be*). They found no evidence that any of these 15 bilingual children go through a phase where their languages share a common system. Only in sporadic cases did they find the wrong placement of the negative marker. It can be concluded that most evidence from syntax favours the Dual Language Representation Hypothesis.

6.1.3 Phonology

Studies on the differentiation of the bilinguals' phonological systems have provided unclear results. Some of these studies suggest completely undifferentiated phonological representations (e.g. Vogel 1975, Celce-Murcia 1978); some argue for a partial differentiation (e.g. Deuchar & Clark 1996); some others claim that bilingual children differentiate their phonological system at or before two years of age (e.g. Johnson & Lancaster 1998; Paradis 1996).

Perhaps one of the reasons for these contradictory results lies in the methodological challenges posed by phonological research. Paradis (2001) points out that one problem with studying early phonological systems is the lack of language-specific features in the production of very young children. Many of the sounds young children produce are cross-linguistically unmarked. Language-specific sounds are generally acquired later. It is then unclear whether common phenomena found in bilinguals' early production of their two languages are due to shared representation or due to this lack of language-specificity.

For instance, the study of Celce-Murcia (1978) suggesting common representation of bilinguals' phonological systems can be reinterpreted in terms of lack of language-specific features as suggested by Paradis (2001). Celce-Murcia observed that the child in her study, who was simultaneously acquiring French and English, used the same phonological substitution processes in both languages. A phonological substitution occurs when a child uses a different (normally less marked) phoneme instead of the correct, adult-like one. One example of this is when a child substitutes an /l/ at the end of a word for a vowel or a glide, so that the word *ball* is pronounced /bɔw/. Celce-Murcia's observation that the same substitutions were made in both the bilingual's languages has been interpreted as evidence for a unitary languages system. However acquisitionists have often shown that some substitution processes are very common cross-linguistically (Ingram 1986), including those observed by Celce-Murcia. This means that monolingual French and monolingual English children around the same age as the French-English bilingual studied by Celce-Murcia, could have had the same substitutions in their speech. In this case the bilingual child in Celce-Murcia's study could be following patterns similar to her monolingual peers and the use of similar substitutions in both the bilingual child's languages cannot be regarded as evidence for common representation.

One way to overcome the lack of language-specific features in studies of phonological acquisition is the use of acoustic analyses, a recent development which has gained strength in this field (Lleó & Kehoe 2002). Acoustic analysis equips researchers with some finer grained information about speech properties allowing for more detailed analysis of the data collected. Johnson & Wilson (2002) for instance use acoustic analysis in their study of acquisition of Voice Onset Time (VOT) by bilingual children in Japanese and English. It has been argued that the languages of the world have three types of VOT: a negative VOT (lead) usually associated with voicing; a short VOT often used to cue voicelessness and a long

VOT cueing aspiration contrast (Lisker & Abramson 1964; but see Cho & Ladefoged 1999 for a more nuanced picture). Languages that have a two-way voice contrast, like English, Japanese, Dutch, and Portuguese, differ in the types of VOT used. In syllable initial position, Japanese and English, the two languages involved in Johnson & Wilson's study, present a crucial difference in the acoustic realization of voicing contrast. Whereas Japanese has a pre-voicing vs. a short-lag to cue respectively voiced and voiceless consonants, English has a short-lag vs. long-lag VOT to mark the same contrast. The young bilingual children investigated by Johnson & Wilson appeared to have one system for both languages because they used the English voicing system in both languages, namely short-lag for voiced vs. long-lag for voiceless consonants. A look at the phonetic detail of their productions, however, showed that these children actually *were* making a difference between the two languages in terms of VOT values, even if this difference was not monolingual-like. Johnson & Wilson's interpretation of the apparent lack of contrast is that these children had not yet mastered the motor control which allows them to pre-voice their stops. This interpretation is supported by studies in monolingual acquisition, which show that pre-voicing is acquired later than short- or long-lag voicing (Macken & Barton 1980).

Although the majority of the studies investigating bilinguals' phonological representation are production studies, the field of speech perception in bilingual infants and children has contributed most to our understanding. One of the advantages of working with perception as opposed to production is that it allows one to investigate very young children, even before they are able to produce sounds. Moreover, perception studies filter out issues specific to production, such as those related to motor coordination found in Johnson & Wilson (2002).

Most of the studies on BFLA children's perception of speech sound focus on the comparison between bilinguals and monolinguals and very few directly address the question of language representation. Bosch & Sebastián-Gallés (2003), however, although not directly attempting to answer any question concerning bilinguals' phonological representation, interpret their results in terms of language representation. In previous studies, Bosch & Sebastián-Gallés (1999, 2001) show that very young bilingual infants (4.5-month-old) are able to differentiate between their languages. In their 2003 study, however, they find that by 8 months of age bilingual infants fail to discriminate a vowel contrast which is present in one of their languages, contrary to their monolingual peers. They interpret these results to mean that bilingual infants have a shared perceptual space common to both languages, even though bilingual infants were able to discriminate between their languages early in acquisition, at 4.5 months of age. In their view this early ability to discriminate between their two languages is not necessarily a consequence of separated storage for phonetic information but rather a combination of representation and input. The inability of the 8-month-old infants to perceive the contrast is accounted for in terms of the distribution of the specific contrast they studied, which, when considering both languages together, is more compatible with a unimodal distribution than with a bimodal distribution. Maye *et al.* (2002) show that infants exposed to a contrast that is in unimodal distribution will not acquire the ability to discriminate it (Maye *et al.*'s study was described in more detail in Chapter

1, Section 1.4.2). Furthermore Bosch & Sebastián-Gallés hypothesize that vocabulary acquisition triggers the separation of phonetic information, explaining how bilingual infants regain their discriminatory abilities at 12 months of age.

To summarize the discussion on bilingual representation, there seems to be reasonable agreement in the current literature about bilinguals having separate systems. Most studies show that children use the language most appropriate to their interlocutor, which shows pragmatic awareness of the difference between the languages being used around them. This pragmatic awareness only makes sense if one assumes that the two languages are separate at least at some level of representation (Lleó & Kehoe 2002). Scholars however have different ideas about the age at which this separation occurs, whether at birth or sometime later, but in any case, early in childhood.

Another apparent consensus in the bilingual literature is the fact that bilinguals' languages interact. Evidence for this interaction comes from numerous studies such as those pointing out differences in time span between bilinguals and monolinguals in the acquisition of specific features (e.g. Bosch & Sebastián-Gallés 2003, Kehoe 2002); language mixing in bilingual children (e.g. Lanza 1992); and code-switching in bilingual children and adults (Poplack 2000).

The overwhelming evidence that the bilinguals' two languages may influence each other does not contradict the assumption that bilinguals have separate language systems. Language differentiation does not necessarily imply autonomous development, as two autonomously developing systems can still interact. This interaction can happen, for instance, as a consequence of mixed input, or it can happen in terms of output, without affecting representation.

These assumptions have had an impact on the way bilingualism is studied. Paradis (2001) for instance stresses that questions regarding bilinguals' language intraction and the mechanism by which this interaction takes place are now of greater importance. Lleó & Kehoe (2002) suggest that rather than asking whether bilinguals have one or two systems, the focus of research on bilingualism should be the relationship between the two simultaneously developing languages.

When addressing topics on the circumstances under which bilinguals' languages interact, one recurrent issue is what Grosjean (1994, 2000) has called the bilingual's Language Modes (see for example Johnson & Wilson 2002; Kehoe 2002; Khattab 2002; Paradis 2001; Whitworth 2000). The bilingual's Language Modes refer to bilinguals' processing mechanisms at a given point in time. In the next section I directly address this concept, starting with a definition and proceeding with a discussion on the implications for speech perception research.

6.2 Language Modes

As mentioned in the previous section, the topic addressed by researchers in phonological representation in bilinguals has changed its focus. The question of whether bilinguals' systems are stored together or not has given place to questions concerning the ways and circumstances under which bilinguals' language systems interact. When dealing with the circumstances under which the languages of a bilingual interact, researchers often refer to the concept of Language Mode (e.g.

Grosjean 1994, 2000.) The specific claim is that interactions are more likely to occur when bilinguals are on a bilingual language mode as opposed to when they are on a monolingual language mode. In the next sections I will discuss the definition of language mode as put forward by Grosjean and its implications for research on bilingualism (Section 6.2.1). In Section 6.2.2 I present several studies in speech perception which have directly addressed the Language Mode issue.

6.2.1 Definition

Grosjean (1994, 2000) defines Language Mode as *the state of activation of the bilingual's languages and language processing mechanisms at a given point in time.* Grosjean clarifies this definition using the illustration presented below in Figure 6.1. The level of activation of each of the bilingual's languages (language A and language B) is seen as a continuum ranging from no activation to complete activation. In the figure the level of activation is illustrated by means of darkness in the squares: a black square represents a completely active language and a white square would represent a non-active language while shades of grey indicate intermediate states of activation. The base language (i.e. the main language at a given point in time) is always the most active one. The other language, language B, varies in its degree of activation, but is always less activated than the base language. The points marked 1, 2 and 3 in Figure 6.1 are interpreted as three different points in time. In position 1 language B is only slightly activated and a bilingual in this situation is said to be at (or close to) a monolingual language mode. In position 2 language B is more activated and the bilingual is said to be in an intermediate mode. In position 3, language B is strongly activated, although still slightly less activated than the base language (language A). Bilinguals in position 3 are said to be in a bilingual language mode.

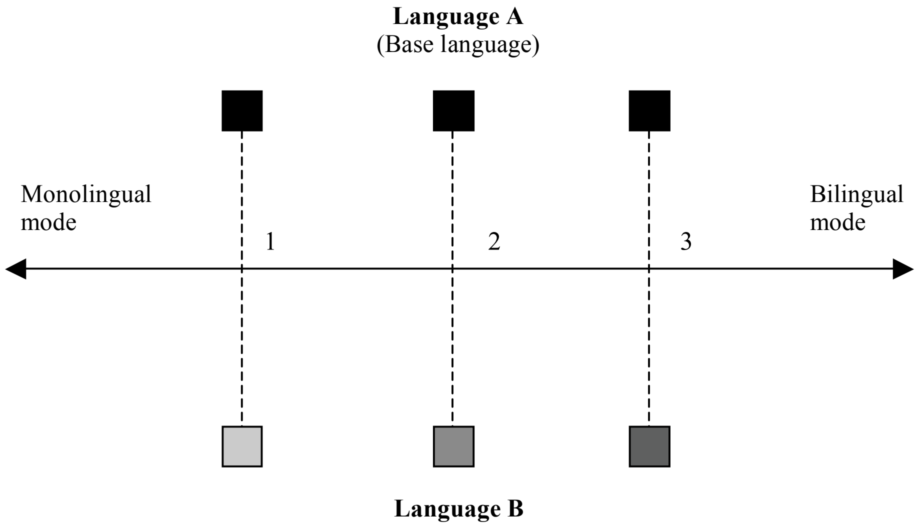

Figure 6.1: Visual representation of the language mode continuum. Figure adapted from Grosjean (2000).

