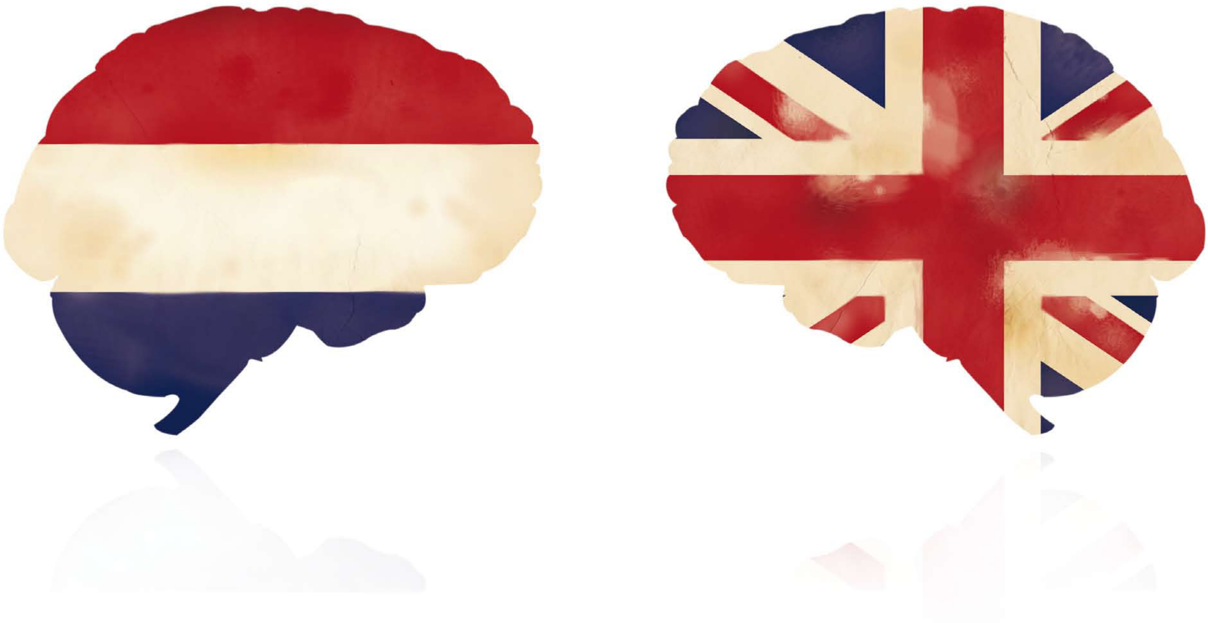


Lexical interactions in non-native speech comprehension: Evidence from electro-encephalography, eye-tracking, and functional magnetic resonance imaging

Ian FitzPatrick

Max Planck Institute for Psycholinguistics

Series

Lexical Interactions
in Non-native Speech Comprehension:

Evidence from electro-encephalography, eye-tracking, and functional magnetic resonance imaging

ISBN: 978–90–76203–38-6

Cover illustration: Sandra Geerlings
Printed and bound by Ipskamp Drukkers b.v.
Typeset in LaTeX

Lexical interactions in non-native speech comprehension: Evidence from electro-encephalography, eye-tracking, and functional magnetic resonance imaging

Een wetenschappelijke proeve op het gebied van de
Sociale Wetenschappen

Proefschrift

ter verkrijging van de graad van doctor
aan de Radboud Universiteit Nijmegen
op het gezag van rector magnificus prof. mr. S. C. J. J. Kortmann
volgens besluit van het college van decanen
in het openbaar te verdedigen op woensdag 16 maart 2011
om 15.30 uur precies

door

Ian FitzPatrick
geboren op 16 juli 1981
te Halmstad (Zweden)

Promotores:
Prof. dr. P. Hagoort
Prof. dr. dr. P. Indefrey, Heinrich Heine Universität, Düsseldorf, DE

Manuscriptcommissie:
Prof. dr. A. F. J. Dijkstra
Prof. dr. A. G. Van Hell
Prof. dr. G. Thierry, Bangor University, Gwynedd, UK

The research reported in this thesis was supported by a grant from the Max–Planck–Gesellschaft zur Förderung der Wissenschaften, München, Germany.

“The Babel fish” said The Hitchhiker’s Guide to the Galaxy quietly, “is small, yellow and leechlike, and probably the oddest thing in the Universe. It feeds on brainwave energy received not from its own carrier but from those around it. It absorbs all unconscious mental frequencies from this brainwave energy to nourish itself with. It then excretes into the mind of its carrier a telepathic matrix formed by combining the conscious thought frequencies with nerve signals picked up from the speech centres of the brain which has supplied them. The practical upshot of all this is that if you stick a Babel fish in your ear you can instantly understand anything said to you in any form of language. The speech patterns you actually hear decode the brainwave matrix which has been fed into your mind by your Babel fish.”

Douglas Adams, *The Hitchhiker’s Guide to the Galaxy*

Acknowledgements

The process of writing a PhD thesis has been compared to a marathon, and I can safely say the analogy stands up to scrutiny surprisingly well. Although my physical exertions have thus far only covered half the required distance, I can fully empathise with the endurance, willpower, and (let's face it) masochism that one must exhibit to go the whole way. Along with the continual fear of not reaching the finish line, the pressures of time, the elation of reaching each waypoint along the way, and the trepidation of embarking on the arduous journey to the next, it must be said that neither running, writing, nor researching are activities that can (or should) be undertaken insularly. For this particular endeavour, I have been fortunate to have had supervisors, friends, family, and colleagues who have encouraged and sometimes even carried me some of the way, and to whom I owe a great debt of gratitude.

First plaudits must go to my supervisor Peter Indefrey. Peter, you provided me with my first taste of science when I joined the multilingualism project as a student-assistant. Over the years you have given me a tremendous amount of support, encouragement, and just the right amount of independence. Without a doubt, the most enjoyable (and probably most fruitful) moments of my PhD period were spent pacing around your whiteboard while you stood pensively at the window. It has been a real privilege to have had you as PhD supervisor, and if even a fraction of your scientific insight has rubbed off on me I will count myself extremely fortunate.

Next I would like to thank my promotor, Peter Hagoort. As one of the driving forces behind the Cognitive Neuroscience Master, you helped lay the foundations of my scientific education. I particularly, fondly remember the 'General Neuroscience' course, taught together with Herman Kolk, which served as a bi-weekly opportunity to profit from your insight and experience and which I still consider to be one of the most educational courses in all my studies. During my time as a PhD student you kept me on my toes with your incisive questions during dissertation committee meetings, project proposals, and various formal and informal talks, and I'm certain

I can count my work hugely improved as a result of rising to the challenges you set me.

I would also very much like to thank the members of the manuscript committee: Ton Dijkstra, Janet van Hell, and Guillaume Thierry, for investing their time to read and comment on my dissertation.

In performing the research in this thesis I ambitiously (or perhaps foolhardily) attempted to employ three separate experimental techniques, each with its own steep learning curve, which I (fortunately) did not have to ascend on my own. Doug Davidson taught me the basics of EEG data acquisition and supervised my 'scalp scrubbing' on innumerable participants. Daniëlle van den Brink helped me set up my very first experiment and has since become the first friendly face I look for at poster sessions. Robert Oostenveld, Ingrid Nieuwenhuis, and Jan-Mathijs Schoffelen helped me navigate the matlab-based corridors of FieldTrip. Susanne Brouwer, Marlies Swinkels, and Andrea Weber taught me various aspects of recording and analysing eye-tracking data, as well as the (oft impenetrable) wonders of NESU programming. Paul Gaalman, the Donders' resident MRI guru, instructed me in the use of the Siemens Trio MRI scanner. Tessa van Leeuwen patiently listened to my inane SPM questions and cured me of my MRI analysis naivety in an admirably calm fashion; and Guido van Wingen, Kirsten Weber, and Eelco van Dongen were each willing to be interrupted by myriad questions about 3D smoothing paramaters, cluster thresholds, and the like. Many thanks to you all!

I would also like to express my gratitude to: my 'backup' supervisors Jos van Berkum and Miranda van Turennout for their insights during dissertation committee meetings; Anne Cutler, who gave me the opportunity to learn eye-tracking and whose diligent scrutiny of my work has been both thought-provoking and extremely educational; and the members of the 'Dynamics of Multilingualism' project at the MPI, for providing fascinating bi-weekly journal clubs and a friendly environment for discussing project ideas. In particular I'd like to thank Marianne Gullberg and Amanda 'the voice of my stimuli' Brown. Marianne, I am extremely grateful for your advice and support over the years and, if truth be told, I must confess to have shamelessly copied much of your presentation style as you give by far the clearest and most enjoyable talks of anyone I know! Amanda, I'm extremely grateful for your willingness to help me out and still feel pangs of guilt when I think back to the hours of voice recordings that I put you through.

I must also offer my gratitude and profound sympathy for my roommates at the Donders Institute: Eelco van Dongen, Hein van Marle, Meike Grol, Sasha Ondobaka, Jan-Mathijs Schoffelen, and Guido van Wingen, who had the unenviable

task of sharing an office with me while I muttered expletives at my computer at random moments of the day.

My thanks also to: two MA students, Juliane Wagner and Travellia Tjokro, whom I was fortunate enough to supervise. As well as providing valuable assistance by running numerous participants you were also extremely fun to work with, and I shall look back fondly on the hours we spent together in experiment control rooms; my army of EEG-scrubbing-volunteers: Michel Bex, Vasiliki Folia, Jana Basnakova, Lilla Magyari, Stephan Miedl, Anouk Peijnenborgh, Willemijn Schot, and Kirsten Weber. You guys saved me hours of work and made the chore of scrubbing 64 electrodes per participant a great deal more fun; the PhD students at the Max Planck and Donders Institutes, and in particular my fellow Cognitive Neuroscience Master Alumni, Lilla Magyari, and Vasiliki Folia for their friendship.

Special thanks go to Sandra Geerlings for designing the cover image. I'm sure that seeing your creativity displayed prominently on the cover of this dissertation will unleash hordes of PhD students all clamoring for a piece of 'Alter' design for their thesis.

My 'paranimfen' Nienke Dijkstra and Kirsten Weber and their supernatural organisational skills are also deserving of my highest praise and gratitude. Kirsten, besides joining me while braving the horizontal rains of Bangor, ascending Mount Snowdon (admittedly not entirely under our own steam), and co-authoring peer commentary, you have also been a great friend and colleague. I still owe you a first authorship on our next collaboration! Nienke, how great is it to share a 15-year friendship with someone who actually understands your passion for language science (and needn't even feign interest in your research)? Ours is the Marmite of scientific fields and I'm extremely glad to have a fellow enthusiast among my closest of friends!

My friends and family, who for a three year period had to put up with an increasingly reclusive, misanthropic, wet-blanket who was unable to contribute anything meaningful to conversations whose topic did not fall within the domains of bilingualism research, neuroimaging, or Blackburn Rovers FC, deserve a mention for their patience as much as their indispensable moral support.

Dear Hester, besides having an invaluable contribution to the final version of this thesis through adding LaTeX code (yes, that's what you were doing) to my stimulus materials, you have enriched my life in more ways than I can express. Thank you for your love.

Contents

General Introduction

CHAPTER 1

Learning a new language can be extremely enriching, but it is also (as many language learners will attest) not without its challenges. During the processes of building up a new vocabulary, learning new grammar, and mastering the subtleties of pronunciation, your new language must somehow find a way, together with your native language, of co-inhabiting your brain. Having already mastered your native language, the processing systems to accomplish producing and processing language in the written, auditory, or even gestural domain are firmly established and, when learning a second language, you would be remiss if you didn't exploit the established native language (L1) brain infrastructure in order to process and produce your second language (L2). Indeed if we consider the entire spectrum of studies that have looked at how your second language makes use of your brain, it becomes clear that it uses many of the structures that had previously subserved only your native language (for a review see: Indefrey, 2006); what's more, there is evidence that this starts to happen after only a few months of exposure to a new language (Indefrey, et al., 2005). In essence, your brain need not "reinvent the wheel" so to speak by creating a new language production or processing system in a brain that already has a perfectly functional L1 infrastructure in place. However this co-dependence on processing infrastructure between your L1 and L2 introduces a new challenge for you as a bilingual, namely: how can you keep your languages separate?

Although the vast majority of empirical research into this particular question has come from studies of bilingual visual word recognition (for a review see: Dijkstra, 2005) and bilingual word production (e.g., Costa, Colomé, Gómez & Sebastián-Gallés, 2003), the issue is equally pertinent – though less extensively researched – in the domain of spoken language comprehension where potential sources of between-language confusion are also abundant (e.g., the phoneme sequence /meɪl/ could correspond to the English words *mail* or *male*, but also sounds extremely similar to the Dutch word *meel* ‘flour’). To answer the question, we first need to know the extent of the problem, in other words, we ask ourselves: to what degree do languages interact in the bilingual brain? Are between-language interactions automatic and unstoppable? Under which circumstances do they occur and are they the same no matter how proficient you are in your second language? These questions form the core of the present thesis, and the answers will hopefully inform us to what extent between-language interactions influence bilingual speech comprehension. In Chapters 2, 3, and 4 of this thesis we will explore the boundaries of between-language interactions and highlight a number of important factors that may influence their extent. In the fifth chapter we move towards a tentative mechanism that may enable the bilingual to tell his languages apart.