Language mode involves two concepts: the choice of the base language, i.e. the language in which the interaction is taking place, and the comparative level of activation of the two languages concerned. These two factors are usually independent of each other. This means that one of these factors can change without affecting the other. The base language can change without there being a change in the relative level of activation of the two languages. For instance, if we focus on position 3 of Figure 6.1, it is possible that a bilingual changes the base language, from language A to language B, but still remains in a bilingual mode. Likewise, it is possible to alter the comparative level of activation of the language without altering the base language. A bilingual can for instance move from position 1 (monolingual mode) to position 3 (bilingual mode) as illustrated in Figure 6.1 without a change in the base language. Grosjean points out that since these two factors are always present and are independent, it is crucial for researchers always to refer to both factors when reporting the participant's language modes. For instance, when reporting on the language mode of a Dutch-English bilingual, it is not enough to say that the bilingual was in an English mode or in a bilingual mode. In the former case only the base language is being taken into account and in the latter only the relative level of activation. To give a complete picture, researchers should refer to, for instance, an English monolingual mode or a Dutch bilingual mode.

Numerous factors can influence the position a bilingual takes on the language mode continuum. Grosjean discusses the factors that have been claimed to play the most crucial roles: (1) participants, including factors such as language proficiency, and language mixing habits; (2) the situation, which involves variables such as the physical location and the presence or absence of monolinguals; (3) form and content of the message, including the language used and the topic; (4) language act, whether a request, or an order, and the speakers' intention to either create social distance or to exclude someone from the conversation; finally, in research settings one has to take into account (5) the specific research factors, such as the aims of the study, whether or not they are known to the participants, the type of the stimulus, the task used, etc.

Grosjean remarks that controlling for language mode is extremely difficult, especially in perception studies, and that setting bilinguals in a completely monolingual mode may be impossible. Considering the number of factors that possibly play a role in language activation (experimenter, task, proficiency, environment, homophony, etc.) it is very complicated to completely prevent the bilingual from activating the other language, even if just to a limited extent (Grosjean 2008).

Two languages are more likely to interact when they are both strongly activated, i.e. when a bilingual is at (or close to) the bilingual end of the language mode continuum. In this view, language mode is taken to affect bilinguals' language behaviour and is an important variable to be taken into account in studies involving bilingualism. So, one can question results supporting 'bilinguals common storage' on the bases of possible confusion between what is due to representational issues and what is caused by the language mode variable. Given that bilingual participants are often in a bilingual mode when taking part in studies involving bilingualism (Grosjean 2000), this could have lead to results indicating a shared system. Let us consider, for instance, how code mixing occurs in young children. The fact that young bilingual children often mix their two languages was often used as an argument supporting shared representational systems in bilinguals, given the high degree of interaction between the systems. One could however claim that the children in these studies were in a bilingual mode during the experiments given the bilingual context. Language mixing might thus be simply a consequence of the mode they were in and does not necessarily imply that the languages are stored together.

Grosjean's Language Mode model is in many aspects parallel to and compatible with Green's model for speech in bilinguals (Green 1986). Green's model is based on inhibitory control, an executive system for activating or inhibiting an individual's linguistic representation, and resources. In Green's view the representational systems of bilinguals' languages are separate. Both languages are active even when only one of them is being used. An inhibitory process suppresses the non-relevant language while the other carries out the task. It is this inhibitory mechanism which allows bilinguals to fluently carry out a conversation in one of their languages without intrusion of the other active language. In this view bilingual development involves not only the acquisition of the sounds of both languages, but also a maturation of this control mechanism.

Grosjean's and Green's models seem to present complementary views of bilingual processing. The main difference is the theoretical mechanism being used: where Green refers to inhibition processes, Grosjean mainly refers to activation. Specifically this means that to account for a (nearly) monolingual mode in Green's model, one of the bilinguals' languages needs to be inhibited; conversely in

Grosjean's model, to obtain the same effect activation has to occur in only one of the bilinguals' languages.

6.2.2 Language Mode and speech perception

There have not been many speech perception studies where language mode is taken into account, or controlled for and apparently similar studies present contradictory results. For instance, Caramazza, Yeni-Komshian, Zurif & Carbone (1973) studied the perception of the VOT continua in English-French bilinguals in English and French language settings. Contrary to the researchers' predictions, participants showed no difference between the two conditions. The authors interpreted this lack of language mode effect as evidence for participants' shared representation. A few years later, Elman, Diehl & Buchwald (1977) did a similar study on English-Spanish bilinguals. In this study, however, the authors intensified the control of the language settings by presenting participants with natural produced speech. This time, the bilingual participants did reveal a boundary shift: participants' responses were more English-like in the English setting and more Spanish-like in the Spanish setting. Grosjean (2000) presents an explanation for the inconsistency between the two studies in terms of language mode. He claims that the language set manipulation in the Caramazza *et al.* study was not sufficient to keep the bilingual listeners at the monolingual endpoint of the continua. In the second study, Elman *et al.*, however, there was constant language specific information, which activated one language much more than the other. Consequently only in this study did bilinguals show a shift in their perceptual boundaries as a function of the language setting they were in.

One of the most influential perception-based models of second language (L2) sound acquisition, the Speech Learning Model (SLM, Flege 1995) ignores the possible effects of language mode in bilinguals' perceptual performance. In a number of studies by Flege and colleagues on the perception of VOT continua (e.g. Flege 1987, 1995, Flege & Eefting 1986, Flege & Hammond 1982, Flege *et al.* 1999), bilinguals turned out to have their category boundary on an intermediary position between the L1 and the L2 boundaries. Based on these results, the SLM assumes the existence of a 'merged category', one single category accommodating two or more sounds. According to the model, only L2 sounds that are perceptually different enough from L1 sounds will trigger the formation of a new category. Otherwise (as it is the case with the stop consonants studied), the L2 sound will simply be 'adopted' by the closest L1 category, creating a 'merged category'. Subsequently, the L1 category will change, or move its boundaries, in order to better fit the L2 input. This way, the SLM predicts a possible negative effect of L2 speech sounds on the categories of the native language. It is possible however to question the concept of a merged categories and its conclusions on the basis of a language mode effect. This variable could have blurred the results of the research given that the participants were probably in a bilingual mode during the experiments, which might have led to an intermediate category.

In Escudero's (2005) Second Language Linguistic Perception (L2LP) model the relationship between Grosjean's language mode continuum and intermediate boundaries is directly addressed. Specifically, Escudero claims that intermediate perception between L1 and L2 is the consequence of parallel activation of the participants' two separate sound systems. This is opposed to Flege's interpretation of bilinguals' single set of categories and mappings for the two languages.

Escudero & Boersma (2002) present some evidence against the concept of a 'merged category' in bilinguals. They presented 25 naturally produced CVC syllables embedded into a Dutch or Spanish carrier phrase to Dutch-Spanish sequential bilinguals. In the first part of the experiment the L1 of the subjects (Dutch) was primed; in the second part, their L2 (Spanish) was primed. At certain points Escudero & Boersma appeal to participants' metalinguistic awareness to set them in the desired mode (e.g., "listen to these vowels with your Spanish ears" when presenting participants with Spanish vowels in order to set them in a Spanish monolingual mode; or "listen to these vowels with your Dutch ears" when presenting participants with Spanish vowels, in order to set them in a 'mixed' or bilingual mode). In Grosjeans' view, such explicit references to a language could affect participants' mode. Even though the participants in Escudero & Boersma's experiment might not have been in a purely monolingual mode during the task, the shift in language setting was enough to play a role in their perception. Listeners changed their responses according to the language being primed. This way, Escudero & Boersma (2002) propose an alternative explanation for bilinguals' intermediary category. They suggest the existence of perception modes. In this view, the intermediary boundaries found in bilinguals by Flege and his co-workers are due to the relative state of the activation of the bilinguals' languages.

It should be pointed out however that Flege's (as well as Escudero's and Escudero & Boersma's) studies involve sequential bilinguals, as opposed to simultaneous bilinguals. Flege does acknowledge the role which age of acquisition plays in the formation of new categories, even for similar sounds. This way it is possible to hypothesize that in Flege's view only sequential bilinguals would show intermediate category boundaries where simultaneous bilinguals would have two separate categories for each of their languages.

6.3 Research question

The main question I address in this chapter is whether bilinguals' perceptual categorization changes as a function of the language mode they are in. It is generally assumed that in a bilingual mode, when both the bilinguals' languages are strongly activated, bilinguals are more likely to differ from monolinguals in their categorization as a consequence of an interaction between the two languages.

In the current study I have set up a perception experiment to look into the representational sound systems in monolingual and bilingual children and their variation as a function of language mode. Language mode has been varied in three steps ranging from a monolingual to a bilingual mode. I will discuss the details of how this variable was manipulated in the next section.

The Language Mode Hypothesis states that in a bilingual mode Dutch-BP bilingual children are expected to behave less like Dutch monolingual children, revealing in their perception of Dutch sounds some features of their other language, BP. Monolingual children on the other hand are expected to show no language mode effect. It is important to note that some degree of variation between the language mode settings is expected for all groups, including the monolingual children and adults. This circumstantial variation can be the consequence of multiple factors such as experimenter, learning effect or simply noise. Changes in the language mode setting, however, are expected to have a stronger effect on bilingual than monolingual children as the language mode variable only plays a role in this group.

6.4 Methods: manipulating bilinguals' Language Modes

In this study bilingual and monolingual children and adults were tested on their perception of the /ɑ/ - /aː/ Dutch contrast. The stimuli were continua where the vowels were manipulated in their spectral and durational characteristics forming a 4x4 matrix. For a thorough description of these groups, as well as the details of the perception experiment the reader is referred to Chapter 3.

Four groups were tested: bilingual Dutch children (N=18), bilingual Brazilian children (N=19), monolingual Dutch children (N=15), and monolingual Dutch adults (N=18). Both groups of bilinguals were simultaneously acquiring Dutch and BP. The bilingual Brazilian children were being brought up in Brazil while the Dutch bilinguals were being brought up in the Netherlands. The number of participants per group and their mean age are given in Table 1.

	N	Age mean
Bilingual Dutch children	18	5;4
Bilingual Brazilian children	19	6;1
Monolingual Dutch children	12	5;5
Dutch adults	18	23

Table 6.1: Number of participants (N) and mean age for bilingual Dutch children, bilingual Brazilian children, monolingual Dutch children and Dutch adults. Mean age corresponds to measure on the first setting.

In order to investigate the hypothesized Language Mode effect I have manipulated this variable in three steps, ranging from a monolingual mode to a bilingual mode. The manipulation was done in such a way as to simulate the three positions in the language mode continuum illustrated in Figure 6.1. As discussed in Section 6.2.1, there are a number of factors likely to influence bilinguals' language mode, such as their proficiency in each language, their physical location, the presence or absence of monolinguals, the language used in the context, and the topic of conversation. In experimental settings, other relevant factors are stimuli and task. Although it is still unclear how heavily each of these factors influences bilinguals' language activation, some factors seem to play a very strong role, such as the language used in a given context and the presence or absence of other bilinguals or monolinguals. To achieve the three language mode positions, I have manipulated the experimenter and the language being used in each of the three settings, as shown in Table 6.2.

1. Monolingual mode	2. Intermediate mode	3. Bilingual mode
• Dutch monolingual researcher • Dutch only • Dutch fillers • Dutch stimuli	• Dutch monolingual & bilingual researchers • Dutch mainly • Dutch fillers • Dutch stimuli	• Bilingual researcher • Dutch & BP equally used • Dutch & BP fillers • Dutch stimuli

Table 6.2: Language Mode manipulation.

In a Dutch monolingual mode setting (1), Dutch was the only language used and the experimenter dealing with the participants was a native speaker of standard Dutch with no knowledge of Brazilian Portuguese. All sentences pre-recorded in the game / experiment (e.g. instructions, words of encouragement like 'very good!') were in Dutch only. Importantly, results presented and discussed in the Chapters 4 and 5 come from tests in this setting. In the intermediate mode setting (2) some Brazilian Portuguese was introduced in the context by the presence of a bilingual experimenter[20] who spoke in both languages to the bilingual participants. Dutch was still the main language used, however, and all pre-recorded sentences in the experiment were in Dutch. In the bilingual mode setting (3) only the bilingual experimenter was present and both languages were used equally. The pre-recorded sentences in the experiment /game were presented in both languages, first in Portuguese and then in Dutch. The same speaker, a female Dutch-BP simultaneous bilingual, recorded both the Dutch and the Portuguese sentence.

In all three settings the stimulus tested was the same Dutch vowel contrast. In addition to the control of the variables described in Table 6.2, a vocabulary task was also used to set the mode. Prior to the perception experiment, children performed a vocabulary production task. In the Dutch monolingual mode, they performed the vocabulary task in Dutch, and in the bilingual mode, bilingual children performed the task in Brazilian Portuguese. In the intermediate mode there was no vocabulary task and children started the perception task right away.

Grosjean (2000, as well as Green 1986) claims that a fully monolingual mode is never achieved[21]. This means that bilinguals are not capable of fully deactivating (or inhibiting) one of their languages. In a recent publication, when directly addressing the topic of Language Mode manipulation in perception studies, Grosjean (2008) discusses the difficult task of setting bilingual participants in a monolingual mode given the number of factors possibly moving them towards the bilingual side of the language mode continuum. In the current study, however, the language mode variable is manipulated on a scale, ranging from a (nearly) monolingual mode to a (nearly) bilingual mode. In this case, the question whether bilinguals can be in a completely monolingual or bilingual mode or not becomes irrelevant. Even if we are not able to set participants in a completely monolingual

[20] The bilingual experimenter was a female native speaker of Brazilian Portuguese who had been living in the Netherlands for over 8 years. She speaks Dutch fluently but has a slight accent.
[21] Uncontroversial evidence for this is, however, still lacking.

mode, differences found between the settings would still present enough evidence for a hypothesized language mode effect.

All groups of participants were tested in all three settings. Although no language mode effect is expected in monolingual listeners, they too were tested under these three settings so that we could disentangle a possible learning effect from the hypothesized language mode effect. The only difference between the experimental settings for the bilinguals and the monolinguals was that the bilingual researcher did not talk in Brazilian Portuguese to the monolingual Dutch participants. The bilingual researcher, however, was always present during tests in the intermediate and in the bilingual mode setting. Monolingual participants did hear bilingual pre-recorded encouragement sentences during the experiment while tested in a bilingual setting, but they were asked to ignore them. The main idea was to keep the testing conditions of the bilinguals and the monolinguals as similar as possible.

Participants were tested in three different test sessions always in the same order: firstly in a monolingual mode setting, secondly in an intermediate mode setting, and finally in a bilingual mode setting. This means that in their first test session (i.e. monolingual mode setting) bilingual children were not able to associate the task with bilingualism. Such an association would likely trigger the activation of their BP language, an effect we were trying to avoid. The interval between the test sessions was at least one week, and at most 3 weeks.

The general prediction from the Language Mode Hypothesis is that bilinguals will behave more like Dutch monolinguals when they are tested on the monolingual setting (1). Non-native-like perception is more likely to occur as we move towards the bilingual language mode end of the continuum as in this situation both of the bilinguals' languages are strongly activated and prone to interaction.

6.5 Results: spectrum and duration reliance across language mode settings

Spectrum reliance and duration reliance[22] were analyzed using analysis of variance (GLM repeated measures procedure of SPSS). These two variables were analyzed independently, each containing 3 levels as all participants were measured on three occasions, in a monolingual, intermediate, and bilingual language mode. The split-plot design of the data allows for an analysis of between-subject factors as well as within-subject factors. The between-subject factors were the 4 Dutch-speaking groups: bilingual Dutch children, bilingual Brazilian children, monolingual Dutch children, and monolingual Dutch adults. Brazilian monolinguals were not tested for a language mode effect. Support for the Language Mode Hypothesis would come from the data if an interaction between the groups and any of the independent variables, spectrum reliance or duration reliance, were found. More specifically, the Language Mode Hypothesis would predict bilinguals to be more strongly affected than monolinguals by a change in the language mode setting.

Figure 6.2 shows the averages of spectrum reliance and of duration reliance per group in each of the settings tested: monolingual, intermediate mode and bilingual mode (see Table 6.2).

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[22] See Chapter 3 for a detailed explanation of the calculation of these two variables.

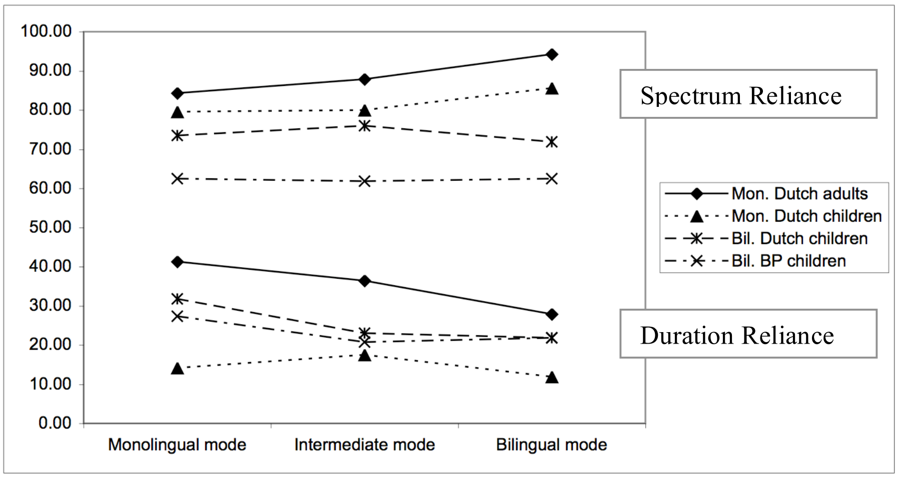

Figure 6.2: Average spectrum reliance (top) and duration reliance (bottom) illustrating the perceptual patters of four different groups (monolingual Dutch adults, monolingual Dutch children, bilingual Dutch children, and bilingual Brazilian children) in three different points on the language mode continuum (monolingual mode, intermediate mode and bilingual mode).

Concerning spectrum reliance, the only significant difference found was a main effect between the groups ($F = 4.533$, $p < 0.01$). There was no interaction between groups and the three measures of spectrum reliance. This means that this difference cannot be interpreted as evidence for the language mode hypothesis. The fact that the groups differ in spectrum reliance was discussed in Chapter 4, noting children's lower spectrum reliance when compared to that of adults.

The results for duration reliance reveal a within-subject effect ($F = 3.491$, $p < 0.05$). Overall, subjects relied increasingly less on duration to identify the vowel contrast (means: 29.13 in the monolingual setting, 24.81 in the intermediate setting, and 21.20 in the bilingual setting). There was however no interaction between the groups, which once again means that we found no support for the Language Mode Hypothesis. The decrease in duration use could potentially be attributed to a general learning effect. I will return to this issue in Section 6.8.1.

Discussion

The lack of significant results found in the repeated measures analysis could suggest lack of support for the language mode hypothesis. However, it is possible that results have failed to reach significance due to distinct (and possibly contradictory) ways in which language mode could affect bilingual participants' perception.

In the next section I will introduce more specific predictions concerning the possible role played by language mode on bilinguals' cue-reliance, followed by a reanalysis of the results discussed here.

6.6 Language Mode and bilinguals' cue reliance

As discussed in Sections 6.3 and 6.4, the general prediction from a language mode effect is that bilinguals will behave more like monolinguals when in a monolingual mode than when in a bilingual mode. But what does it mean to behave less like a Dutch monolingual in this specific case? How will that affect bilinguals' responses to the task?

In this section I discuss a more explicit prediction of the hypothesized language mode effect, given what we already know about participants' cue-reliance. The question I will be addressing here concerns the exact consequences a language mode effect would have on bilinguals' perception regarding their cue-reliance.

Based on the monolingual data discussed in Chapter 4, two possible effects can be hypothesized. In the next section, I will firstly explain these two predictions in detail and show that, although contradictory, they are both possible and plausible.

6.6.1 Discussing two possible effects

The main prediction of bilinguals behaving less like monolinguals when in a bilingual mode is that we should be able to trace some effect of BP in Dutch categorization. How does this effect take place? More importantly, we have seen that BP monolingual children and adults differ in their use of acoustic cues in the perception of the Dutch contrast. So, when we say that bilingual children will be more like BP monolinguals in a bilingual mode, it is crucial that we carefully consider if they will be more like BP monolingual adults or children.

My main claim in this section is that in a bilingual mode bilingual children will behave more like BP monolingual *adults* (and less like Dutch monolinguals) than in a Dutch monolingual mode. The reason why bilingual children could show patterns more similar to BP adults (rather than to BP children) is a consequence of one of the points previously made. Before I discuss these patterns I summarize the findings in Chapter 4, since they will be relevant for the prediction.