Central to our investigation of between language interactions is the concept of multiple lexical activation. Essentially, this means that when confronted with a word (whether in the spoken or written input modality) your brain entertains multiple concurrent hypotheses as to the identity of that word. Consider, for instance, the word *capital*; the first phonemes of this word sound very similar to those in *captain*. In fact, when you hear the word *capital* and are subsequently asked to identify visually presented words (e.g., Zwitserlood, 1989), you would be faster to identify the words *money* (related to *capital*) and *ship* (related to *captain*) compared to a word like *nose* (unrelated to *capital* or *captain*). The example illustrates that when hearing a stretch of speech (e.g., /kæp/) similar sounding words (e.g., *capital* and *captain*) and their corresponding semantic associates (e.g., *money* and *ship*) are briefly activated in your mental lexicon. In other words your brain initially keeps its options open and (briefly) considers multiple lexical candidates (Goldinger, Luce & Pisoni, 1989; Marslen-Wilson & Tyler, 1980; McClelland & Elman, 1986; Norris, 1994). This feature of the word recognition process raises a number of interesting questions, namely: what happens when you speak more than one language? Given the difficulties of non-native speech comprehension, does the L2 listener have the necessary processing resources to consider different lexical candidates? And, if so, are lexical candidates activated across languages? These questions constitute the starting point of our investigation into lexical interactions in bilingual speech comprehension.

1.1 This Thesis

In Chapter 2 of this thesis we sought to investigate whether non-native listeners activated multiple lexical candidates during speech comprehension and, if so, whether they also considered lexical candidates between their languages. The question of between-language lexical activation has been extensively dealt with in the domain of visual word recognition and a large body of evidence seems to suggest that bilinguals indeed activate words in a language non-selective manner (for a review see: Dijkstra, 2005). There is, however, ample reason to believe that lexical activation may be subject to different constraints in the domain of speech comprehension. For one thing, the speech signal unfolds over time, which means that you don't encounter entire words at once (as you would arguably do in reading), but that you are presented with a signal that is unfolding phoneme by phoneme. In addition, however close speech sounds may be between languages, studies have shown that bilinguals are attuned to pronunciation differences and are able to judge language membership of incoming words at an early stage during the speech recognition process (Grosjean, 1988). Nevertheless a number of studies have found cross linguistic lexical activation in non-native speech comprehension (e.g., Marian & Spivey, 2003a; Marian & Spivey, 2003b; Marian, Spivey & Hirsch, 2003; Schulpen, Dijkstra, Schriefers & Hasper, 2003; Spivey & Marian, 1999; Weber & Cutler, 2004). In Chapter 2 we aimed, firstly, to investigate whether bilinguals activated multiple lexical candidates during non-native speech processing and, secondly, to extend previous findings of cross-linguistic lexical activation during speech comprehension to the more ecologically valid situation of L2 word recognition in a sentence context.

How the presence of a sentence context could influence word recognition in L2 speech comprehension was the subject of Chapter 3. In this Chapter we delved further into the potential influence of both sentence contextual information as well as the bilingual's target language proficiency on cross-linguistic lexical activation. Both these factors have been shown to limit cross-linguistic lexical activation in studies of bilingual visual word recognition (Duyck, Van Assche, Drieghe & Hartsuiker, 2007; Schwartz & Arêas Da Luz Fontes, 2008), thus our primary aim in Chapter 3 was to extend these findings to the domain of non-native speech comprehension.

The fourth Chapter in this thesis examines a very special type of between language overlap: namely interlingual homophones. These are words that sound very similar between two languages but mean something different (e.g., the English word *pet* which means 'hat' in Dutch). This, of course, raises the question whether or not bilinguals activate the meanings of these interlingual homophones across languages (i.e., would they activate the L1 meaning of the homophone while listening to L2 speech). There is already some evidence that interlingual homophones in isolation activate both their meanings (Schulpen, et al., 2003) and that the bilingual may be able to use contextual information to bias towards one or other of the homophone meanings (Li & Yip, 1998). In Chapter 4 we aimed to expand on these findings and asked whether we could find evidence of between language meaning activation for interlingual homophones in spoken sentence contexts. In a second step, we also examined how comparable interlingual homophone processing was to processing actual language switches (i.e., when the retrieval of a between-language meaning is explicitly required).

In the final Chapter of this thesis, we will attempt to uncover how bilinguals are capable of separating their languages, especially in the face of potential between-language interference. Bilinguals have an astounding ability to rapidly switch languages and easily judge to which language a given word belongs (Grosjean, 1988). This requires that the bilingual has fast and robust access to language membership information. Essentially there are two ways in which this could be accomplished. One possibility is that the bilingual relies on subtle pronunciation differences to judge language membership, another is that there is an abstract language membership representation in the bilingual brain linked to each lexical item. Chapter 5 aims to tease apart these two possibilities by investigating how the bilingual brain processes language switches with overt non-context language form features (e.g., Dutch words, which were pronounced according to Dutch phonology and embedded in English sentence contexts) or with exclusively context language form features (e.g., Dutch-English homophones, which were pronounced according to English phonology and embedded in English sentence contexts).

1.2 Experimental Techniques

In this thesis we approached the question of between language lexical interactions from different angles and exploiting various experimental techniques. In the work reported in Chapters 2 and 4 we recorded Electroencephalograms (EEGs) from bilingual participants while they listened to second-language speech. EEGs reflect concurrent activation of a large number of laminarly organized neurons (predominantly in the neocortex). Activity in these bundles of neurons evokes an electric field, which propagates to the scalp where it is picked up by an array of electrodes. Each scalp-mounted electrode is compared to a common reference electrode that is thought to exhibit a minimal amount of brain activity (in this case on the nose of the participant), thus removing electrical background noise from the environment of the participant. Epochs of EEG data comprising one or two seconds are time-locked to a stimulus (in our case the acoustic onset of a critical word) and a large number of these epochs (trials) are then averaged together separately for each experimental condition. This procedure minimizes the noise and helps derive a brain signature of the process under investigation (in this case the processing of semantically congruent and incongruent critical words), in each separate condition, with millisecond accuracy. Statistical comparisons between the different experimental conditions are made using the individual subject averages.

In the experiments reported in Chapter 3 we used a head-mounted camera system to track participants' eyes while looking at an array of objects presented on a computer monitor. From the viewpoint of the head-mounted camera, the position of the participant's pupil as well as the reflective properties of their cornea change as he/she looks around the visual scene. By calibrating the eye-movement registration software to each individual's pupil position and corneal reflection using a pre-defined template, we can infer where on the computer screen the participant is directing his/her gaze with a temporal resolution of 250 Hz. The utility of this procedure for investigating activation of lexical candidates stems from observations (e.g., Allopenna, Magnuson & Tanenhaus, 1998; Tanenhaus, et al., 1995) that participants hearing a stretch of speech would tend to direct their gaze toward visual objects whose name corresponded to the speech signal (e.g., when hearing /biːt/ a participant would look more often at a pictures of a beetle or beaker than at pictures of a carriage).

In the experiments reported in Chapter 5 we used functional Magnetic Resonance Imaging (fMRI). In contrast to EEG or Eye-tracking this technique has a temporal resolution in the order of seconds (rather than milliseconds) but it does allow us to localize brain activation at an accuracy of 3 mm. Participants are placed in the scanner where there is a strong static magnetic field with superimposed magnetic gradients in three different spatial planes. Under these conditions the water-bound protons in the participants' bodies behave like tiny magnets and the majority will tend to orient themselves along with (low-energy state) the static magnetic field, while a minority of water bound protons will orient themselves in the opposite direction (high energy state) to the static magnetic field. The protons precess about the axis of the static magnetic field at a frequency (Larmor frequency) proportional to the magnetic field strength. The three magnetic gradients change the frequency and phase of these photon precessions to allow us to subdivide the participants' brains into spatially defined voxels (analogous to pixels in a digital image). A radiofrequency (RF) pulse can be used to coerce more protons from low to high-energy states. This creates a net magnetic moment in the spatial plane transversal to the static magnetic field, which can be measured using an RF receiver. While the protons slowly return to their low energy state, the magnetic moment in the transverse plane decays and the RF signal is attenuated. The speed at which the protons return to their low energy state depends on the type of tissue (faster in water or cerebrospinal fluid; slower in grey matter; even slower in bone or cartilage) and local perturbations in the magnetic fields that they are exposed to. Among other things an important source of such local perturbations is the relative concentration of oxygenated and deoxygenated blood in the vicinity of the proton. While oxygenated blood is diamagnetic, deoxygenated blood is paramagnetic thus each differentially effects the local magnetic field. When a particular brain area is active, it consumes oxygen. This initially leads to an increase in deoxygenated blood in the capillaries close to the site of activation (causing an initial signal decrease) followed by a so-called luxury perfusion of oxygenated blood (causing a substantial signal increase). This pattern of signal change following brain activation is called the Blood Oxygen Level Dependent or BOLD effect. This BOLD effect has a very characteristic time course, thus observing a voxel that exhibits this time course is taken as an indicator of activation in that voxel. Volumes of voxel intensities are thus acquired for a number of experimental participants and spatially transformed to match a standard brain template. The variations of voxel intensity values over a period of time following stimulus onset (in our case critical word onset) of each voxel in the normalized brain are subjected to a linear regression analysis in which the regressors reflect the timings of stimulus (e.g., critical words) presentation, convolved with a canonical representation of the BOLD response or Haemodynamic Response Function (HRF). The resulting statistical maps are compared against a conservative statistical threshold to minimize the risk of finding false positive activations due to the large number of statistical comparisons.

1.3 References

Allopenna, P., Magnuson, J., & Tanenhaus, M. (1998). Tracking the time course of spoken word recognition using eye movements: Evidence for continuous mapping models. *Journal of Memory and Language*, *38*(4), 419-439.

Costa, A., Colomé, A., Gómez, O., Sebastián-Gallés, N. (2003). Another look at cross-language competition in bilingual speech production: Lexical and phological factors. *Bilingualism: Language and Cognition*, *6*(3), 167-179.

Dijkstra, T. (2005). Bilingual Visual Word Recognition and Lexical Access. In J. F. Kroll & A. M. B. de Groot (Eds.), *Handbook of bilingualism: Psycholinguistic approaches* (pp. 179-201). New York: Oxford University Press.

Duyck, W., Van Assche, E., Drieghe, D., & Hartsuiker, R. J. (2007). Visual word recognition by bilinguals in a sentence context: Evidence for nonselective lexical access. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *33*(4), 663-679.

Goldinger, S. D., Luce, P. A., & Pisoni, D. B. (1989). Priming lexical neighbors of spoken words: Effects of competition and inhibition. *Journal of Memory and Language*, *28*(5), 501-518.

Grosjean, F. (1988). Exploring the recognition of guest words in bilingual speech. *Language and Cognitive Processes*, *3*(3), 233-274.

Indefrey, P. (2006). A meta-analysis of hemodynamic studies on first and second language processing: Which suggested differences can we trust and what do they mean? *Language Learning*, *56*(s1), 279-304.

Indefrey, P., Hellwig, F., Davidson, D., & Gullberg, M. (2005). Native-like hemodynamic responses during sentence comprehension after six months of learning a new language. Poster presented at the 11th Annual Meeting of the Organization for Human Brain Mapping, Toronto, Canada.

Li, P. & Yip, M. C. (1998). Context effects and the processing of spoken homophones. *Reading and Writing*, *10*(3-5), 223-243.

Marian, V., & Spivey, M. J. (2003a). Bilingual and monolingual processing of competing lexical items. *Applied Psycholinguistics*, *24*(2), 173-193.

Marian, V., & Spivey, M. J. (2003b). Competing activation in bilingual language processing: Within- and between-language competition. *Bilingualism: Language and Cognition*, *6*(2), 97-115.

Marian, V., Spivey, M. J., & Hirsch, J. (2003). Shared and separate systems in bilingual language processing: Converging evidence from eyetracking and brain imaging. *Brain and Language*, *86*(1), 70-82.

Marslen-Wilson, W. D., & Tyler, L. K. (1980). Temporal structure of spoken language understanding. *Cognition*, *8*(1), 1-71.

McClelland, J. L., & Elman, J. L. (1986). The TRACE model of speech perception. *Cognitive Psychology*, *18*(1), 1-86.

Norris, D. (1994). Shortlist - A connectionist model of continuous speech recognition. *Cognition*, *52*(3), 189-234.

Schulpen, B., Dijkstra, T., Schriefers, H. J., & Hasper, M. (2003). Recognition of interlingual homophones in bilingual auditory word recognition. *Journal of Experimental Psychology: Human Perception and Performance*, *29*(6), 1155-1178.

Schwartz, A.I., & Arêas Da Luz Fontes, A. B. (2008). Cross-language mediated priming: Effects of context and lexical relationship. *Bilingualism: Language and Cognition*, *11*(1), 95-110.