In Chapter 4, Section 4.5.1 I suggested that BP children processed the Dutch vowels on the basis of their native vowel inventory and that there were different paths they could take. Most BP children reported hearing the native BP /a/ - /ɔ/ contrast during the experiment. This means that the two Dutch vowels are mapped onto two distinct BP vowels (the Dutch /aː/ to BP /a/; and the Dutch /ɑ/ to BP /ɔ/) and only spectrum is used to make the contrast (this strategy was labelled 'Strategy B' in Chapter 4). BP children rarely use the other possible perceptual strategy, in which the two Dutch vowels /aː/ and /ɑ/ are both mapped onto one single BP vowel, the acoustically close /a/, in which vowel duration would be needed for the perception of contrast (referred to as 'Strategy A' in Chapter 4). Moreover I mentioned that there were a number of children whose initial perceptual stage was that depicted in Strategy A but that these children were not able to pick up the durational information and reported that the vowels were the same. These children were not able to perform the task and hence were not included in the analysis. Among the BP monolingual adults, however, we do find participants using both strategies. I claimed that the use of duration in the perception of the Dutch contrast might be an extra-linguistic strategy, one that monolingual BP children were not able to develop.

In summary, we see BP adults taking two different paths (Strategies A and B), which lead them to use both spectral and durational cues; conversely the BP children who were able to perform the test overwhelmingly use Strategy B, as a consequence of the fact that this group is not able to pick up on durational differences.

There are two questions I must address in this section. Firstly, I must answer the question why bilingual children are more likely to behave like BP adults than BP children when in a bilingual mode. Secondly I must discuss the consequences this effect would have on bilingual children's perception when they are in a bilingual mode.

To answer the first question it is important to bear in mind that bilingual children differ from monolingual BP children in a crucial way. Specifically bilingual children already use duration as a phonological cue due to their early exposure to Dutch. Most BP children were not able to perform the task once they needed duration as a cue for the specific contrast. This is not expected to be the case for most bilingual children.

As a consequence, bilingual children are likely to show perceptual paths derived from both strategies, either Strategy A or Strategy B when in a bilingual mode. More specifically, I expect to find two different paths, leading to two different predictions:

I. As a consequence of Strategy A some children will use more spectrum (as compared to duration) in a bilingual mode than in a Dutch monolingual mode;
II. As consequence of Strategy B some children will take the opposite path and will use relatively more duration (as compared to spectrum) in a bilingual mode than in a Dutch monolingual mode.

Note that the first prediction implies that in a bilingual mode bilingual children's cue reliance is more similar to that of Dutch monolingual adults than in a monolingual mode. This is a consequence of the fact that BP adults show perceptual results very similar to that of Dutch adults. It is worth mentioning, however, that this prediction does not imply that bilingual children have a more adult-like perception in bilingual settings outside the laboratory. Recall that BP monolinguals use their native vowel inventories to perceive the foreign contrast. Hence they would possibly find it difficult to identify the contrast in online conversation, when the entire Dutch vowel system would be present (including, for instance, the Dutch /ɔ/).

6.7 Results: comparing Δ-cue reliance across test settings

Given the predictions stated in the previous section, the GLM repeated measure procedure used in Section 6.5 could pose a problem, since Prediction I and Prediction II state two possibly contradictory paths. Analysing these contradictory predictions could be statistically challenging since, when working with means, negative and positive numbers (related, for instance, to an increase or decrease in spectrum reliance, both justifiable from the predictions) would cancel each other out. For this reason I have created a new variable to analyse the language mode results, namely "Δ-cue reliance".

Calculating the variable "Δ-cue reliance".

The variable Δ-cue reliance is basically the difference in cue reliance between the three settings, regardless of whether it is a positive or negative difference. Δ-cue reliance was calculated for both cues, giving us a Δ-spectrum reliance and a Δ-duration reliance. The formula for calculating the new variables is expressed below:

Δ-spectrum reliance = (|spec reliance mono mode – spec reliance interm mode| + |spec reliance interm mode – spec reliance bi mode|) / 2
Δ-duration reliance = (|dur reliance mono mode – dur reliance interm mode| + |dur reliance interm mode – dur reliance bil mode|) / 2

A high Δ-cue reliance means great variability between the settings. Although all groups are expected to show some variation between the settings, a direct consequence of the Language Mode Hypothesis is that the bilinguals' Δ-cue reliance should be greater than that of the monolingual groups. The reason for that is that in addition to the noise in the data and to whichever possible learning effect takes place between the tests, bilinguals would have an additional language mode effect.

Analysis

A one-way analysis of variance however reveals no significant differences between the groups for any of the cues. There is some degree of variation in all groups between the settings, as illustrated in Figure 6.3. This is not related to the language settings, however, but partially due to wide variation within each group.

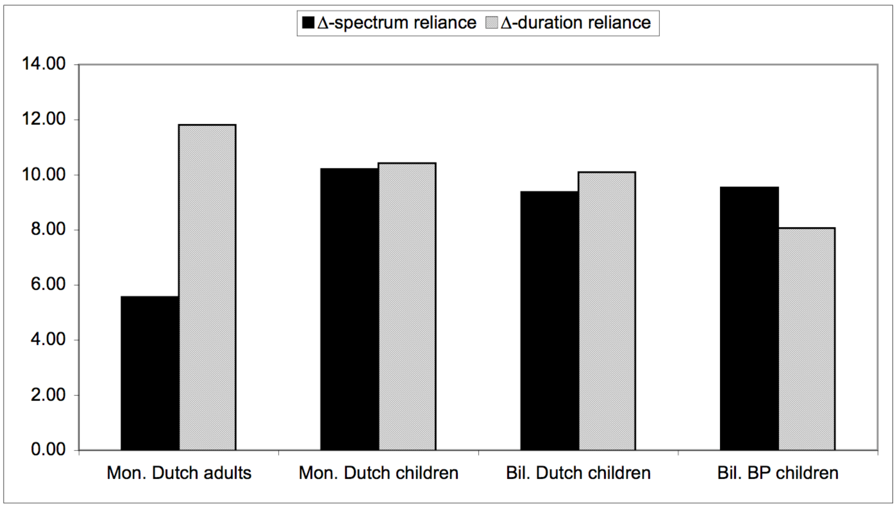

Figure 6.3: Average Δ-spectrum reliance and Δ-duration reliance for the four groups tested: monolingual Dutch adults, monolingual Dutch children, bilingual Dutch children, and bilingual Brazilian children. The variable Δ-spectrum / duration reliance measures participant's variation in spectrum / duration reliance between the three test settings (monolingual mode, intermediate mode, and bilingual mode).

To further control for the contradictory paths derived from Prediction I and Prediction II, and the possibility that they cancel each other out, I examined individual results, in search of possible trends within the bilingual participants. Figures 6.4 and 6.5 illustrate in a simplified way the individual results of spectrum and duration reliance for the Dutch and the BP bilingual children, respectively, in the three language settings.

These results do not indicate the presence of any such patterns. According to Prediction I, participants should show a decrease in spectrum reliance as they move towards a bilingual mode. Conversely Prediction II is that participants would increase both spectrum and duration reliance in a bilingual mode. The schematic results displayed in Figures 6.4 and 6.5 however reveal that the majority of the participants do not show such uniform increase or decrease as a function of language mode.

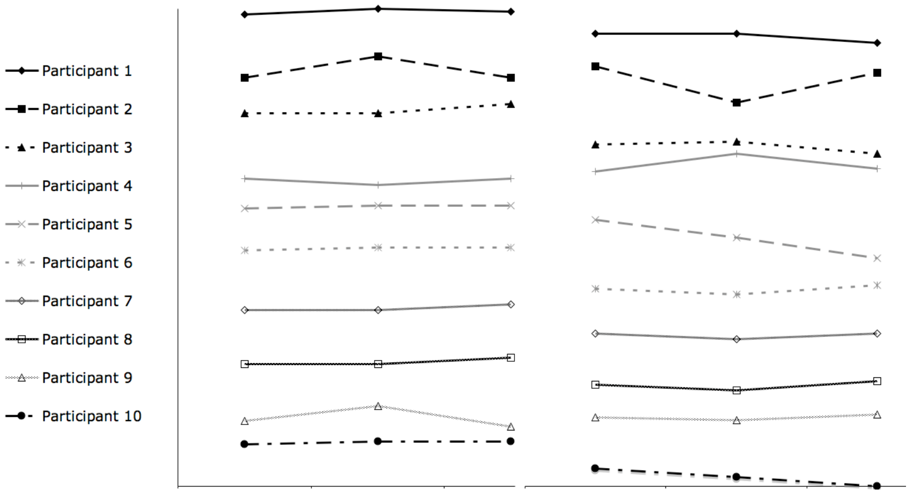

Figure 6.4: Simplified illustration of spectrum-reliance (left) and duration-reliance (right) for 10 Dutch bilingual children in the three language settings: monolingual, intermediate, and bilingual. Each line in the figure illustrates one participant's reliance in spectrum and duration.

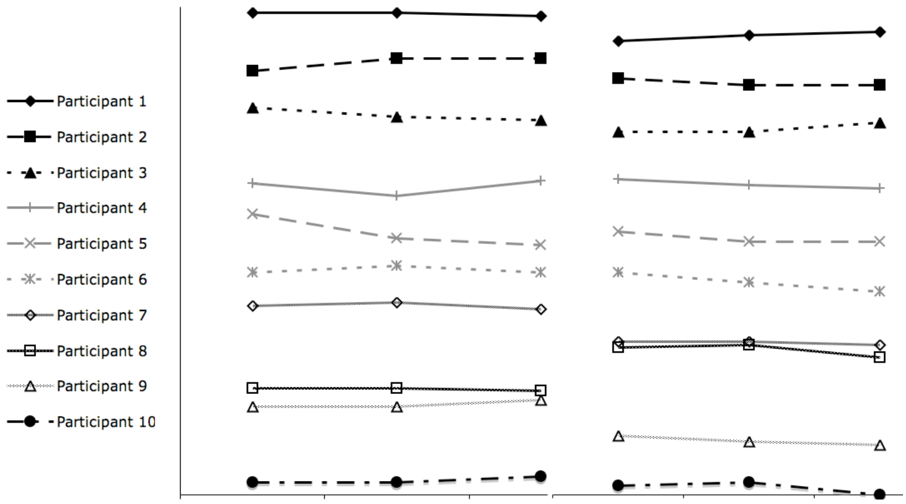

Figure 6.5: Simplified illustration of spectrum-reliance (left) and duration reliance (right) for 10 Brazilian bilingual children in the three language settings: monolingual, intermediate, and bilingual. Each line in the figure illustrates one participant's reliance in spectrum and duration.

In the next section I return to some of the issues raised here and relate them to other factors such as methodological design and language dominance.

6.8 Discussion

In this chapter I have presented the results of a perception experiment performed under three different settings. Each setting was created in such a way as to manipulate participants' language mode during the test, ranging from a monolingual mode to a bilingual mode. Language mode has been previously argued to affect bilinguals' and L2-learners' perception (see for example Grosjean 2000 and Escudero & Boersma 2002). The general prediction is that in a bilingual mode the bilingual's two languages are more likely to interact than in a monolingual mode. The results of my experiment do not confirm this prediction.

6.8.1 Participants' decrease in duration reliance

A GLM repeated measures analysis did not reveal any interaction between the three test conditions (language mode) and the groups. This means that my data do not offer any evidence for bilinguals being more affected by a change in language mode than monolinguals. The repeated measures analysis, however, does reveal a main effect of test conditions in duration reliance. Overall, participants' duration reliance decreased as a function of language setting: duration reliance in the bilingual mode was lower than in the intermediate mode; and in the intermediate mode it was lower than in the monolingual mode.

But how can we explain this overall decrease in duration reliance? We have seen in Chapter 4 that the Dutch vowel contrast is primarily made on the basis of spectrum. Duration is then a secondary cue used for enhancement. Possibly duration is mostly used by native listeners when the stimuli are ambiguous. Through a learning effect, participants became used to the stimuli, as they performed the task for the second or third time, and were able to disambiguate the contrast on the basis of spectrum only. In this case, they had less need to use duration and their reliance in this cue decreased.

6.8.2 Language mode effect: to be or not to be?

The discussion in Section 6.6.1 suggested that it was possible that different bilingual individuals would be affected differently, which would imply that a possible language mode effect would be cancelled out within the groups. For this reason I chose to carry out a less conservative analysis, comparing the variation of the groups between the test conditions, using two new variables I have called Δ-spectrum reliance and Δ-duration reliance. A one-way ANOVA showed that these variables do not differ significantly between the four groups. This means that the results in my analysis do not support the claim that bilinguals are affected by variation in the language mode setting.

In sum, the results of this experiment do not offer any support for the Language Mode hypothesis. There are two particular issues which might have played a strong role in this finding. The first issue is related to the participants in this study and large variation within each group. Particularly when working with children, data tend to become very noisy. Combined with the restricted number of subjects per group it is possible that this is one of the reasons why no significance level was reached. This however does not seem to be a convincing explanation for the lack of a Language Mode effect. Firstly, the number of participants is relatively large (N=67) and this should be able to compensate for the noise in the data, especially in the repeated measure analysis where individual variation is not an issue. Secondly, the data do not reveal any uniform tendency, as shown for group results in Figure 6.2, and for individual results in Figures 6.4 and 6.5. This lack of uniformity suggests that an increase in the number of subjects would not increase the likelihood of significant language mode results.

The second issue concerns language dominance. Most bilingual children in this study are dominant in one of their languages. The bilingual Dutch children are overall Dutch dominant and the bilingual BP children are overall BP dominant. Only a few of these children are (nearly) balanced. It could be argued that no language mode effect was found for the Dutch bilinguals because they were being tested in a Dutch contrast, which is their dominant language. It is uncertain how much Brazilian Portuguese input these participants would need in order to activate this language highly enough for it to interfere with their stronger language. This argument, however, would not hold for the Brazilian bilinguals, who were also tested on a Dutch contrast, which is their weaker language. It is arguably much harder to set up a fully Dutch monolingual mode for the Brazilian bilinguals than for their Dutch counterparts. The manipulation of the Dutch monolingual setting, however, was done very carefully: only a Dutch monolingual researcher was present, children were tested at school, often being taken to a separate room during their Dutch language course. This should be enough to set participants, if not to a fully Dutch monolingual mode, at least close to it. Furthermore it is reasonable to assume that any amount of Brazilian Portuguese input, their dominant language, would be enough to trigger a bilingual (or intermediate mode). As a consequence of this it is in this group where a language mode effect should be the most visible. A quick glance at Figures 6.2 and 6.3 is enough to see that this is not the case, and indeed statistic analyses reveal no significant differences.

How can these results be compared to the evidence for language mode in speech perception found earlier in Elman *et al*. (1977) and Escudero & Boersma (2002)[23]? The main difference between these two studies and the current study is related to how the language settings were manipulated. Both Elman *et al*.'s and Escudero & Boersma's studies test participants in two language settings: English and Spanish in the former, and Dutch and Spanish in the latter. They changed the language of the conversation / instructions and participants were lead to believe the stimuli they were listening to were in that language: in Elman *et al.* participants categorized the stimuli as either being English or Spanish; in Escudero & Boersma participants categorized the stimuli as being either Dutch or Spanish. It seems that the main variable being manipulated in these studies was not the level of activation of bilinguals' language, but the base language. Conversely, in the current study base language was kept constant and only the relative level of activation of each language was manipulated. Although a change in base language may affect the relative level of activation of the bilingual's languages these two variables are not the same. Recall from the discussion in Section 6.2.1 that "base language" and "relative level of activation" are assumed to be two autonomous factors and to vary independently

[23] Recall that these studies were discussed in Section 6.2.2.

from each other. The difference in the perception of bilinguals in the two different language settings in Elman *et al.*'s and Escudero & Boersma's studies might not be directly related to a language mode issue. Participants are likely to have categorized the same sound but using different language systems.

There are still a few methodological issues to be taken into account before concluding that Language Mode plays no role in speech perception. There are a number of confounding variables involved in this study that could be argued to have influenced the results. Examples of such variables are place of residence, vocabulary size and age. The research design has controlled for all these variables (see Chapter 3), in order to minimize their effect. Since 100% control was not feasible, however, it is possible that all these factors have interacted in such away as to blur possible language mode effects.

The fact that this study does not find any support for the language mode hypothesis does not imply a unitary account for bilinguals' sound system. The evidence for an early differentiation discussed in the first part of this chapter (Section 6.1) is too overwhelming to be ignored. Instead I suggest that bilinguals' two languages are separate but constantly interact, and at least in speech perception are not as sensitive to language mode as has been previously claimed.

6.9 Summary

In this chapter I have directly addressed the Language Mode issue. It has often been claimed that Language Mode influences bilinguals' performance. Specifically, it has been claimed that when both languages are strongly activated (and bilinguals are thus in a bilingual mode) they are more likely to interact than when only one of the languages is strongly activated (and the other is inhibited, in Green's terms).

In my study the test setting has been manipulated in three steps in order to set participants to three different points of the language mode continuum: monolingual, intermediate, and bilingual mode. Participants performed the same perceptual test, using the same set of stimuli, under these three conditions. To find support for the Language Mode Hypothesis we would expect bilinguals to be more sensitive to the changes in the settings than monolinguals would, as they would be susceptible to a language mode effect. The results of this experiment, however, do not corroborate this prediction. Bilinguals and monolinguals show no differences between the settings. Moreover there are also no uniform tendencies among the bilinguals (i.e. it is not the case that there is for instance an increase or decrease in duration reliance as bilinguals shift from a monolingual to a bilingual language mode). I suggest that bilingual speech perception may not be as sensitive to a change in language mode as has been previously argued in the literature.

In the next and final chapter of this dissertation (Chapter 7) I present an overall summary and discussion of what has been dealt with in the different chapters. I relate some of the issues which have been discussed separately and offer suggestions for further research in the field of bilingual speech perception.

7 GENERAL DISCUSSION

This final chapter presents a brief summary of the main results of this dissertation, brings together the various issues discussed in the individual chapters, and briefly discusses the implications of these findings for different fields of Linguistics.

The main question addressed in this dissertation was whether bilingualism affects children's perception of speech sounds and its acquisition path. To this end bilingual children and control groups of monolingual children and monolinguals adults were (longitudinally) tested on their perception of a vowel contrast. The bilinguals in this study were speakers of Dutch and Brazilian Portuguese and the monolinguals were speakers of either language. The contrast tested was the Dutch /ɑ/ - /aː/, which differs in terms of spectral and durational cues. Participants were analysed for how much they rely on each of these acoustic cues in their perception of the contrast, an analysis which provides us with valuable information about the phonetic detail of their perceptual categories. The results presented here show that, although at a certain point in their development bilingual and monolingual children have similar perceptual categories, their developmental paths differ. Specifically we find bilinguals showing patterns of both *delay* and *acceleration* in their development when compared to their monolingual peers. I suggest that the main cause for this difference is related to a difference in the input received by these children and not to bilingualism *per se*.

In the first section of this chapter (Section 7.1) I briefly summarize the main claims and findings of the current study. In Section 7.2 I present a general discussion on the main issue addressed by this dissertation, namely that of possible effects of bilingualism on the perception of speech sounds. Section 7.3 discusses the relevance of the findings presented in this dissertation for research into speech perception and acquisition in general. The last section of this dissertation, Section 7.4, presents a personal note on how the results discussed here should be interpreted.

7.1 Recapitulating questions and findings

This dissertation investigated the acquisition of a vowel contrast by children raised bilingually. The main question addressed here was the following: *does bilingualism affect children's perceptual development of speech sounds?* In Chapter 1 I split this main question into 4 sub-questions, repeated below for clarity's sake:

1. *Do perceptual categories in bilingual children differ from those in monolingual children*?
2. *What is the influence of language dominance on bilingual children's acquisition of perceptual categories*?
3. *Do bilingual and monolingual children follow the same developmental path in their perceptual acquisition*?
4. *Do bilingual children change their perception of vowel contrasts as a result of a change in the relative activation of each of their languages (i.e. is there a Language Mode effect)*?

In order to answer these questions this study took an experimental approach. One hundred and sixty participants were investigated for their perception of a vowel contrast. The participants were divided into 6 subgroups:

1. 31 bilingual children in Dutch and Brazilian Portuguese raised in the Netherlands, the Dutch bilinguals;
2. 33 bilingual children in Brazilian Portuguese and Dutch raised in Brazil, the Brazilian bilinguals;
3. 43 Dutch monolingual children;
4. 14 Dutch monolingual adults;
5. 26 Brazilian Portuguese monolingual children;
6. 13 Brazilian Portuguese monolingual adults.

The contrast tested was the Dutch /ɑ/ - /aː/. The vowels of this contrast differ in terms of spectral and durational cues. The participants in this study were longitudinally and latitudinally analysed as to how much they rely on each cue on their perception.

Questions 1-4 presented above were discussed in Chapters 4, 5 and 6. Each of these chapters will be summarized below along with a recapitulation of their main findings.

In Chapter 4 a thorough investigation was carried out of bilingual and monolingual use of spectral and durational cues on their perception of the /ɑ/ - /aː/ contrast, in order to address Question 1. Monolingual and bilingual children were carefully matched in terms of age, geographical distribution, and social background. Moreover, two groups of bilingual children were involved: Dutch bilinguals, who were dominant in Dutch, and Brazilian bilinguals, who were dominant in Brazilian

Portuguese (BP). The inclusion of two groups of bilinguals differing from each other in terms of language dominance made it possible to address question 2, concerning the role of language dominance on bilingual perception.

An analysis of the results showed that both bilingual and monolingual children differ from Dutch adults in that the children had lower spectrum and duration reliance in the perception of the Dutch /ɑ/ - /aː/ contrast. Among the children, there was a positive correlation between spectrum reliance and age, suggesting that this cue was still in the process of being acquired. Moreover, the results discussed in Chapter 4 showed that at 6 years of age Brazilian bilinguals relied significantly less on spectral cues than age-matched Dutch monolingual and Dutch bilingual children. Importantly, Dutch bilingual children did not differ from Dutch monolingual children. These results suggest that language dominance plays a role in bilinguals' perception of speech sounds as bilinguals show monolingual-like perception in their dominant language, but not in their non-dominant language. Crucially, the synchronic data discussed in that chapter did not present any evidence for a *bilingualism* effect.