Spivey, M. J., & Marian, V. (1999). Cross talk between native and second languages: Partial activation of an irrelevant lexicon. *Psychological Science*, *10*(3), 281-284.

Tanenhaus, M.K., Spivey-Knowlton, M.J., Eberhard, K.M., & Sedivy, J.C. (1995). Integration of visual and linguistic information in spoken language comprehension. *Science*, *268*(5217), 1632-1634.

Weber, A., & Cutler, A. (2004). Lexical competition in non-native spoken-word recognition. *Journal of Memory and Language*, *50*(1), 1-25.

Zwitserlood, P. (1989). The locus of the effects of sentential-semantic context in spoken-word processing. *Cognition*, *32*(1), 25-64.

Lexical Competition in Non-Native Speech Comprehension

CHAPTER 2

Ian FitzPatrick and Peter Indefrey

Abstract

Electrophysiological studies consistently find N400 effects of semantic incongruity in non-native (L2) language comprehension. These N400 effects are often delayed compared to native (L1) comprehension, suggesting that semantic integration in one's second language occurs later than in one's first language. In this study we investigated whether such a delay could be attributed to: (1) intralingual lexical competition, and/or (2) interlingual lexical competition. We recorded EEG from Dutch-English bilinguals who listened to English (L2) sentences in which the sentence-final word was: a) semantically fitting, b) semantically incongruent, or semantically incongruent, but initially congruent due to sharing initial phonemes with c) the most probable sentence completion within the L2 or d) the L1 translation equivalent of the most probable sentence completion. We found an N400 effect in each of the semantically incongruent conditions. This N400 effect was significantly delayed to L2 words, but not to L1 translation equivalents, that were initially congruent with the sentence context. Taken together these findings firstly demonstrate that semantic integration in non-native listening can start on the basis of word initial phonemes (i.e., before a single lexical candidate could have been selected on the basis of the input), and secondly suggest that spuriously elicited L1 lexical candidates are not available for semantic integration in L2 speech comprehension.

Journal of Cognitive Neuroscience (2010), *22*(6), 1165-1178.

2.1 Introduction

As Grosjean (1989) rightly points out: "The bilingual is not two monolinguals in one person", alluding to the fact that there may be qualitative differences between how one produces and comprehends language in a second language (L2) and how a monolingual native (L1) speaker of that language would do so.

Important qualitative differences are evident in the domain of bilingual speech comprehension. For instance, when tasked with identifying spoken words in their second language, bilinguals are slower (e.g., Scarborough, Gerard & Cortese, 1984; Soares & Grosjean, 1984), less proficient, and less confident in their identification than monolinguals (Schulpen, Dijkstra, Schriefers & Hasper, 2003). Notably, bilinguals consistently take longer to process semantic anomalies in sentence contexts (e.g., "He spread the warm bread with *socks*") than monolinguals. That is, while bilinguals exhibit the same N400 effect (Kutas & Hillyard, 1980) to semantic incongruity in sentences as monolinguals, the effect is often delayed (Hahne, 2001; Weber-Fox & Neville, 1996; for a review see: Moreno, Rodriguez-Fornells & Laine, 2008). The functional interpretation of this delay is far from clear and a number of possible accounts have recently been put forward (see also: Rueschemeyer, Nojack & Limbach, 2008). These accounts centre on the notion that bilinguals, despite knowing fewer words in their second language, have to identify words from among a larger pool of concurrently activated candidates than monolinguals. In other words, in bilinguals more lexical candidates compete for recognition than in monolinguals.

Two sources for this enhanced competition have been postulated: (1) due to less efficient phonological processing and/or confusable phonemes between languages, bilinguals may experience greater competition from intralingual lexical candidates (e.g., Broersma, 2005; Weber & Cutler, 2004), and (2) shared lexical storage systems between a bilingual's languages may cause concurrent activation of word candidates from both of the bilingual's languages (e.g., Marian & Spivey, 2003a; Marian & Spivey, 2003b; Marian, Spivey & Hirsch, 2003; Schulpen, Dijkstra, Schriefers & Hasper, 2003; Spivey & Marian, 1999; Weber & Cutler, 2004), hence bilinguals may experience greater competition from interlingual lexical candidates. In order to earmark either of these possible sources of enhanced competition as plausible causes for N400 delays in bilinguals it is important to establish whether or not concurrently activated intra- and/or interlingual lexical items are actively evaluated during word recognition. Consequently, the main aim of the present study is to investigate what influence intra- and/or interlingual lexical competition has on the time course of semantic processing in non-native speech comprehension. Expanding on previous studies that have shown intra- and/or interlingual competition in single word (e.g., Schulpen, et al., 2003) and invariant sentence contexts (e.g., Spivey & Marian, 1999; Weber & Cutler, 2004), this is the first study to investigate non-native lexical competition using semantically rich sentences.

Monolingual Word Recognition

The concept of multiple lexical activation plays an important role in how we currently conceive of the word recognition process. Models of monolingual word recognition agree that multiple lexical candidates that match the input to a certain extent are briefly active during word recognition (Goldinger, Luce & Pisoni, 1989; Marslen-Wilson & Tyler; McClelland & Elman, 1986; Norris, 1994). For example, hearing the word *box* would briefly activate words such as *bottle*, *boss*, or *body.* The collection of candidates is sometimes referred to as a cohort (Marslen-Wilson & Tyler, 1980) or shortlist (Norris, 1994). Concurrent activation of multiple lexical candidates is not simply an epiphenomenon of the speech recognition process; rather cohort members are thought to actively compete with each other for recognition. In fact, recognition of a particular lexical item becomes progressively harder the more lexical candidates are concurrently active (McQueen, Norris & Cutler, 1994; Norris, McQueen & Cutler, 1995; Soto-Faraco, Sebastián-Gallés & Cutler, 2001; Vroomen & De Gelder, 1995). As the speech signal unfolds fewer and fewer candidates in the cohort will match the input and the size of the cohort will shrink (lexical selection). Words in the cohort must activate their semantic features (lexical access), and the activated semantic features can then be checked against the sentence context in a process called semantic integration.

Early electrophysiological studies of written language comprehension have identified an Event-Related Potential (ERP) component that is sensitive to the process of semantic integration. This component has been designated the N400 to reflect the fact that it is a negative going component that peaks between 300 and 500 ms after critical word onset (Kutas & Hillyard, 1980). The N400 is more negative to words that are semantically incongruent within a sentence context than to congruent words. Certain characteristics of the N400 have proven useful indicators of underlying cognitive processes. For instance, the amplitude of the N400 component is taken to reflect the ease of semantic integration (Brown & Hagoort, 1993; Kutas & Hillyard, 1984) and the peak and onset latency of the N400 component are sensitive to the point at which a semantic incongruity is detected (O'Rourke & Holcomb, 2002; Praamstra, Meyer & Levelt, 1994).

The N400 arises under similar circumstances in auditory language comprehension (Connolly & Phillips, 1994; Connolly, Phillips, Stewart & Brake, 1992; Connolly, Stewart & Phillips, 1990; Diaz & Swaab, 2007; Hagoort & Brown, 2000; Holcomb & Neville, 1991; McCallum, Farmer & Pocock, 1984; Newman, Connolly, Service & McIvor, 2003; Van den Brink, Brown & Hagoort, 2001, 2006; Van den Brink & Hagoort, 2004; Van Petten, Coulson, Rubin, Plante & Parks, 1999). Studies of speech comprehension report the earliest point at which an incongruity effect manifests itself to be around 200 ms after critical word onset. This early effect is sometimes reported as being functionally distinct from the N400 (e.g., Connolly & Phillips, 1994; Connolly, Phillips, Stewart & Brake, 1992; Connolly, Stewart & Phillips, 1990; Newman, Connolly, Service & McIvor, 2003; Van den Brink, Brown & Hagoort, 2001; Van den Brink & Hagoort, 2004). Others regard the early negativity as an early manifestation of the N400 component (Diaz & Swaab, 2007; Van den Brink, Brown & Hagoort, 2006; Van Petten, Coulson, Rubin, Plante & Parks, 1999). The existence of an early negative effect demonstrates that monolinguals are capable of noticing incongruity of a spoken word in a sentence context after only 200 ms. As Marslen-Wilson (1980) points out, after the first 200 ms of a word (roughly corresponding to its first two phonemes) tens of possible word candidates remain viable on the basis of the input alone. This implies that detection of incongruity is initiated even before incoming words are fully recognised.

The fact that incongruity can be detected at such an early point in time begs the question to what extent concurrently activated lexical candidates are considered for semantic integration. That is, when we hear a sentence like "When we move house I have to put all my books in a *box*", would semantic integration be attempted for all activated candidates (i.e., *bottle*, *boss*, *body*, etc.) or would only the selected candidate be considered? To address this question, Van den Brink, Brown, and Hagoort (2006), examined the relationship between the point at which a stimulus word was isolated (i.e., recognised) and the onset of the N400 effect. They found that the latency of the N400 effect did not differ between words with a late isolation point (IP) and words with an early IP. The latency of semantic integration is thus independent of the moment at which words are recognised. This finding clearly speaks against the concept of a 'magic moment' at which lexical selection ends and semantic integration can start. It implies that semantic integration is attempted for a number of concurrently active lexical candidates even before one candidate is uniquely identified (selected) on the basis of the input.

Bilingual Word Recognition

Bilinguals generally know fewer words in their second language than do monolingual speakers of that language (e.g., Verhoeven & Vermeer, 1985; Vermeer, 1992). Although this fact might be expected to restrict the number of concurrently activated word candidates and hence constitute an advantage for bilingual word recognition, accumulating evidence seems to indicate that bilinguals even have to contend with a larger amount of concurrent lexical activation than monolinguals.

Converging experimental findings suggest that less efficient pre-lexical processing could contribute to spurious activation of additional intralingual competitors. One striking example of spurious competitor activation arises when non-native listeners are confronted with lexical items that contain confusable phonemes. Dutch-English bilinguals, for instance, have difficulty perceiving the contrast between /æ/ as in *pan* and /ɛ/ as in *pen* (Schouten, 1975). Such phonemic confusability has been shown to cause bilinguals to erroneously consider non-words that differ only on a (for them) perceptually ambiguous phonemic contrast (e.g., *lemp* - *lamp*) as words (e.g., Broersma, 2002; Sebastián-Gallés, Echeverria & Bosch, 2005). Thus, whereas English monolinguals hearing the word *pan* might activate lexical competitors like *panda*, *panther* or *pancake*, Dutch-English bilinguals may experience additional competition from words like *pen*, *pencil*, or *pentagon*. That this is indeed the case has been demonstrated by a number of recent experiments. For instance, in a cross-modal priming paradigm Broersma (2005) presented Dutch-English bilinguals and English native speakers with identical, mismatching or unrelated auditory prime/visual target pairs. Mismatching primes were partial words that initially differed from the target on the /æ/ - /ɛ/ vowel contrast (e.g., *daffo* from daffodil or *defi* from deficit). Whereas recognition of visual targets was inhibited following mismatching primes in English native speakers, auditory presentation of either *daffo* (identity) or *defi* (mismatching) led to significant priming of DAFFODIL in Dutch-English bilinguals. This consequence of phonemic confusability is not simply a reflection of increased tolerance for phonemic mismatches in non-native speech comprehension as becomes evident when we consider findings from Weber and Cutler (2004, Exp. 1a & 1b). They used an eye-tracking paradigm, in which participants identify the visual referent of an auditory stimulus from among phonologically related and unrelated distractors. Dutch-English bilinguals fixated more often on intralingual competitors when they differed from the target by way of a confusable (e.g., *panda-pencil*) rather than an unconfusable (e.g., *bottle-beetle*) phonemic contrast. Cutler (2005) estimates that, due to the perceived /æ/ - /ɛ/ ambiguity, considerable numbers of non-words embedded in larger real words (e.g., *daf* in daffodil, *lem* in lemon) may be erroneously perceived as real words (e.g., *deaf*, *lamb*). Increased intralingual lexical activation may thus pose a substantial challenge and, unfortunately for the bilingual, the difficulties with non-native listening may go even further. Recent findings suggest that they may also have to contend with spuriously activated words from their other language (i.e., interlingual lexical activation).

A great deal of evidence for cross-linguistic lexical activation originates from bilingual visual word recognition studies demonstrating between-language lexical neighbourhood size effects. The speed at which you recognise a word from one language is directly related to the number of words from the other language with a similar orthography in your lexicon (e.g., Van Heuven, Dijkstra and Grainger, 1998) This language non-selective lexical activation has since become an important feature of many influential models of bilingual word recognition such as the BIA (Dijkstra & Van Heuven, 1998; Grainger & Dijkstra, 1992) and BIA+ models (Dijkstra & Van Heuven, 2002). But while cross-linguistic lexical activation is a well-established phenomenon in visual word recognition the case for auditory word recognition is slightly more complex.

At first glance it may not seem obvious why cross-linguistic activation in speech comprehension would happen at all. Whereas an interlingual homograph (e.g., BRAND, which is the Dutch word for 'fire') in isolation provides little clue as to its language membership, a bilingual may rely on a multitude of subtle phonemic and subphonemic cues to distinguish between different tokens of an interlingual homophone. Indeed, bilinguals are able to accurately judge language membership of words based on their initial phonemes alone (Grosjean, 1988) and have been shown to be sensitive to fine-grained acoustic-phonetic between language differences (Ju & Luce, 2004). Nevertheless, a number of important findings make a strong case for the existence of cross-linguistic lexical activation. Using Dutch-English bilinguals Schulpen et al. (2003) showed that both pronunciations of an auditorily presented interlingual homophone could prime its L2 orthographic form (e.g., *lief* 'sweet' - LEAF vs. *leaf* - LEAF). The authors took this as evidence that hearing a homophone activates both its L1 and L2 forms simultaneously. Equally striking evidence for language non-selective access to the bilingual lexicon comes from eye-tracking paradigms that show that bilinguals fixate on both intra- and interlingual competitors while listening to verbal instructions in their L2 (Marian & Spivey, 2003a, 2003b; Marian, Spivey & Hirsch, 2003; Spivey & Marian, 1999; Weber & Cutler, 2004). Thus it seems that cross-linguistic lexical activation is not restricted to visual word recognition but can also occur in spoken language comprehension.

Objectives

Although it has been shown that bilinguals experience greater intra- as well as interlingual lexical competition in auditory word recognition, we are still somewhat removed from establishing whether either (or indeed both) of these sources of lexical competition are plausible causes for delayed semantic processing in L2 speech comprehension. An important first step to investigate the possibility of such a causal relationship would be to establish whether, firstly, concurrently activated intralingual competitors are considered for semantic integration in non-native speech comprehension, and secondly whether the same holds for cross-linguistically activated interlingual competitors.

In the present study we use a monolingual L2 experimental setting in which our L2 listeners are kept unaware that their L1 is also under investigation. This setting is intended to reflect a common situation in L2 listening, namely full immersion in an all L2 environment. Although mixed language contexts are also common in L2 listening, we explicitly chose a monolingual L2 context to avoid unintentionally inducing interlingual competition. This experimental setting constitutes a strong test for interlingual lexical competition in L2 comprehension. Thus, finding interlingual competition under these restrictive circumstances would also allow us to infer the availability of interlingual lexical candidates if the L1 would have been more salient.

We investigate the availability of intralingual and interlingual competitors for semantic integration by exploiting the sensitivity of the N400 to the time point at which a semantic incongruity arises. As has been shown previously (e.g., Van den Brink, Brown & Hagoort, 2001, 2006; Van Petten, Coulson, Rubin, Plante & Parks, 1999) it is possible to infer the time course of lexical selection and semantic integration by examining the latency of the N400 to congruent words, incongruent words and words that are initially congruent but become incongruent after the first few phonemes (e.g., "It was a pleasant surprise to find that the car repair bill was only seventeen *dollars/scholars/dolphins*"). If only one lexical candidate is considered for semantic integration (in other words: if semantic integration occurs after lexical selection has occurred) the N400 should have the same time course for initially congruent words as for incongruent words. That is, the semantic features of the cohort would only be assessed at the moment that one (in this case incongruent) item remains in the cohort. A delay of the N400 to initially congruent words indicates that semantic integration has started before lexical selection has occurred. Thus multiple candidates have been considered for semantic integration.

We presented Dutch (L1)-English (L2) bilinguals with spoken sentences in their

L2. The participants were drawn from the same population as was used in Weber and Cutler (2004) and Schulpen et al. (2003). Using semantically constraining sentence contexts, we manipulated the semantic fit of sentence final target words such that they were either: (a) fully congruent (e.g., "The goods from Ikea arrived in a large cardboard *box*"), (b) fully incongruent (e.g., "He unpacked the computer, but the printer is still in the *towel*"), (c) initially congruent within the L2 (e.g., "When we moved house, I had to put all my books in a *bottle*"), or (d) initially overlapping with a congruent L1 lexical item (e.g., "My Christmas present came in a bright-orange *doughnut*"; which shares phonemes with the Dutch *doos* 'box').

Firstly, in accordance with earlier studies (Hahne, 2001; Hahne & Friederici, 2001) we expect an N400 effect between the fully incongruent (FI) condition and the fully congruent (FC) condition. Secondly, if intralingual lexical candidates are not considered for semantic integration in L2 listening (i.e., L2 listeners wait for lexical selection to occur before initiating semantic integration) the peak and/or onset latency of the N400 effect should not differ between the fully incongruent and initially congruent condition. If L2 listeners can initiate semantic integration after the word initial phonemes we expect a difference in the onset and/or peak latency of the N400 between the condition where the critical word is initially congruent with the sentence context (ICL2) and the FI condition. This would reflect the fact that during the initial phonemes the congruent item is still in the cohort thus semantic integration at this stage would treat the cohort as congruent with the sentence. Lastly, if concurrently activated L1 lexical candidates are considered for semantic integration this should also be reflected in the onset and/or peak latency of the N400 between the L1 overlap condition (ICL1) and the FI condition. If L1 candidates are not considered for semantic integration the participant should treat words with initial overlap with L1 items as if they were any other semantically incongruent word, in which case there would be no difference in N400 peak and/or onset latency between the ICL1 and FI conditions.

2.2 Methods

Participants

Thirty right-handed, highly proficient, late onset (after age 10), Dutch-English bilinguals participated in the experiment, 24 of which were included in the final analysis (7 men; mean age 23.7 years). The participants' English proficiency was assessed using 50 grammaticality judgement items of the Oxford Placement Test (Allan, 1992) (mean score: 43.65, "advanced level", $SD = 2.68$; maximum score:

50) and a non-speeded lexical decision test (60 items), created by Meara (1996) and later adapted by Lemhöfer, Dijkstra and Michel (2004) (mean score: 44.42, $SD = 5.78$; maximum score: 60). Participants were either paid a small fee or they received study credits. None of the participants had any neurological impairment. All participants gave their written informed consent.

Materials

Participants listened to English sentences that belonged to one of four conditions. In the FC condition sentences ended in a high cloze probability word, for example: "The goods from Ikea arrived in a large cardboard *box*". In the FI condition sentences ended in a semantically incongruent word, for example: "He unpacked the computer, but the printer is still in the *towel*". In the ICL2 condition the sentence final word shared initial phonemes with the highest cloze probability word, for example: "When we moved house, I had to put all my books in a *bottle*." (initial overlap with *box*). In the ICL1 condition the sentence final word shared initial phonemes with the direct translation of the highest cloze probability word in the participant's L1, for example: "My Christmas present came in a bright-orange *doughnut*" (initial overlap with "doos" where *doos* is Dutch for 'box'). We defined a number of correspondences between Dutch and English vowels and diphthongs (see Table 2.1), which we considered to be sufficiently similar to constitute an overlap. In each case the extent of the overlap was the initial consonant or consonant cluster and the vowel. This amount of phonological overlap has been shown to be sufficient to elicit lexical competition in monolingual speech comprehension (e.g., Van den Brink, et al., 2001; Van Petten, 1999). The stimulus sentences were selected from among 414 sentences that had been cloze tested by an independent group of participants ($n = 15$). Sentences with high-cloze alternatives that shared initial phonemes with the (semantically congruent) target word were discarded. The average cloze probability for the remaining sentences was 0.47.

Thirty-eight English target words (e.g., *box*; FC condition) that were semantically congruent with the sentence context were matched with 38 semantically incongruent words that shared initial phonemes (e.g., *bottle*; ICL2 condition) with congruent target words, 38 semantically incongruent words that shared initial phonemes with a translation equivalent (Dutch: *doos* 'box') of the congruent word (e.g., *doughnut*; ICL1 condition) and 38 semantically incongruent words that were phonologically unrelated to the congruent word (e.g., *towel*; FI condition). For each set of four target words (e.g., *box*, *bottle*, *doughnut*, *towel* four sentence frames were created that had the FC item (e.g., *box*) as the most plausible continuation. We

Dutch	*English*
aː	aː
ɑ	ʌ
ɛ,ɘ	ɛ,æ
ɪ	ɪ
i	iː
ɔ	ɒ
oː	oː,əʊ
u,ɤ	uː
ə	ə
ɔu	aʊ

Table 2.1: Phoneme correspondences between Dutch and English, displayed using the International Phonetic Alphabet (IPA) (International Phonetic Association, 1999), used to define phonemic overlap.

created two stimulus lists in which the four target words of each set were randomly assigned to each of the four corresponding sentence frames. Each sentence frame occurred only once per stimulus list. Every participant thus heard four sentences that had *box* as the most plausible sentence-final word. One of the sentences actually ended with the word *box*, the other three with *bottle*, *doughnut*, and *towel*.

Seventy-six semantically congruent filler sentences were created and added to both lists to balance the number of sentences that were incongruent and congruent. One stimulus list thus consisted of 152 experimental sentences (38 sentences per condition) and 76 filler items for a total of 228 sentences. Half of the participants were presented with stimuli from the first list, and half were presented with stimuli from the second list.

To give us a clear marker of critical word onset for time-locking the EEG, all critical words were chosen from English nouns that had either a plosive onset or vowel onset with a glottal stop. The distribution of critical words with a voiced plosive, unvoiced plosive, and vowel onset was kept constant over conditions. Critical words were controlled across conditions with respect to the number of phonemes and word frequency (see Table 2.2). Word frequencies were taken from the CELEX English lemma database (Baayen, Piepenbrock & van Rijn, 1993). None of the critical words were cognates or homophones between English and Dutch. The experimental sentences, fillers, and practice items were spoken by a female English native speaker at a normal speaking rate and with normal intonation. The materials were digitally recorded in a sound attenuating booth and digitised at a

Condition	*Frequency (SD)*	*Phonemes (SD)*
FC	3.34 (0.95)	5.29 (2.30)
FI	3.06 (1.03)	5.17 (1.90)
ICL1	2.94 (1.19)	4.90 (1.55)
ICL2	2.89 (1.29)	5.60 (1.90)

Table 2.2: Mean log frequency per million and mean number of phonemes for the: FC, FI, ICL1 and ICL2 conditions. Standard deviations are given in parentheses.

rate of 44.1 kHz. Sound files were later equalised to eliminate any differences in sound level. A full list of experimental materials is available in Appendix A, Table A.1.

Procedure

Participants were exclusively addressed in English by an English native speaker, both preceding and during the experiment, in order to make certain they were in a monolingual L2 language mode (Grosjean, 1982). Participants were placed in a sound-attenuating booth and were instructed to listen attentively to the sentences, which were played over two loudspeakers at a distance of roughly 1.5 m, and to try to understand them. The sound level was kept constant over participants. To ensure that participants remained focused on the sentences, they were prompted to make an animacy decision regarding the previous sentence (i.e., “Was there anything living in the last sentence?”) at five randomly occurring time points during the experiment. On average, participants gave 4.0 out of five correct responses, suggesting that they listened to the sentences attentively.

Each trial began with a 300 ms warning tone, followed by 1200 ms of silence, then a spoken sentence. The next trial began 4100 ms after the sentence offset. To ensure that participants did not blink during and shortly after presentation of the sentence, 1000 ms prior to the beginning of the sentence a fixation point was displayed. Participants were instructed not to blink while the fixation point was on the screen. The fixation point remained until 1600 ms after the offset of the spoken sentence. Participants had a practice session with five sentences to familiarize themselves with the experimental setting. After the EEG recording the participants completed a word translation test on the critical items to verify that they were known and a cloze test on all the experimental sentences to check whether participants expected the sentence continuation that we had envisaged.

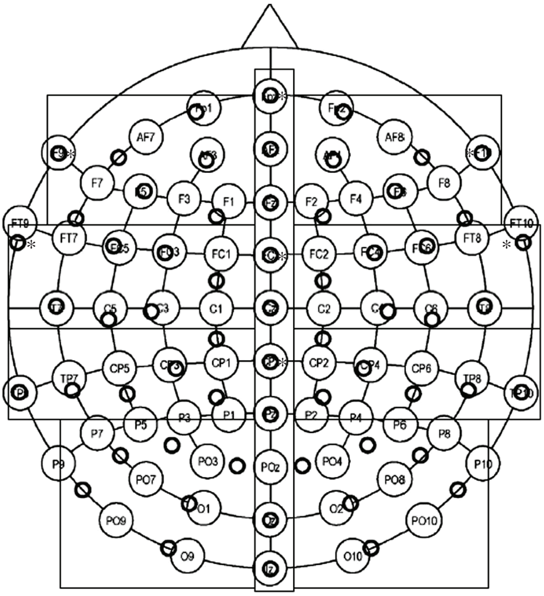


Figure 2.1: Radial projection of electrode positions of the equidistant placement system (small black circles) relative to the 10-20 system. Boxes denote regions for statistical analyses. Asterisks denote electrodes excluded from analysis.

EEG Recording

The EEG was recorded continuously from 64 sintered Ag/AgCl electrodes, each referred to an electrode on the nose of the participant. The electrodes were mounted in an equidistant elastic cap (`http://www.easycap.de`; see Figure 2.1 for the electrode distribution). The EEG and EOG recordings were amplified with a BrainAmp DC amplifier (Brain Products, München, Germany) using a high-cutoff of 200 Hz, a time constant of 10s (0.016 Hz), and a sampling rate of 500 Hz. Impedances were kept below 5 kΩ. Trials with eye blinks or deflections exceeding 70 μV were rejected.