Chapter 5 presented the results of the longitudinal study, directly addressing Question 3. Dutch bilingual children and monolingual children and adults were tested 3 times within a period of 3 years on their perception of the Dutch /ɑ/ - /aː/ contrast. Participants' reliance on spectral and durational cues was calculated and their developmental paths compared.

The results of the longitudinal data discussed in Chapter 5 showed that monolingual and bilingual children differed in their perceptual acquisition of the /ɑ/ - /aː/. In comparison with monolingual children, bilingual children showed signs of both delay and acceleration in their perceptual development. Specifically bilinguals were delayed in their acquisition of spectrum reliance, the primary cue for the contrast, and accelerated in their acquisition of duration reliance, the secondary cue for the contrast. This difference can be interpreted as being a matter of quantity (i.e. delay and acceleration) or quality (i.e. difference in strategies). I will return to this issue later in this chapter, in Section 7.2.

Chapter 6 addressed question 4 and investigated the possible effects of Language Mode on bilinguals' perception. Language Mode has often been claimed to affect bilinguals' performance in that when bilinguals have both languages strongly activated (i.e. when they are in a bilingual mode) their languages are more likely to interact with each other. In this study participants' Language Mode was manipulated in three steps, ranging from a monolingual mode to a bilingual mode. Bilingual children and Dutch monolingual children and adults performed the same perceptual task involving the Dutch /ɑ/ - /aː/ contrast under three different experimental settings. Each experimental setting triggered a Language Mode: monolingual mode, intermediate mode, or bilingual mode. Participants' spectral reliance and duration reliance were calculated for each Language Mode setting.

The results of the Language Mode manipulation yielded no evidence for a Language Mode effect. Bilingual children showed no differences in their perception when experimentally set in a bilingual or monolingual mode. I concluded that bilingual speech perception may not be as sensitive to a change in Language Mode as has been previously argued in the literature.

In the next section I will combine the results presented in the three chapters discussed above to address the main question of this dissertation.

7.2 The effects of bilingualism on children's perception of speech sounds

Studies on how bilingual children perceive their languages are of crucial importance in language research as they allow accessing bilingual representation of speech sounds. Cue weighting studies, in particular, provide us with meaningful information concerning the details of bilinguals' sound categories, the acoustic cues used and, more specifically, how much each cue is used.

When cross-sectionally comparing the phonetic detail in bilingual and monolingual children's perceptual categories, our results showed that the Brazilian bilingual children had significantly lower spectrum reliance than Dutch bilingual and Dutch monolingual children. Crucially, Dutch bilinguals were indistinguishable from Dutch monolinguals. We concluded that bilingualism in itself did not affect children's perception of their native vowels.

The differences found between Brazilian bilingual and Dutch monolingual children were plausibly related to language dominance and, hence, indirectly to input. The relationship between input and language dominance is a very intricate one: in a bilingual situation, greater and richer input in one language will typically lead to dominance in that language. Perhaps quantifying input is the only way to disentangle these two factors. This way one could compare two groups who are dominant in the same language but differ in the amount of input in that language. Differences between these two groups would suggest that the role of input in perceptual acquisition overwhelms the role of language dominance in itself.

In the current study language dominance, but not amount of input, was directly manipulated, and hence we can only refer to input in an indirect manner, through reasonable assumptions based on what is known about participants' language background. In the specific case of Brazilian bilinguals vs. Dutch bilinguals a reasonable assumption is that Dutch bilinguals have had a richer and more frequent exposure to Dutch than the Brazilian bilinguals as they were raised in a community where Dutch is the dominant language.

Unfortunately we lack longitudinal data for these children to investigate whether they develop towards the Dutch adult norm, a pattern which would suggest an acquisitional *delay* (quantitative difference). Alternatively, these children may have reached the end state in their perceptual development and may have developed categories that differ from the Dutch adults, suggesting a qualitative difference between this group and the Dutch listeners. Perhaps due to the amount of accented speech they are exposed to, these children might have a different target language than the Dutch children. I will return to the discussion concerning quantitative vs. qualitative differences further in this section.

As Dutch bilingual and Dutch monolingual children did not differ from each other in the synchronic data analyzed in Chapter 4, it was concluded that bilingualism in itself did not affect children's perception of their native vowels. This picture, however, was nuanced in Chapter 5 when analysing longitudinal data. Our results showed that Dutch bilingual and Dutch monolingual children differ in their development. Specifically we found that bilingual children were delayed in their spectrum reliance when compared to monolingual children. This same group, however, was accelerated in the acquisition of duration reliance.

In the remainder of this section I will address in more detail two controversial aspects concerning the differences between bilingual and monolingual children: the nature of these differences, whether quantitative or qualitative; and the causes of these differences, i.e. whether they are due to input or to interaction between the bilinguals' languages.

Quantitative or qualitative differences?

The results found in this dissertation are noteworthy in that they show that the same group of bilinguals can present signs of both *acceleration* and *delay* when compared to monolinguals. Although both patterns have been previously mentioned in the bilingualism literature (see e.g. Bosch & Sebastián-Gallés 2003 for bilingual delay and e.g. Lleó *et al*. 2003 for bilingual acceleration) bilinguals in these situations are typically found to be accelerated in one language and delayed in the other, or at least accelerated in one structure and delayed in another. Strikingly, however, the current study reveals bilinguals being both accelerated and delayed in the same language and regarding the same contrast, the crucial difference being the perceptual dimension, either spectral (delay) or durational (acceleration). In Chapter 5 I entertained the possibility that this might be the result of a difference in strategies between bilingual and monolingual children, indicating a qualitative rather than a quantitative difference between bilingual and monolingual children's development.

The literature on bilingual speech perception seems more often to suggest quantitative differences (i.e. differences related to time course of acquisition) between bilinguals and monolinguals, where bilingual children are either delayed (Bosch & Sebastián-Gallés 2003, Sundara *et al.* 2006) or develop at the same pace (Sundara *et al.* 2008) as monolingual children. Even in the case where bilingual children were delayed, they eventually caught up with their monolingual peers, sometimes within just a few months. Perception studies which involve only discrimination tasks, however (as was the case for Bosch & Sebastián-Gallés 2003, Sundara *et al.* 2006 and Sundara *et al.* 2008), do not allow us to access qualitative differences. Since different means may achieve the same end, it is possible for different groups of listeners to achieve equally accurate perception even when the details of their categories differ. Hence it is possible that qualitative differences between bilingual and monolingual children in speech perception have not been reported not because they did not occur, but because they have not been properly accessed.

At this point however, suggesting a qualitative difference between bilingual and monolingual children is just a speculation, as this study does not provide the means to differentiate between one and the other. To gather more insight into this question we need cue weighting studies involving different contrasts, different cues, and different languages. Specifically if results were to consistently yield patterns similar to the current study, i.e. a combination of delay and acceleration, this might lead us to conclude that bilingual and monolingual children differ in their categorization strategies.

A direct comparison between different studies of bilingual speech perception, however, is particularly challenging. In the case tested here, for instance, we have seen that a large number of factors played a role, such as the vowel inventories of the language in question, specific use of spectral and durational cues in each language, accented speech, and so on. In order to address the question whether bilinguals differ quantitatively or qualitatively from monolinguals in the trend suggested here, one would need to control for all these factors. Possibly bilinguals do not differ from monolinguals in all contrasts, and even when they do, they might not always differ in the same fashion. In the particular case addressed here, I suggested that bilinguals had a particular need to use a different strategy from that used by monolinguals. Specifically I claimed that the input received by bilingual children is more spectrally crowded since they have to deal with two semi-overlapping vowel systems plus mispronounced tokens due to the accented speech they are exposed to. This suggests that monolingual children might be able to cope with the perception of the contrast by relying on the primary cue only, whereas bilinguals, due to their crowded spectral space, needed to develop the use of durational cues, the secondary cue for the contrast. Studying different languages or simply a different contrast would affect this scenario, and possibly lead to different results.

Input or interaction between bilinguals' languages?

In monolingual speech acquisition, input has been shown to play an important role. Infants have been shown to have high sensitivity to the distributional properties of their languages (e.g. Kuhl 2000) and to be able to use this information in language learning (e.g. Kuhl *et al.* 1992, Maye *et al*. 2002). Kuhl *et al*. show that phonetic distribution affects vowel perception in 6-month-old infants. Similarly Maye *et al.* (2002) show that 6- and 8-month-olds use the distributional properties of their languages to form their sound categories: bimodally distributed sounds would cue the formation of two categories whereas unimodally distributed sounds would lead to the formation of a single category.

The findings and interpretations of the results presented in this dissertation are in line with these studies, suggesting a crucial effect of input in language acquisition, regardless if monolingual or bilingual acquisition. Small changes in input already seem to have consequences for the way children learn to perceive the sounds of their native language(s). In Chapter 4 I explained the differences found between Brazilian bilingual and Dutch monolingual children in terms of quantity and quality of input. Specifically I suggested that since Brazilian bilingual children receive less Dutch input they need a longer time to acquire the contrast (quantity), or that their exposure to accented speech might affect the time course of their acquisition and perhaps even these children's representation of the sounds of their language (quality).

The results in Chapter 5 reveal that Dutch bilingual children acquire spectrum reliance more slowly than Dutch monolingual children. Also this difference can be explained in terms of quantity and quality of input. In terms of quantity, I assume that bilingual children receive less Dutch input than monolingual Dutch children, since part of the language input they receive is in Brazilian Portuguese. The results of Chapter 5 show that at 5;5 years of age, monolingual children are still acquiring spectrum reliance and that their spectrum reliance increases with age, revealing that language exposure facilitates the process. Following this line of reasoning, reduced exposure to a language implies that children would need a longer period of time to acquire the same contrast, leading to a bilingual delay.

In terms of quantity, I argued that the input bilingual children receive is spectrally more crowded, given the overlap between the vowels within and between each language, and given their exposure to accented speech. Although spectral overlap can lead to acquisitional delay (e.g. Bosch & Sebastián-Gallés 2003), Sundara *et al.* (2008) show that infants can deal with overlap, provided they are given enough input. In the contrast tested in the current study positive evidence abounds, as the vowels involved are the most frequent vowels in both of the bilinguals' languages, thus overlap alone cannot explain bilingual delay. It is possible, however, that overlap combined with reduced amount of input is the cause of delay in spectral reliance by bilinguals.