ERP Analysis

Data from six participants were not analysed, leaving 24 participants in the final analysis. Four of the excluded participants were left out due to excessive alpha. Data from one participant were incomplete due to a technical malfunction. One other participant was excluded due to failure to complete the post-tests.

The data were analysed using the FieldTrip (`http://fieldtrip.fcdonders.nl`) toolbox for Matlab (`http://www.mathworks.com`). EEG data were time-locked to critical word onset. Average waveforms were calculated for each participant using a 150 ms pre-stimulus baseline. Grand average waveforms were calculated by averaging the individual average waveforms. Statistical analysis was performed by taking the mean amplitude per site (see Figure 2.1), in the N400 latency range (300-800 ms), from the grand averaged data. We used an omnibus analysis of variance (ANOVA) with condition (4 levels) and site (9 levels) as within subject factors. Seven electrodes were excluded from the analysis in order to have an equal number of electrodes in each site (see Figure 2.1). The latency range was chosen based on the previous literature and visual inspection of the grand average waveforms. All p values are reported after Greenhouse-Geisser correction (Greenhouse & Geisser, 1959). Contrasts between pairs of conditions were tested using a randomization approach that corrects for multiple comparisons (Maris, 2004; for a brief description see: Takashima, et al., 2006; Tuladhar, et al., 2007). Cluster randomization was performed on the following pairs of conditions: FI versus FC, ICL1 versus FC, ICL2 versus FC, ICL1 versus FI, and ICL2 versus FI; using the same latency range as the ANOVA (300-800 ms).

To determine the peak and onset latencies of the N400 in the three semantically incongruent conditions, we applied a low-pass filter at 5 Hz to the difference waveforms (FI-FC, ICL1-FC, and ICL2-FC) of the individual averages. We restricted our search to electrodes that show a significant N400 effect as determined by the cluster-randomisation analysis. The peak of the N400 component was defined as the minimum of the filtered individual difference waveforms, in the 300-800 ms latency range. Visual quantification of onset latencies was complicated due to variability of individual averages. We therefore computed the mean amplitude values of the difference waveforms in 30 ms bins that shifted in steps of 10 ms in the latency range between critical word onset and 600 ms after critical word onset (cf., Hagoort & Brown, 2000). The values of these latency bins were tested against the null hypothesis that they did not differ from zero using t-tests. We defined the onset latency of the N400 as the first bin at which 3 successive bins reached a significance threshold of $p<0.05$.

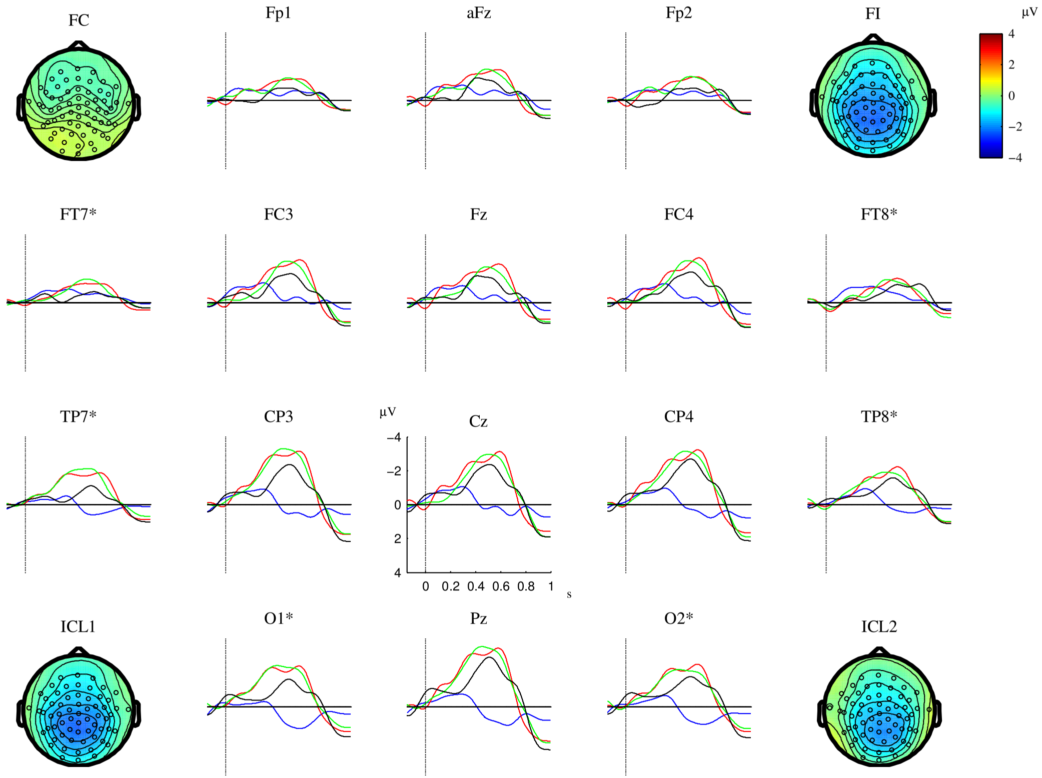


Figure 2.2: Grand average waveforms on 16 scalp electrodes and scalp topographies. (Blue lines, top left) Fully congruent; (red lines, top right) fully incongruent; (black lines, bottom right) initially congruent with the L2; and (green line, bottom left) initially congruent with the L1. All waveforms were filtered with a 5 Hz low-pass filter for display purposes. Asterisk denotes nonstandard electrode location. For unfiltered waveforms see Appendix A, Figure A.1

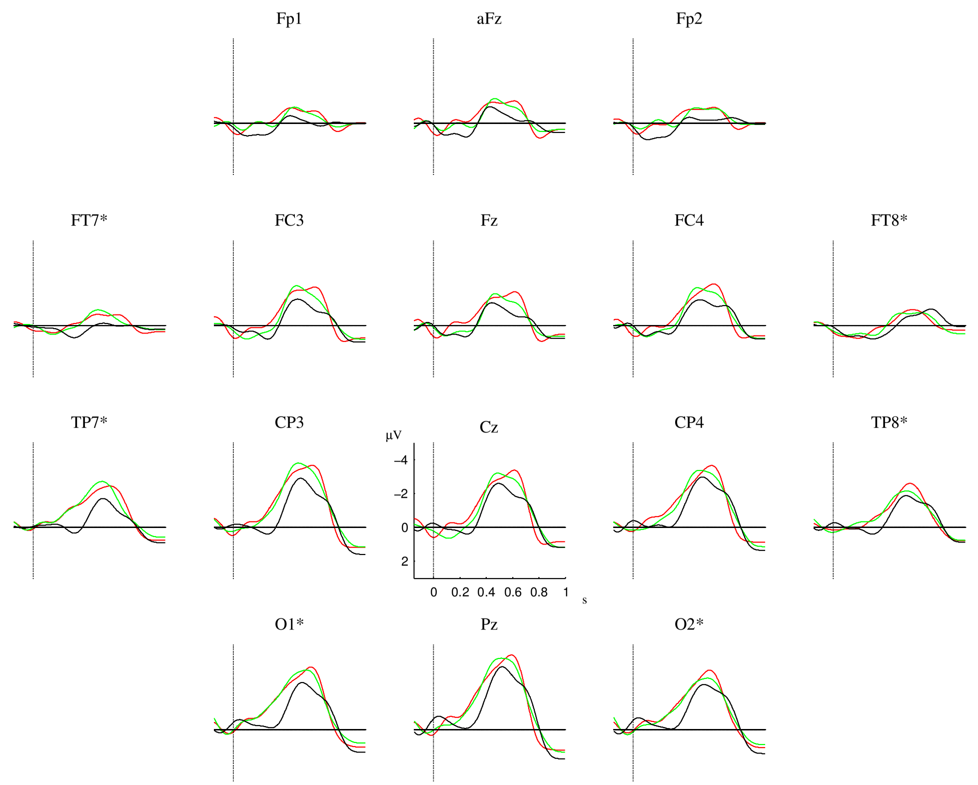


Figure 2.3: Difference waveforms on 16 scalp electrodes. (Red lines) Fully incongruent - fully congruent; (black lines) initially congruent with the L2 - fully congruent; and (green lines) initially congruent with the L1 - fully congruent. All waveforms were filtered with a 5-Hz low-pass filter for display purposes. Asterisk denotes nonstandard electrode location.

2.3 Results

Grand Averages

Figure 2.2 shows the grand average waveforms on 16 scalp electrodes and the topographical distribution of potentials in each condition. The waveforms for the three incongruent conditions (FI, ICL1, and ICL2) show an increased negativity in the 300-800 ms latency range relative to the fully congruent condition. This negativity is most pronounced on the centro-parietal electrodes. Figure 2.3 shows the difference waveforms of the incongruent conditions minus the fully congruent condition on 16 scalp electrodes.

Omnibus ANOVA

In the 300-800 ms latency range, the ANOVA yielded a significant main effect of condition ($F(3{,}69) = 6.128$, $p < 0.01$, $\varepsilon = 0.210$). A priori contrasts revealed significant differences between the FC condition and FI ($F(1{,}23) = 10.507$, $p<0.01$, $\varepsilon=0.314$), ICL2 ($F(1{,}23) = 6.448$, $p<0.05$, $\varepsilon=0.219$), and ICL1 ($F(1{,}23) = 18.368$, $p<0.001$, $\varepsilon=0.444$).

There was also a significant main effect of site ($F(8{,}184) = 9.099$, $p<0.001$, $\varepsilon=0.283$) with midline ($F(1{,}23)=46.762$, $p<0.001$, $\varepsilon= 0.670$), right pre-central ($F(1{,}23)=12.000$, $p<0.01$, $\varepsilon= 0.343$) , left post-central ($F(1{,}23)=4.738$, $p<0.05$, $\varepsilon= 0.171$) and right post-central ($F(1{,}23)=13.403$, $p<0.01$, $\varepsilon= 0.368$) sites showing the greatest negativity.

Finally, there was a significant interaction of condition with site ($F(24{,}552) = 5.596$, $p < 0.01$, $\varepsilon= 0.196$) reflecting the fact that the greatest negativity in the FI versus FC, ICL2 versus FC, and ICL1 versus FC comparisons was found over midline (FI vs. FC: $F(1{,}23) = 8.676$, $p<0.01$, $\varepsilon= 0.274$; ICL2 vs. FC: $F(1{,}23) = 10.753$, $p<0.01$, $\varepsilon= 0.319$; ICL1 vs. FC: $F(1{,}23) = 12.361$, $p<0.01$, $\varepsilon= 0.350$), right post-central (FI vs. FC: $F(1{,}23) = 9.972$, $p<0.01$, $\varepsilon= 0.302$; ICL2 vs. FC: $F(1{,}23) = 11.446$, $p<0.01$, $\varepsilon= 0.332$; ICL1 vs. FC: $F(1{,}23) = 7.457$, $p<0.05$, $\varepsilon= 0.245$), and right occipital sites (FI vs. FC: $F(1{,}23) = 8.047$, $p<0.01$, $\varepsilon= 0.259$; ICL2 vs. FC: $F(1{,}23) = 5.034$, $p<0.05$, $\varepsilon= 0.180$; ICL1 vs. FC: $F(1{,}23) = 4.425$, $p<0.05$, $\varepsilon= 0.161$). Additionally, the comparisons: FI versus FC, and ICL1 versus FC showed strong negativities over left post-central (FI versus FC: $F(1{,}23) = 17.670$, $p<0.001$, $\varepsilon= 0.434$; ICL1 versus FC: $F(1{,}23) = 42.691$, $p<0.001$, $\varepsilon= 0.650$) and left occipital (FI versus FC: $F(1{,}23) = 11.902$, $p<0.01$, $\varepsilon= 0.341$; ICL1 versus FC: $F(1{,}23) = 16.845$, $p<0.001$, $\varepsilon= 0.423$) sites.

Fully Incongruent

Relative to the FC condition, there was a significant negative cluster starting at 366 ms after critical word onset (p<0.001, cluster size = 6516 data points) and lasting until 704 ms. Figure 2.4a–c shows the grand average onset latency of the negativity for each electrode that showed a significant negative effect as determined by the cluster-randomisation analysis. Figure 2.4d–f shows the grand average peak latency of the negativity for each electrode that showed a significant negative effect as determined by the cluster-randomisation analysis.

Initially Congruent with the L2

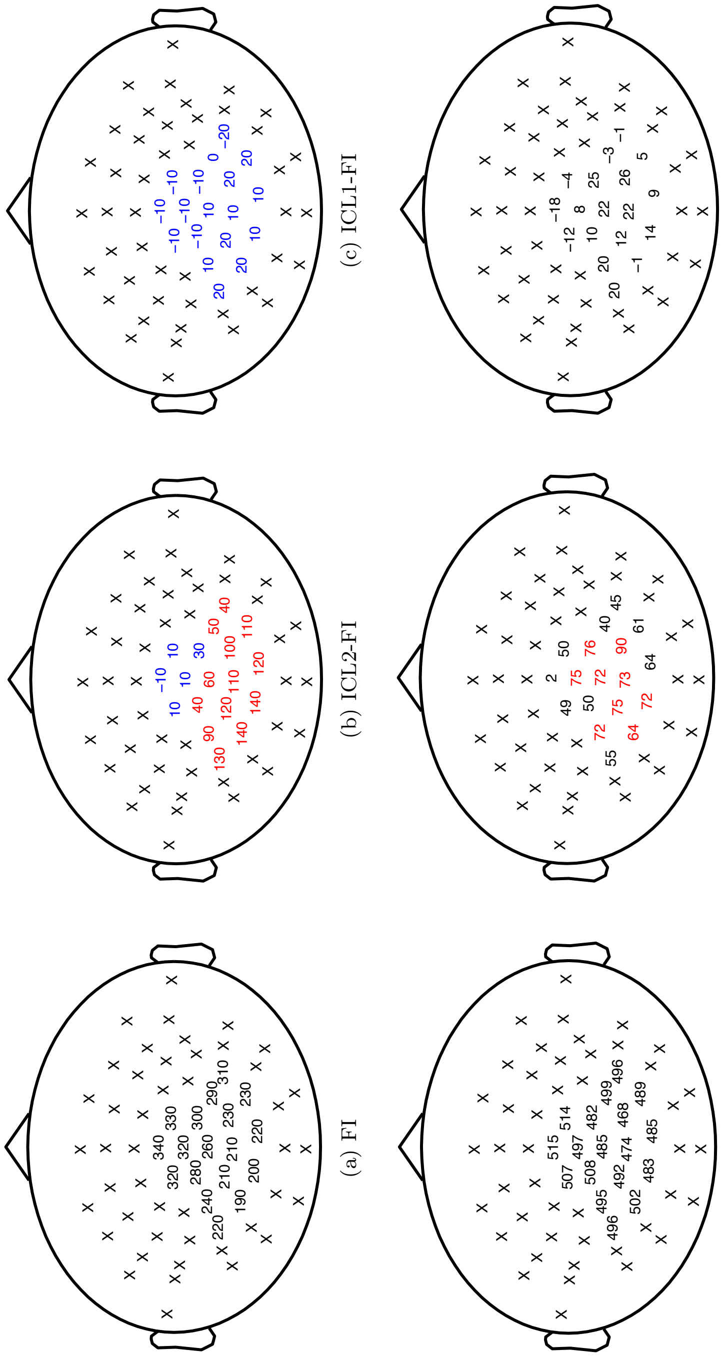
No significant clusters were found in the comparison of the ICL2 condition with the FI condition. Relative to the FC condition, there was a negative cluster starting at 422 ms (p<0.001, cluster size = 4136 data points) and lasting until 732 ms. The onset latency of the negativity, in the 300-800 ms time window, was substantially delayed compared to the corresponding negativity in the FI condition (see Figures 2.4a–c & 2.4h–i). To test whether the peak latency delay similarly delayed, we performed paired-samples t-tests on the peak latencies of negativity in the ICL2 condition versus the FI condition (one tailed for: ICL2 >FI) for each electrode that showed a significant negative effect as determined by the cluster-randomisation analysis. After Bonferroni correction 9 out of 18 electrodes showed a significant delay (p-corrected<0.05) (Figure 2.4d–f).

Initially Congruent with the L1

No significant clusters were found in the comparison of the ICL1 condition with the FI condition. Relative to the FC condition, there was a significant negative cluster starting at 368 ms (p<0.001, cluster size = 6900 data points) and lasting until 710 ms. Neither the onset (Figures 2.4a–c & 2.4h–i) nor the peak latency (Figures 2.4d–f & 2.4h–i) of the negativity in the 300-800 ms time window differed from the corresponding negativity in the FI condition.

2.4 Discussion

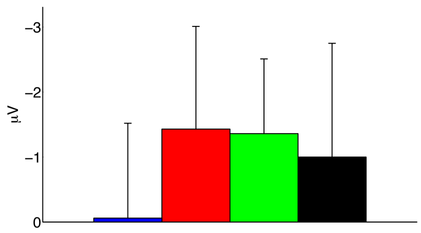
The present study investigated whether concurrently active intra- and interlingual lexical candidates are considered for semantic integration in non-native speech comprehension. Highly proficient, late onset Dutch-English bilinguals listened to sentences in English that ended in a word that was: semantically congruent (FC



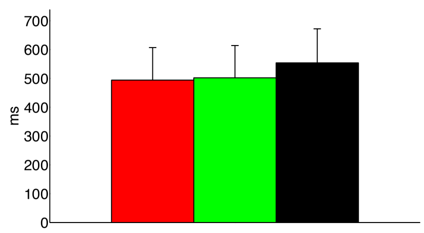
(a) FI (b) ICL2-FI (c) ICL1-FI

(d) FI (e) ICL2-FI (f) ICL1-FI

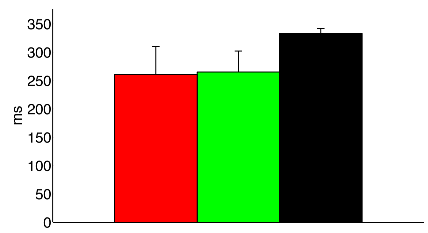
Figure 2.4: Continued on next page



(g) Amplitude



(h) Peak latency



(i) Onset latency

Figure 2.4: Topographical representation of the (a-c) onset and (d-f) peak latencies (in milliseconds from critical word onset) on N400 electrodes for the fully incongruent (FI) condition (a, d) and latency differences between the initially congruent with the L2 condition (ICL2; b,e) and the initially congruent with the L1 condition (ICL1; c,f) compared with the FI condition. Red color denotes latency difference greater than one bin size (30 msec; a-c) or significant latency difference (d-f; p-corrected$<.05$). Blue color denotes latency difference smaller than one bin size (a-c only). "X" denotes electrode that was excluded from the latency analysis. Bar charts (g-i) of the average N400 amplitude (left), N400 peak latency (middle), and N400 onset latency (right) in the FC (blue bar; amplitude plot only), FI (red bars), ICL1 (green bars), and ICL2 (black bars) conditions.

condition), semantically incongruent (FI condition), semantically incongruent but initially overlapping with the most probable sentence completion (ICL2 condition), or semantically incongruent but initially overlapping with the L1 translation equivalent of the most probable sentence completion (ICL1 condition). We explicitly chose an all L2 experimental setting to avoid unintentionally inducing the effects of interest. Our findings provide evidence that, under these circumstances, intralingual but not interlingual lexical candidates are considered for semantic integration in non-native speech comprehension. Possible effects of bilingual language proficiency, linguistic-, and non-linguistic context will be discussed below.

Semantic Integration in Non-native Listening

As expected, we observed a significant negativity between 300 and 800 ms following critical word onset, in each of the semantically incongruent conditions compared to the fully congruent condition, consistent with an N400 effect (Kutas & Hillyard, 1980). The scalp topography of the N400 effect is comparable to earlier findings from monolingual studies of speech processing (e.g., Van den Brink, Brown & Hagoort, 2001), however the latency of the N400 may be slightly longer in our study. As far as we know, the only studies to report peak latency measures of the N400 for speech processing in monolingual English speakers, with the sentence final word as the critical word, are Connolly and Phillips (1994; 1992). Whereas the N400 in their phoneme mismatch-semantic mismatch condition peaked around 420 ms, we found the average peak latency of the N400 in the Fully Incongruent condition to be approximately 490 ms. Although our study did not include a monolingual control condition, which would allow for a direct comparison of N400 latencies in native and non-native listening, we note that this apparent delay is consistent with earlier findings of delayed N400s in non-native written (Ardal, et al., 1990; Weber-Fox & Neville, 1996) and spoken language comprehension (Hahne, 2001).

Intralingual Competition

We hypothesised that if intralingual lexical candidates are considered for semantic integration in L2 listening, the peak and/or onset latency of the N400 effect would be later for initially congruent words than for fully incongruent words. This would reflect the fact that during the initial phonemes the congruent item is still in the cohort thus semantic integration at this stage would treat the cohort as congruent with the sentence. Indeed, initial phonemic overlap with the most probable sentence continuation delayed both the peak latency and onset latency of the N400 by nearly 70 ms compared to the semantically fully incongruent condition (Figure 2.4). Similar results were obtained in native speech comprehension studies by Van den Brink et al. (2001) and Van Petten et al. (1999) using almost the same paradigm. Van den Brink et al. (2001) argue that this effect is driven by an N200 component that is present for fully incongruent words but absent for initially congruent words. In the present study, however, we found no evidence to suggest that this early negative effect is functionally and/or physiologically distinct from the N400 effect (see also: Diaz & Swaab, 2007). A N400 peak latency delay to initially congruent words compared to fully incongruent words has also been reported earlier by Connolly and Phillips (1994) for native language listening. Visual inspection of their waveforms suggests that the onset of the N400 may also have been delayed for initially congruent words, though this is not reported by the authors.

Our results thus replicate peak- and onset latency delays of the N400 to initially congruent words relative to fully incongruent words for non-native listening. This finding suggests that non-native listeners process speech in the same cascaded manner as do native listeners. They treat the initial phonemes of these words as congruent with the sentence context and only later detect the semantic incongruity. As the semantic assessment of word initial phonemes is contingent upon starting semantic integration it follows that semantic integration must have started before lexical selection has occurred (for a similar view see: Van den Brink, Brown & Hagoort, 2006). That is, listeners start semantic integration while multiple lexical candidates are consistent with the input. This finding therefore not only shows multiple lexical activation, but also cascaded lexical selection and semantic integration in L2 speech comprehension. We have thus established that intralingual competitors are available for semantic integration in non-native speech comprehension leaving open the question whether the same holds for interlingual competitors.

Interlingual Competition

We did not find a delay in either the peak or the onset latencies of the N400 in the initially congruent with the L1 condition relative to the fully incongruent condition (Figure 2.4). Thus it seems that non-native listeners do not treat initial overlap with the translation of the most likely sentence continuation as though it were initially congruent with the sentence context. This finding could mean one of two things: (1) either no L1 lexical candidates were elicited, or (2) elicited L1 lexical candidates are not available for semantic integration. We will explore both of these accounts below.

A potential absence of L1 lexical activation could be explained in a relatively trivial manner, that is, that the degree of interlingual phonemic overlap was simply insufficient to elicit cross-linguistic lexical candidates. Although such an explanation cannot be completely discounted on the basis of these data, we note that previous studies that found cross-linguistic activation did so despite using stimulus materials with non-identical phonemic correspondences between languages. Indeed the present study used stimulus materials with similar phonemic correspondences to Weber and Cutler (2004). Thus it is improbable that mere phonemic mismatch could completely account for our findings. However, activation of cross-linguistic competitors may have been influenced by effects of both linguistic and non-linguistic context.

To date, studies that demonstrated cross-linguistic lexical activation in auditory word recognition have presented critical items in isolation (Schulpen, Dijkstra, Schriefers & Hasper, 2003) or in imperatives such as: "Pick up the *stamp*" (Spivey & Marian 1999; Weber and Cutler 2004) that did not vary over the course of the experiment. In our study, critical words were presented in the final position of semantically rich sentence contexts. The presence of such a sentence context may have influenced the degree of cross-linguistic activation.

Modulatory effects of sentence context on word recognition are not unique to bilingual language comprehension. In a monolingual study, Zwitserlood (1989) showed that concurrently activated lexical candidates (e.g., *kapitein* 'captain', *kapitaal* 'capital') remain in competition for longer when embedded in low-constraint sentences than when embedded in highly constraining sentences. Furthermore, numerous studies have shown that sentence context can modulate the relative availability of the dominant and subordinate meanings of intralingual homophones (e.g., Tabossi, 1988) or increase the salience of particular semantic features (e.g., Moss & Marslen-Wilson, 1993). The most thorough investigation of the role of sentence context on the degree of cross-linguistic activation in L2 reading to date comes from Duyck, Van Assche, Drieghe and Hartsuiker (2007). They exploited the well known facilitatory effect of between language cognates and near cognates on bilingual word recognition. In isolation and for sentences presented word by word, the authors observed cross-linguistic activation for both cognates and near-cognates, however the near-cognate effect disappeared when the full sentence was presented, while the cognate effect remained. The authors thus concluded that the presence of a sentence context "may influence, but does not nullify" cross-linguistic lexical activation. Our study employed critical items that had considerably less cross-linguistic overlap than the cognates in Duyck et al. (2007). It is therefore not implausible that cross-linguistic lexical candidates are only available given enough bottom up support (i.e., enough phonological overlap).

That non-linguistic context can also influence cross-linguistic activation is nicely demonstrated by Elston-Guettler, Gunter, et al. (2005). They found cross-linguistic homograph priming in L2 sentence comprehension but only in participants that had previously been exposed to an L1 narrated silent film and only in the first experimental block. This led them to posit that bilinguals restrict their lexical search by gradually "zooming in" to the language at hand. This may indicate that cross-linguistic activation may only occur in situations where the salience of the non-target language is in some way enhanced. In our study we took care not to cue our participants to the fact that their L1 was under investigation by addressing them in their L2 for the duration of the experiment, thereby arguably decreasing the chances of finding cross-linguistic activation. It should be noted, however, that the studies by Weber and Cutler (2004) and Marian and Spivey (2003a, 2003b; Marian, Spivey & Hirsch, 2003) employed similar measures, but still found cross-linguistic activation.