The results in Chapter 5 also reveal that Dutch bilingual children are increasing their duration reliance as a function of age whereas monolingual children are not. When discussing these results, I entertained three possible explanations for this bilingual acceleration, one input-related and two related to interaction between the bilinguals' languages. The first explanation, concerning the role of input, depends on the fact that bilingual children are constantly exposed to accented speech, since at least one of their parents is always a non-native speaker of Dutch. Previous studies have shown that the perception of Brazilian L2 learners of Dutch differs from that of native Dutch listeners in that L2ers overuse durational cues in their perception (Brasileiro & Escudero 2006). This perceptual pattern is possibly reflected in their production and hence bilingual children are exposed to excessively long or short exemplars of the Dutch vowels, which might affect their reliance on durational cues.

The second and third explanations concern the interaction between the bilinguals' languages. The second explanation considers that it is possible for bilingual children to develop their reliance on duration in order to cope with the spectrally crowded input. Recall from the discussion in the previous paragraph that bilinguals' input has a greater degree of spectral overlap than that of monolinguals as it contains the vowels of two languages as well as mispronounced tokens. Hence the acquisition of durational cues by bilingual children might be a necessary strategy for disambiguating spectral cues. The third explanation suggests that bilingual children may be aided in their use of duration in Dutch by their other language, since the use of duration in BP is highly functional as a cue to stress.

In sum, input differences only are enough to explain both delay and acceleration patterns. Interaction between the bilinguals' languages, on the other hand, could explain the acceleration but not the delay. It is possible that both factors combined lead to differences in developmental patterns. Even though the test situation was controlled such as to minimize interaction between the bilinguals' languages (i.e. participants were set on a Dutch monolingual mode) we cannot rule out such effects.

7.3 General implications

In this section I briefly discuss implications of the conclusion of this study for different fields such as monolingual acquisition of the /ɑ/ - /aː/ Dutch contrast (Section 7.3.1), cue weighting development (Section 7.3.2) and methodologies in speech perception (Section 7.3.2).

7.3.1 Monolingual acquisition of the /ɑ/ - /aː/ Dutch contrast

The monolingual acquisition of spectral and durational cues in the Dutch /ɑ/ - /aː/ contrast had previously been addressed by Gerrits (2001) and by Heeren (2005). Gerrits directly addressed children's reliance on *spectral* cues and found that 4- and 6-year-olds weighted spectral information less heavily than 9-year-olds and adults did. Gerrits found no difference between children's and adults' duration reliance, leading to the conclusion that 4-year-old children had acquired adult-like use of this cue. Heeren (2006) questioned this conclusion on the basis of Gerrits's stimuli: whereas spectral cues were manipulated along a 7-step continuum, duration was binarily distributed, either short or long. Heeren investigated the acquisition of *durational* cues on the perception of the same contrast and found that 7-year-olds but not 5- or 6-year-olds had acquired adult-like duration reliance. One important conclusion in Gerrits' study was that duration reliance was acquired earlier than spectrum reliance. Although this claim was questioned by Heeren, her study did not provide counterevidence, since the children in both studies differ in age: we know that adult-like spectrum acquisition takes place somewhere between 6 and 9 years of age; and we know that duration acquisition takes place between 6 and 7 years of age, but we do not know yet which one comes first. From both studies, however, we can conclude that at 6 years of age Dutch children have not yet acquired adult-like reliance on either spectral cues (Gerrits) or durational cues (Heeren).

The synchronic results reported in Chapter 4 of the current study showed that at around 5;5 years of age Dutch children relied less on both spectrum and duration than adults in their perception of the /ɑ/ - /aː/ contrast. Furthermore, the results of the longitudinal study showed that at 6;5 years of age, Dutch children still had not acquired spectrum reliance in an adult-like fashion and Dutch bilinguals, but crucially not Dutch monolinguals, had acquired duration reliance. These results are in line with the studies by Gerrits, for spectrum, and Heeren, for duration. Moreover, these results suggest evidence that spectral rather than durational cues are acquired earlier, since at 6;5 Dutch monolingual children have acquired spectrum but not duration reliance.

One question that had remained unanswered in previous studies concerns the acquisition of durational cues. In Heeren's study, Dutch children had adult-like use of duration by 7 years of age, whereas the 6;5-year-old children in the current study do not even show signs of development (possible explanations for this finding were discussed in Chapter 5 of this dissertation). It is possible that this cue quickly develops, between the ages of 6;5 and 7, or that differences in methodology led to different results. Specifically the stimuli used in Heeren's study were spectrally ambiguous, which might have pushed children into using durational cues. Conversely, in the current study both cues were available and children seemed to have relied more strongly on the primary cue, i.e. spectrum.

7.3.2 The development of cue weighting

One of the most prominent controversies in the cue weighting literature concerns the causes for differences found between children and adults. On one side of the controversy there is the claim that these differences are related to maturation in the auditory system. Sussman (2001), for instance, claims that children are less able than adults to deal with insufficient acoustic information due to an immature auditory system. Hence children rely more strongly on cues that are more prominent, where prominence is described in terms of loudness, length, and degree of distinctiveness. In this view, children reach adult-like cue weighting once their auditory system has matured. On the other side of the controversy, differences in cue weighting between children and adults have been claimed to be the consequence of linguistic development (e.g. Nittrouer 1996). Nittrouer argues that children develop their cue weighting such as to achieve the optimal strategy, which will lead to accurate perception of the phonemic inventory of their native language.

In the view that differences in cue weighting between children and adults are the consequence of auditory system maturation, one would expect bilingual and monolingual children to show parallel cue weighting development since bilingual and monolingual children's auditory systems are identical. The current study, however, shows that bilingual and monolingual children differ in their development of cue weighting. This finding suggests that cue weighting development is intrinsically related to language experience, providing evidence which is more in synchrony with Nittrouer's view. Importantly, the claim I make here is not that maturation in the auditory system does not play any role in cue weighting development, but simply that it cannot be the only explanation for differences between children's and adults' cue weighting.

7.3.3 Longitudinal vs. cross-sectional designs

A review of the literature shows that the studies pointing to delay in the development of bilingual children (Bosch & Sebastián-Gallés, Sundara *et al.* 2006) had cross-sectional designs. It is well attested that individual children, regardless of whether they are monolingual or bilingual, differ in their rate of development, hence comparing children at different ages and generalizing these conclusions to predict their developmental paths is not the ideal design.

The findings of the current study clearly illustrate this possible discrepancy between results from cross-sectional and longitudinal studies. When examining cross-sectional data (Chapter 4) we found no difference between bilingual and monolingual children; nevertheless when examining longitudinal data (Chapter 5) we found crucial differences between bilingual and monolingual children's development.

There are different factors possibly causing these differences between the results from cross-sectional and longitudinal data. Firstly it is possible that within group differences are too large, as each individual's development is unique, rendering between group differences irrelevant. Secondly, the point at which children were tested possibly affects the results. Even groups of children who differ in (rate of) development may go through a stage at which their perceptual categories are identical. If we focus on the developmental path predicted for bilingual and monolingual children (see Figures 5.2 and 5.6 in Chapter 5 for reference) we see that at earlier ages their developmental lines are much closer to each other than at later ages. This means that younger children have similar spectrum and duration reliance. If a cross-sectional comparison were made at that point, no difference would be found.

These issues are crucial for speech perception research and should be taken into account when addressing developmental questions. This is especially true for studies involving bilinguals or second language learners, which form particularly heterogeneous populations.

7.4 Final remark

The current study has shown that bilingual children may differ from monolingual children in the acquisition of a perceptual contrast even in their dominant language. This is true even when their test conditions reduce chances of interaction between the bilinguals' languages to the minimum (i.e. when they are on a monolingual mode).

One needs to be very careful not to interpret these results as meaning that bilinguals never fully attain either of their languages. The suggestion made in this dissertation is that bilingual language acquisition, like monolingual language acquisition, is strongly related to language input. Not attaining monolingual-like perceptual categories does not mean that bilingual children are more or less proficient in their languages than monolingual children; it simply means bilingual children *differ* in their development from monolingual children, forming categories that are more in line with their language input. After all, due to a difference in input between bilingual and monolingual children, they may differ in their target language. This is in line with the view that bilingualism should be studied not as the sum of two monolingual situations in one, but as a phenomenon on its own.

APPENDICES

Appendix A – Praat script used for stimulus manipulation

```
# Generate synthetic vowels with duration, F1 and F2 steps
# Stores resulting sounds in specified directory

form Generate vowels (cascade mode) with duration, F1 and F2 steps
    positive Initial_F0_(Hz) 150
    positive Final_F0_(Hz) 100
    sentence Directory_to_write_to C:\Desktop\vowels
    positive Minimum_duration_(ms) 96
    positive Maximum_duration_(ms) 203
    positive Number_of_duration_values 4
    positive Minimum_F1_(Hz) 698
    positive Maximum_F1_(Hz) 830
    positive Number_of_F1_values 4
    comment If F1 values are equal to or higher than F2 values the sounds are
    comment marked as "1" in the column "rep". The marked sounds are not
generated!
    comment
    positive Minimum_F2_(Hz) 1070
    positive Maximum_F2_(Hz) 1336
    positive Number_of_F2_values 4
endform

# calculate duration steps
logrange = log10(maximum_duration / minimum_duration)
logstep = logrange / (number_of_duration_values - 1)

for i to number_of_duration_values
    d'i' = minimum_duration * 10^((i-1)*logstep)
endfor

# calculate F1 values
if number_of_F1_values > 1
    maxmel = hertzToMel(maximum_F1)
    minmel = hertzToMel(minimum_F1)
    melrange = maxmel - minmel
    melstep = melrange / (number_of_F1_values - 1)
    for i to number_of_F1_values
        melvalue = minmel + (i-1) * melstep
        first'i' = melToHertz(melvalue)
    endfor
else
```

```
    first1 = minimum_F1
endif

# calculate F2 values
if number_of_F2_values > 1
    maxmel = hertzToMel(maximum_F2)
    minmel = hertzToMel(minimum_F2)
    melrange = maxmel - minmel
    melstep = melrange / (number_of_F2_values - 1)
    for i to number_of_F2_values
        melvalue = minmel + (i-1) * melstep
        second'i' = melToHertz(melvalue)
    endfor
else
    second1 = minimum_F2
endif

# initialize duration and formants table
numsounds = number_of_duration_values * number_of_F1_values *
number_of_F2_values
Create TableOfReal... params numsounds 4
Set column label (index)... 1 rep
Set column label (index)... 2 f1
Set column label (index)... 3 f2
Set column label (index)... 4 dur

# generate sounds & update table
row = 0

for d to number_of_duration_values
    dur = d'd'/1000
    for second to number_of_F2_values
        f2 = second'second'
        for first to number_of_F1_values
            rep = 0
            f1 = first'first'
            if f1 >= f2 - 100
                rep = 1
            endif
            select TableOfReal params
            row += 1
            Set row label (index)... 'row' 'first'_'second'_'d'
            Set value... row 2 f1
            Set value... row 3 f2
            Set value... row 4 dur
            if rep = 1
               Set value... row 1 rep
```

```
            endif
            call generate
            if rep = 0
                Write to WAV file... 'directory_to_write_to$'\'first'_'second'_'d'.wav
            endif
            Remove
# pause 'f1' 'f2' 'dur'
        endfor
    endfor
endfor
select TableOfReal params
Write to binary file... 'directory_to_write_to$'\vowelparams.TableOfReal
Write to headerless spreadsheet file... 'directory_to_write_to$'\vowelparams.txt

procedure generate

# Create voice source signal
Create PitchTier... sweep 0.0 dur
Add point... 0 initial_F0
Add point... dur final_F0
To PointProcess
Remove points between... 'dur'-0.005 'dur'
To Sound (phonation)... 44100 1 0.01 0.7 0.01 3 4

# Add some extra formants to get a flatter spectrum.
f3 = max (2500, f2 + 1000)
f4 = max (3500, f3 + 400)
f5 = max (4000, f4 + 600)
f6 = f5 + 1000
f7 = f6 + 1000
f8 = f7 + 1000
f9 = f8 + 1000
f10 = f9 + 1000
for i to 10
    Filter with one formant (in-line)... f'i' sqrt(80^2+(f'i'/20)^2)
endfor

# clear up
select PitchTier sweep
plus PointProcess sweep
Remove

select Sound sweep
Scale... 0.99

endproc
```