Effects of both the linguistic and non-linguistic context can be accounted for by the BIA+ (Dijkstra & Van Heuven, 2002) model of bilingual language comprehension. This model was primarily intended to be applied within the domain of visual word recognition, however many of the tenets of BIA+ may still hold for speech comprehension. The model assumes that the bilingual language comprehension system is fundamentally non-selective in nature, allowing for cross-linguistic activation of lexical candidates. Such cross-linguistic activation is thought to be unencumbered by top-down influences of linguistic or non-linguistic context. These factors come in to play at a task schema level and thus may influence post lexical selection and/or semantic integration processes.

Our choice of participants may also have influenced the likelihood of finding interlingual competition. All our participants were highly proficient speakers of English, who learned English at high-school and continued using it at University level. The Revised Hierarchical Model of the bilingual lexicon (Kroll & Stewart, 1994) assumes that lexical access is less reliant on the L1 in highly proficient- than in less proficient bilinguals. Indeed, Elston-Guettler, Paulmann, and Kotz (2005; Elston-Guettler & Gunter, 2008) show that highly proficient bilinguals are more able to "zoom in" to the target language compared to less proficient bilinguals. We cannot fully exclude that we would have found interlingual competition with a less proficient group of participants. However, we note that our participants were drawn from the same population as was used in the studies by Weber and Cutler (2004) and Schulpen et al. (2003), both of which show cross-linguistic lexical activation.

By choosing Dutch and English as the language pair under investigation we may also have affected our chances of finding non-target language competition, due to the fact that these two languages are closely related and share a high proportion of cognates and near cognates. Note, however that this property of the two languages might rather lead one to expect increased competition because language membership might be relatively more difficult to asses for Dutch-English bilinguals than for speakers of two unrelated languages.

This consideration becomes relevant because an alternative interpretation of our findings could be that cross-linguistic lexical candidates are active, but are simply not considered for semantic integration. Because our study focuses on the N400 effect, our data preclude semantic integration of non-target language items based on initial phonemic overlap alone, however these data do not exclude competition by activated L1 lexical candidates. Various studies have shown bilinguals to be sensitive to fine-grained phonetic information in the speech signal which enables them to accurately judge the language membership of incoming words based on very little input (Grosjean, 1988; Ju & Luce, 2004; Li, 1996; Pallier, Colomé & Sebastián-Gallés, 2001). The early availability of language membership information may be sufficient to exclude spuriously activated cross-linguistic lexical candidates from further semantic processing. In order to reconcile such an interpretation with previous findings, one would have to argue that cross-linguistically elicited lexical candidates can nonetheless be active to such a degree that they can cause orthographic priming effects (e.g., Schulpen, et al., 2003) and influence the visual search for a referent in eye-tracking paradigms (e.g., Spivey & Marian, 1999; Weber & Cutler, 2004). Further studies will need to be conducted in order to disentangle the effects of sentence context, non-linguistic context, language proficiency, and the degree of interlingual phonological overlap on cross-linguistic lexical activation.

2.5 Conclusions

Our findings may represent mixed blessings for the proficient non-native listener. On the one hand we show that non-native listeners are capable of semantically integrating words in speech before a unique lexical candidate is identified. This is encouraging as subjectively reported lowered confidence in non-native word identification does not cause the L2 listener to adopt a more cautious approach to word recognition, such as delaying semantic integration until words can be positively identified by the input. Our findings further suggest that, in an all L2 context, non-target language candidates are not considered for semantic integration based on initial phonemic overlap alone. Although this is good news for immersed non-native listeners, it is at least conceivable that it might lead to a delay in recognizing non-target language words that actually do appear, such as code-switches. This implication constitutes an intriguing question for future studies.

2.6 References

Allan, D. (1992). *Oxford placement test.* Oxford: Oxford University Press.

Baayen, R. H., Piepenbrock, R., & van Rijn, H. (1993). *The CELEX lexical database.* Philadelphia, PA: University of Pennsylvania, Linguistic Data Consortium.

Broersma, M. E. (2002). Comprehension of non-native speech: Inaccurate phoneme processing and activation of lexical competitors. *Proceedings of the 7th International Conference on Spoken Language Processing*, 261-264.

Broersma, M. E. (2005). *Phonetic and lexical processing in a second language.* Unpublished Doctoral Dissertation, Radboud University Nijmegen, Nijmegen.

Brown, C. M., & Hagoort, P. (1993). The processing nature of the N400 - Evidence from masked priming. *Journal of Cognitive Neuroscience*, *5*(1), 34-44.

Connolly, J. F., & Phillips, N. A. (1994). Event-related potential components reflect phonological and semantic processing of the terminal word of spoken sentences. *Journal of Cognitive Neuroscience*, *6*(3), 256-266.

Connolly, J. F., Phillips, N. A., Stewart, S. H., & Brake, W. G. (1992). Event-related potential sensitivity to acoustic and semantic properties of terminal words in sentences. *Brain and Language*, *43*(1), 1-18.

Connolly, J. F., Stewart, S. H., & Phillips, N. A. (1990). The effects of processing requirements on neurophysiological responses to spoken sentences. *Brain and Language*, *39*(2), 302-318.

Cutler, A. (2005). The lexical statistics of word recognition problems caused by L2 phonetic confusion. *Proceedings of the 9th European Conference on Speech Communication and Technology*, 413-416.

Diaz, M. T., & Swaab, T. Y. (2007). Electrophysiological differentiation of phonological and semantic integration in word and sentence contexts. *Brain Research*, *1146*, 85-100.

Dijkstra, T., & Van Heuven, W. J. B. (1998). The BIA model and bilingual word recognition. In J. Grainger & A. Jacobs (Eds.), *Localist connectionist* *approaches to human cognition* (pp. 189-225). Mahwah, NJ: Erlbaum.

Dijkstra, T., & Van Heuven, W. J. B. (2002). The architecture of the bilingual word recognition system: From identification to decision. *Bilingualism: Language and Cognition*, *5*(3), 175-197.

Duyck, W., Van Assche, E., Drieghe, D., & Hartsuiker, R. J. (2007). Visual word recognition by bilinguals in a sentence context: Evidence for nonselective lexical access. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *33*(4), 663-679.

Elston-Guettler, K. E., Gunter, T. C., & Kotz, S. A. (2005). Zooming into L2: global language context and adjustment affect processing of interlingual homographs in sentences. *Brain Research: Cognitive Brain Research*, *25*(1), 57-70.

Elson-Guettler, K. E., Paulmann, S., & Kotz, S. A. (2005). Who's in Control? Proficiency and L1 Influence on L2 processing. *Journal of Cognitive Neuroscience*, *17*(10), 1593-1610.

Elston-Guettler, K. E., & Gunter, T.C. (2008). Fine-tuned: phonology and semantics affect first- to second-language zooming in. *Journal of Cognitive Neuroscience*, *21*(1), 180-196.

Goldinger, S. D., Luce, P. A., & Pisoni, D. B. (1989). Priming lexical neighbors of spoken words: Effects of competition and inhibition. *Journal of Memory and Language*, *28*(5), 501-518.

Grainger, J., & Dijkstra, T. (1992). On the representation and use of language information in bilinguals. In R. J. Harris (Ed.), *Cognitive Processing in Bilinguals* (pp. 207-220). Amsterdam: Elsevier Science Publishers.

Greenhouse, S. W., & Geisser, S. (1959). On methods in the analysis of profile data. *Psychometrika*, *24*(2), 95-112.

Grosjean, F. (1980). Spoken word recognition processes and the gating paradigm. *Perception & Psychophysics*, *28*(4), 267-283.

Grosjean, F. (1982). *Life with two languages: An introduction to bilingualism.* Cambridge, MA: Harvard University Press.

Grosjean, F. (1988). Exploring the recognition of guest words in bilingual speech. *Language and Cognitive Processes*, *3*(3), 233-274.

Grosjean, F. (1989). Neurolinguists, beware! The bilingual is not two monolinguals in one person. *Brain and Language*, *36*(1), 3-15.

Hagoort, P., & Brown, C. M. (2000). ERP effects of listening to speech: semantic ERP effects. *Neuropsychologia*, *38*(11), 1518-1530.

Hahne, A. (2001). What's different in second-language processing? Evidence from event-related brain potentials. *Journal of Psycholinguistic Research*, *30*(3), 251-266.

Hahne, A., & Friederici, A. D. (2001). Processing a second language: late learners' comprehension mechanisms as revealed by event-related brain potentials. *Bilingualism: Language and Cognition*, *4*(2), 123-141.

Holcomb, P. J., & Neville, H. J. (1991). Natural speech processing - An analysis using event-related brain potentials. *Psychobiology*, *19*(4), 286-300.

Ju, M., & Luce, P. A. (2004). Falling on sensitive ears: constraints on bilingual lexical activation. *Psychological Science*, *15*(5), 314-318.

Kroll, J. F., & Stewart, E. (1994). Category interference in translation and picture naming: Evidence for asymmetric connections between bilingual memory representations. *Journal of Memory and Language*, *33*(2), 149-174.

Kutas, M., & Hillyard, S. A. (1980). Reading senseless sentences - Brain potentials reflect semantic incongruity. *Science*, *207*(4427), 203-205.

Kutas, M., & Hillyard, S. A. (1984). Brain potentials during reading reflect word expectancy and semantic association. *Nature*, *307*(5947), 161-163.

Lemhöfer, K., Dijkstra, T., & Michel, M. C. (2004). Three languages, one ECHO: Cognate efects in trilingual word recognition. *Language and Cognitive Processes*, *19*(5), 585-611.

Li, P. (1996). Word recognition of code-switched words by Chinese-English bilinguals. *Journal of Memory and Language*, *35*(6), 757-774.

Marian, V., & Spivey, M. J. (2003a). Bilingual and monolingual processing of competing lexical items. *Applied Psycholinguistics*, *24*(2), 173-193.

Marian, V., & Spivey, M. J. (2003b). Competing activation in bilingual language processing: Within- and between-language competition. *Bilingualism: Language and Cognition*, *6*(2), 97-115.

Marian, V., Spivey, M. J., & Hirsch, J. (2003). Shared and separate systems in bilingual language processing: Converging evidence from eyetracking and brain imaging. *Brain and Language*, *86*(1), 70-82.

Maris, E. (2004). Randomization tests for ERP topographies and whole spatiotemporal data matrices. *Psychophysiology*, *41*(1), 142-151.

Marslen-Wilson, W. D., & Tyler, L. K. (1980). Temporal structure of spoken language understanding. *Cognition*, *8*(1), 1-71.

McCallum, W. C., Farmer, S. F., & Pocock, P. V. (1984). The effects of physical and semantic incongruities on auditory event-related potentials. *Electroencephalography and Clinical Neurophysiology Supplement*, *59*(6), 477-488.

McClelland, J. L., & Elman, J. L. (1986). The TRACE model of speech perception. *Cognitive Psychology*, *18*(1), 1-86.

McQueen, J. M., Norris, D., & Cutler, A. (1994). Competition in spoken word recognition: Spotting words in other words. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *20*(3), 621-638.

Meara, P. M. (1996). *English vocabulary tests: 10k*. Swansea, UK: Centre for Applied Language Studies.

Moreno, E. M., Rodriguez-Fornells, A., & Laine, M. (2008). Event-related potentials (ERPs) in the study of bilingual language processing. *Journal of Neurolinguistics*, *21*(6), 477-508.

Moss, H. E., & Marslen-Wilson, W. D. (1993). Access to word meanings during spoken language comprenhension: effects of sentential semantic context. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *19*(6), 1254-1276

Newman, R. L., Connolly, J. F., Service, E., & McIvor, K. (2003). Influence of phonological expectations during a phoneme deletion task: Evidence from event-related brain potentials. *Psychophysiology*, *40*(4), 640-647.

Norris, D. (1994). Shortlist - A connectionist model of continuous speech recognition. *Cognition*, *52*(3), 189-234.

Norris, D., McQueen, J. M., & Cutler, A. (1995). Competition and segmentation in spoken-word recognition. *Journal of Experimental Psychology: Human Perception and Performance*, *21*(5), 1209-1228.

O'Rourke, T. B., & Holcomb, P. J. (2002). Electrophysiological evidence for the efficiency of spoken word processing. *Biological Psychology*, *60*(2-3), 121-150.

Pallier, C., Colomé, A., & Sebastián-Gallés, N. (2001). The influence of native-language phonology on lexical access: Exemplar-based versus abstract lexical entries. *Psychological Science*, *12*(6), 445-449.

Praamstra, P., Meyer, A. S., & Levelt, W. J. M. (1994). Neurophysiological manifestations of phonological processing - Latency variation of a negative ERP component timelocked to phonological mismatch. *Journal of Cognitive Neuroscience*, *6*(3), 204-219.