Appendix B – Instruction for experimenter

(Original in Dutch)

General Instruction

- Your schedule is very tight so start working as soon as you can. Introduce yourself briefly and ask where the test will take place. You can continue your chat while setting up the equipment;
- Place the computer in such a way that the child is facing a wall (with her back to the other people present). This is to avoid they will be distracted;
- Explain to the parent what you will do but keep it general. You can ask them if they would like to try it first, but do not forget to use the headphone so that the child will not listen along;
- As the parents to avoid contact with the child during the experiment. They may stay in the same room but may not talk to the child or sit next to her. Explain that children are easily influenced by their parents;
- Do not be afraid to ask for silence when necessary;
- If other children are around during the experiment ask the parents to keep them quiet. You can also give them a drawing and ask them if they want to paint something for you (you will find the necessary material in the bag);
- In the case of the bilingual children, try to avoid any influence from Portuguese during the task. It is very important that everything happens in Dutch;
- If you are going to test moor than one child in the same place explain the instructions individually to each child;
- During the task, try to reduce your role to the minimum;
- There is a logbook in the experiment bag. When you are finished testing the children describe the situation as detailed as possible: how many people were present, if the child seemed concentrated, where the child sat, if the surroundings was quiet, etc.

Instrutions for vocabulary task

- The goal of the task is to see if children are familiar with one specific word. Thus if you think that a child does not recognize the drawing you can help setting her on the right track;
- Do not give too much information about the drawing: if it is easy / difficult / weird… Let the child come to her own conclusions;
- If a child does not know a word, do not tell her.

Instructions for 'Danny and Donny' task

- Before you start the task set the headphones on a comfortable volume;
- Play the example as often as necessary until you know for sure that the child understand what she has to do. Pay attention if she gives the right answer, at least twice in a row;
- When you are finished with the examples take off the headphones and explain what is going to happen next;

- Mention during the instructions that Danny and Donny are learning how to *speak*. It is very important that the children recognize the sounds as vowels;
- Tell the children that Danny and Donny are not very good speakers yet and that sometimes it is difficult to choose who was the best one, but that she will always have to choose a winner;
- If a child cannot handle the mouse you will control it for her. In this case always leave the arrow in the middle, pointing at the teacher. The child can then point to either Danny or Donny with her finger. Let them (nearly) touch the screen so that there is no doubt about whom the child meant. Please make sure the child has clean hands before starting the test;
- During the "sticker ceremony" let the child stand up and take the headphones off, as this is meant to be their break. It is usually a good idea to leave the sticker card far away;
- During the breaks you can talk to the children but during the experiment you should avoid that. You can smile, nod, keep eye contact, just avoid talking;
- Do not forget to save the results and the back up!

Appendix C – Instruction for parents and teachers

(This instruction followed a personal note for the parent / teacher, thanking them for their co-operation; original in either Dutch or Brazilian Portuguese)

All we need for the task is a quiet place with a table, two chairs and a plug..

As parent / teacher you may be present during the task but you should avoid contact with the child during the actual experiment. There will be three breaks during the experiment and you can use them to talk to the child (in the case of bilingual children, please only talk Dutch; if you can talk Dutch of if communicating with your child in this language is very unusual for you, then please avoid any conversation during the experiment).

If other children are present during the experiment please try to keep them quiet. We always have colour pencils and drawings in our bags so just let us know if you need them.

Before the child starts the experiment you can try it yourself. I understand that many parents are curious or even cautious. But once the child start I ask you to not sit next to her or look over her shoulder. If you chose to stay in the same room try to focus on another activity. Many parents (unconsciously) influence their child's choices and this is something we need to avoid.

Appendix D – Answer sheet for vocabulary Test

(Original in Dutch)

Date	
Name child	
Experimenter	

	Right	Wrong	Other

Lezen ‘to read’			
Tang ‘nippers’			
Vleermuis ‘bat’			
Kers ‘cherry’			
Winter ‘winter’			
Maïs ‘corn’			
Aardbei ‘strawberry’			
Nijlpaard ‘hippopotamus’			
Speelgoed ‘toys’			
Ui ‘onion’			
Mier ‘ant’			
Toetsenbord ‘keyboard’			
Helm ‘helmet’			
Uil ‘owl’			
Pompoen ‘pumpkin’			
Struisvogel ‘ostrich’			
Liniaal ‘ruler’			
Bijenkorf ‘beehive’			
Worst ‘sausage’			
Knippen ‘to cut’			
Stoom ‘steam’			
Popcorn ‘popcorn’			
Kraan ‘tap’			
Kreeft ‘lobster’			
Leeg ‘empty’			
Puntenslijper ‘sharpener’			
Appel ‘apple’			
Driehoek ‘triangle’			
Octopus ‘octopus’			
Aansteken ‘to lighten’			
Ananas ‘pineapple’			
Walvis ‘whale’			
Lijm ‘glue’			
Leeuw ‘lion’			
Fee ‘fairy’			
Horens ‘horns’			
Bad ‘bath’			
Kwast ‘paintbrush’			
Paard ‘horse’			
Dorst ‘thirst’			

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SAMENVATTING IN HET NEDERLANDS

Het algemene onderwerp van dit proefschrift is tweetaligheid, en in het bijzonder de verwerving van spraakklanken door tweetalige kinderen. De kernvraag van dit onderzoek is de volgende: *heeft tweetaligheid een effect op de perceptuele ontwikkeling van spraakklanken bij kinderen?*

Er bestaat een rijke en uitgebreide wetenschappelijke literatuur over tweetaligheid. Echter veel vragen over tweetalige perceptuele ontwikkeling blijven tot op heden onbeantwoorde. Een van de redenen hiervoor is de heterogene aarde van wat als de *tweetalige populatie* wordt beschouwd. Door deze heterogeniteit kunnen resultaten van verschillende onderzoeken moeilijk met elkaar worden vergeleken; zelfs binnen hetzelfde onderzoek, kunnen in veel gevallen verschillende leeftijdsgroepen van tweetalige kinderen moeilijk met elkaar worden vergeleken.

De discussie in dit proefschrift probeert vragen te verduidelijken die gerelateerd zijn aan de perceptuele ontwikkeling van spraakklankcontrasten bij tweetalige kinderen, door een grote groep tweetalige kinderen te vergelijken met hun eentalige leeftijdsgenoten. De opzet van het huidige onderzoek vermindert de ruis in de data door de term *tweetaligen* te beperken tot sprekers/luisteraars die *vanaf hun geboorte* in contact staan met hun twee talen.

De benadering van het in dit proefschrift beschreven onderzoek is experimenteel. Tweetalige kinderen, eentalige kinderen en eentalige volwassenen namen deel aan een longitudinaal onderzoek waarin hun perceptie van spraakklanken werd getoetst. De tweetalige kinderen waren sprekers van het Nederlands en van het Braziliaans Portugees (BP); terwijl de eentaligen één van deze beide talen spraken. Alle groepen werden getoetst op hun perceptie van het Nederlandse klinkercontrast /ɑ/ - /aː/, een contrast waarbij de klinkers verschillen in zowel spectrale eigenschappen (F1 en F2) als in temporele eigenschappen (klinkerduur). De antwoorden van de deelnemers werden geanalyseerd op hun *cue reliance*, d.w.z., hoeveel een luisteraar op spectrale en op temporele eigenschappen vertrouwt om het contrast te percipiëren. *Cue reliance* verstrekt informatie over de fonetische details in de *perceptuele categorieën* van de luisteraars. Een perceptuele categorie wordt hier begrepen als een reeks akoestische eigenschappen die gebruikt wordt door luisteraars om de contrastieve spraakklanken van hun moedertaal te identificeren. Dit proefschrift doet echter geen uitspraak over de fonologische status of representatie van deze akoestische informatie.

De resultaten van dit onderzoek laten zien dat, hoewel een- en tweetalige kinderen identiek perceptueel gedrag vertonen op een bepaald meetmoment, de twee groepen wel verschillende ontwikkelingspaden volgen. Deze resultaten komen overeen met een groot deel van de literatuur over perceptuele ontwikkeling bij tweetalige kinderen. Echter, de resultaten in dit proefschrift onderscheiden zich van de bestaande literatuur in *hoe* de twee groepen van elkaar verschillen. Alhoewel eerdere literatuur heeft laten zien dat tweetalige kinderen *vertraagd* of *versneld* kunnen zijn in hun ontwikkeling vergeleken met eentalige kinderen, vertonen de tweetalige kinderen in het huidige onderzoek deze beide ontwikkelingspatronen *simultaan*. Meer specifiek, de tweetalige kinderen waren vertraagd in hun verwerving van spectrale eigenschappen en versneld in hun verwerving van temporele eigenschappen.

Dit proefschrift beweert dat het verschil tussen tweetalige kinderen en hun eentalige leeftijdsgenoten het gevolg is van twee factoren: (i) de aard van de taalinput die het taallerend kind ontvangt, welke voor de twee groepen verschilt in zowel kwantiteit als kwaliteit; (ii) de interactie tussen de twee linguïstische systemen van de tweetalige spreker/luisteraar.

CURRICULUM VITAE

Ivana Brasileiro Reis Pereira was born on 4th May 1977 in Teresina, Brazil. She moved to the Netherlands in 1998 and was enrolled for a year in a Dutch course at the James Boswell Institute, after which she successfully took the Dutch *staatexamen*. In 1999 she started het study on Portuguese Language and Culture at the Utrecht University, graduating in 2004 with a specialization in Language Acquisition and Language Development. She was employed as a PhD student at the Utrecht Institute of Linguistics OTS from 2004 until 2008. This dissertation is the result of her research carried out in this period.