Rueschemeyer, S. A., Nojack, A., & Limbach, M. (2008). A mouse with a roof? effects of phonological neighbors on processing of words in sentences in a non-native language. *Brain and Language*, *104*(2), 132-144.

Scarborough, D. L., Gerard, L., & Cortese, C. (1984). Independence of lexical access in bilingual word recognition. *Journal of Verbal Learning and Verbal Behavior*, *23*(1), 84-99.

Schouten, M. E. H. (1975). *Native-language interference in the perception of second-language vowels: An investigation of certain aspects of the acquisition of a second language.* Unpublished Doctoral Dissertation, Utrecht University, Netherlands, Utrecht.

Schulpen, B., Dijkstra, T., Schriefers, H. J., & Hasper, M. (2003). Recognition of interlingual homophones in bilingual auditory word recognition. *Journal of Experimental Psychology: Human Perception and Performance*, *29*(6), 1155-1178.

Sebastián-Gallés, N., Echeverria, S., & Bosch, L. (2005). The influence of initial exposure on lexical representation: Comparing early and simultaneous bilinguals. *Journal of Memory and Language*, *52*(2), 240-255.

Soares, C., & Grosjean, F. (1984). Bilinguals in a monolingual and a bilingual speech mode -The effect on lexical access. *Memory and Cognition*, *12*(4), 380-386.

Soto-Faraco, S., Sebastián-Gallés, N., & Cutler, A. (2001). Segmental and suprasegmental mismatch in lexical access. *Journal of Memory and Language*, *45*(3), 412-432.

Spivey, M. J., & Marian, V. (1999). Cross talk between native and second languages: Partial activation of an irrelevant lexicon. *Psychological Science*, *10*(3), 281-284.

Tabossi, P. (1988). Accessing lexical ambiguity in different types of sentential contexts. *Journal of Memory and Language*, *27*(3), 324-340.

Takashima, A., Jensen, O., Oostenveld, R., Maris, E., van de Coevering, M., & Fernández, G. (2006). Successful declarative memory formation is associated with ongoing activity during encoding in a distributed neocortical network related to working memory: A magnetoencephalography study. *Neuroscience*, *139*(1), 291-297.

Tuladhar, A. M., Ter Huurne, N., Schoffelen, J. M., Maris, E., Oostenveld, R., & Jensen, O. (2007). Parieto-occipital sources account for the increase in alpha activity with working memory load. *Human Brain Mapping*, *28*(8), 785-792.

Van den Brink, D., Brown, C. M., & Hagoort, P. (2001). Electrophysiological evidence for early contextual influences during spoken-word recognition: N200 versus N400 effects. *Journal of Cognitive Neuroscience*, *13*(7), 967-985.

Van den Brink, D., Brown, C. M., & Hagoort, P. (2006). The cascaded nature of lexical selection and integration in auditory sentence processing. *Journal of Experimental Psychology: Human Perception and Performance*, *32*(2), 364-372.

Van den Brink, D., & Hagoort, P. (2004). The influence of semantic and syntactic context constraints on lexical selection and integration in spoken-word comprehension as revealed by ERPs. *Journal of Cognitive Neuroscience*, *16*(6), 1068-1084.

Van Heuven, W. J. B., Dijkstra, T., & Grainger, J. (1998). Orthographic neighborhood effects in bilingual word recognition. *Journal of Memory and Language*, *39*(3), 458-483.

Van Petten, C., Coulson, S., Rubin, S., Plante, E., & Parks, M. (1999). Time course of word identification and semantic integration in spoken language. *Journal of Experimental Psychology: Human Perception and Performance*, *25*(2), 394-417.

Verhoeven, L., & Vermeer, A. (1985). Ethnic group differences in children's oral proficiency of Dutch. In G. Estra & T. Vallen (Eds.), *Ethnic Minorities and Dutch as a Second Language* (pp. 105-132). Dordrecht, The Netherlands: Foris Publications.

Vermeer, A. (1992). Exploring the second language learner lexicon. In L. Verhoeven & J. H. A. L. de Jong (Eds.), *The Construct of Language Proficiency: Applications of Psychological Models to Language Assessment* (pp. 147-162). Amsterdam: John Benjamins.

Vroomen, J., & De Gelder, B. (1995). Metrical segmentation and lexical inhibition in spoken word recognition. *Journal of Experimental Psychology: Human Perception and Performance*, *21*(1), 98-108.

Weber, A., & Cutler, A. (2004). Lexical competition in non-native spoken-word recognition. *Journal of Memory and Language*, *50*(1), 1-25.

Weber-Fox, C. M., & Neville, H. J. (1996). Maturational constraints on functional specializations for language processing: ERP and behavioral evidence in bilingual speakers. *Journal of Cognitive Neuroscience*, *8*(3), 231-256.

Zwitserlood, P. (1989). The locus of the effects of sentential-semantic context in spoken-word processing. *Cognition*, *32*(1), 25-64.

Context and Proficiency Effects on Cross-Linguistic Lexical Activation

CHAPTER 3

Ian FitzPatrick, Anne Cutler, and Peter Indefrey

Abstract

In two eye-tracking experiments we investigated cross-linguistic lexical access in bilingual speech comprehension. We measured eye-movements from Dutch-English bilinguals while they listened to English (L2) sentences. When tasked to click on a visual representation of a target object (e.g., *desk*) embedded in an invariant sentence context (e.g., "Click on the *desk*"), participants more often fixated on between-language competitors (e.g., *lid* 'deksel') than on unrelated distractors (e.g., *flower* 'bloem'). This competitor effect was more pronounced for low proficient compared to highly proficient bilinguals. However, when target words were embedded in variable, meaningful sentences (e.g., "My grandma has an ugly *desk*"), we found no significant competitor effect. These findings show that cross-linguistic lexical activation is subject to modulatory influences from sentence context and language proficiency.

Submitted for publication

3.1 Introduction

As widely attested, listening to speech in a language other than one's native language is far from easy. It is obvious that the difficulties in non-native speech comprehension are largely attributable to a lack of proficiency in the language in question. However, converging evidence suggests that between-language interactions (notably intrusions from the non-target language) may also play a major role in complicating non-native speech comprehension (e.g., Spivey & Marian, 1999; Broersma & Cutler, in press). A central feature of the speech comprehension process is the fact that multiple lexical candidates compete with each other for recognition (e.g., McClelland & Elman, 1986; Norris, 1994; Norris, McQueen & Cutler, 1995). The more concurrently activated lexical candidates, the more difficult the word recognition process (Norris, McQueen & Cutler, 1995). Herein lies the challenge for the bilingual listener as it has repeatedly been shown (Marian & Spivey, 2003a; 2003b; Marian, Spivey & Hirsch, 2003; Spivey & Marian, 1999; Weber & Cutler, 2004) that bilinguals may not only experience intralingual (i.e., within-language) lexical competition, but also interlingual (i.e., between-language) lexical competition during speech comprehension. Using the visual world eye-tracking paradigm (e.g., Cooper, 1974; Tanenhaus, Spivey-Knowlton, Eberhard & Sedivy, 1995), Spivey and Marian (1999; Marian & Spivey, 2003a; 2003b; Marian, et al., 2003) showed that Russian-English bilinguals, tasked to pick up a particular object (e.g., a *stamp* 'marku') among three distracting objects, fixated more often on objects whose English (non-target language) name shared phonology with the target item (e.g., a *marker* 'flomaster') than a phonologically unrelated item (e.g., a *ruler* 'lineika'), thus showing cross-linguistic lexical activation of English lexical items within a Russian task. It is not difficult to imagine that the added lexical competition attributable to cross-linguistic lexical activation adds to the difficulty of non-native speech comprehension with the bilingual having to recognise words from among a greater pool of concurrently activated competitors.

One way a bilingual may resolve between language competition is by using cues from the sentence context. Having contextual information that is consistent with one language (target language) but not the other (non-target) could conceivably attenuate cross-linguistic lexical activation and thereby expedite the bilingual's lexical search. Indeed, while studies using single word stimuli or sparse sentence contexts consistently show cross-linguistic lexical activation (Marian & Spivey, 2003a; 2003b; Marian, et al., 2003; Spivey & Marian, 1999; Weber & Cutler, 2004), one study employing semantically rich contexts did not (FitzPatrick &

Indefrey, 2010; Chapter 2 of this thesis). The study exploited the sensitivity of the N400 (Kutas & Hillyard, 1980), an extensively researched ERP component, to the moment at which a semantic incongruity becomes apparent to the listener. FitzPatrick and Indefrey recorded ERPs from Dutch-English bilinguals listening to English (i.e., second language) sentences. They compared the latency of the N400 effect between semantically fitting target words (e.g., "The goods from Ikea came in a large, cardboard *box*") and semantically incongruent target words that were temporarily congruent due to sharing initial phonemes with: (a) the most probable sentence completion within the L2 (*box*), or (b) the L1 translation equivalent of the most probable sentence completion (*doos* 'box'). The authors reasoned that, should the target word be initially perceived as congruent, the N400 would be delayed in comparison to non-overlapping semantically incongruent target words. Whereas intralingual phonemic overlap led to a significantly delayed N400, interlingual phonemic overlap did not, suggesting that within-, but not between-language lexical competitors are available for semantic integration.

Monolingual studies of speech recognition have long acknowledged the influence of sentence context on the word recognition process (e.g., Moss & Marslen-Wilson, 1993; Tabossi, 1988). Thus it stands to reason that a semantically rich sentence context could exert a similar influence on the bilingual word recognition process. In fact, evidence for a modulatory influence of sentence context on cross-linguistic lexical activation in bilingual visual word recognition has been mounting (e.g., Duyck, Van Assche, Drieghe & Hartsuiker, 2007; Schwartz & Arêas Da Luz Fontes, 2008). Duyck et al. (2007) presented bilinguals with between- language cognates, near-cognates, and non-cognate control words in isolation and in sentences presented word-by-word. Recognition of both cognates and near-cognates was facilitated compared to control words; however the near-cognate effect disappeared when the full sentence was presented while the cognate effect remained. These findings strongly suggest that sentence context could modulate cross-linguistic lexical access in bilingual speech comprehension. This could then (at least partially) account for the discrepancy between findings from FitzPatrick and Indefrey (2010; Chapter 2) and Weber and Cutler (2004), who had earlier demonstrated cross-linguistic activation using the same participant population (i.e., proficient Dutch-English bilinguals) and stimuli with a similar amount of between-language phonological overlap.

This study aims to directly investigate the influence of context on cross-linguistic lexical activation in non-native spoken word recognition, by determining to what extent the presence of a sentence context can modulate cross-linguistic

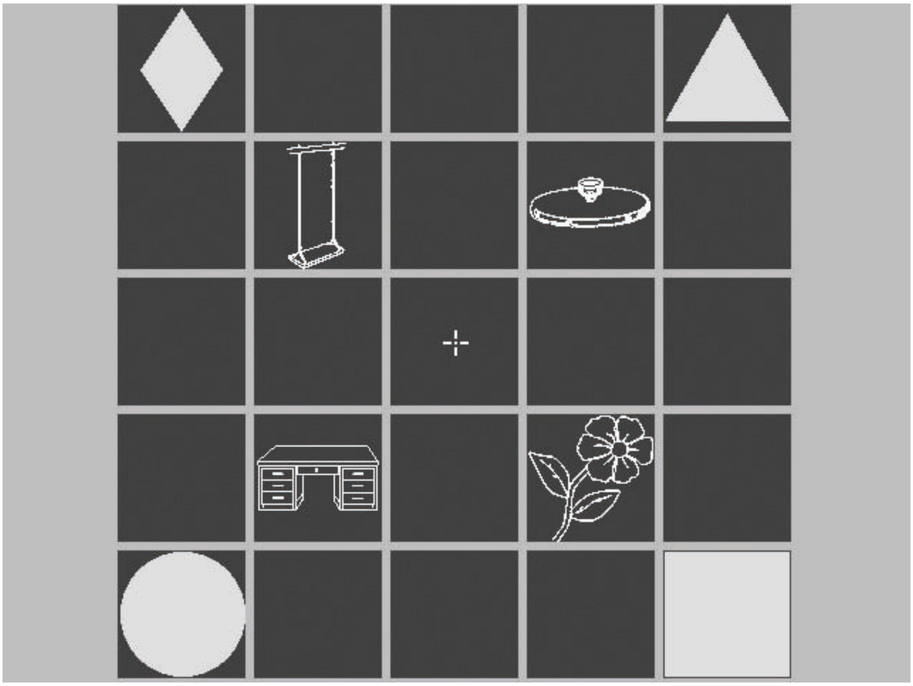


Figure 3.1: Example of visual display.

lexical activation in non-native listening. Additionally, we used measures of L2 (English) language proficiency to further investigate the influence of proficiency on cross-linguistic lexical activation. In Experiment 1 we attempted to replicate findings by Weber and Cutler (2004) using the same experimental stimuli and an equivalent participant population. For this experiment, target words were presented in invariant sentence contexts (e.g., "Click on the *desk*"). Experiment 2 investigated the possible modulatory role of sentence context on cross-linguistic lexical activation by embedding the target words in semantically richer sentences (e.g., "My grandma has an ugly *desk*").

In order to compare language proficiency with earlier studies, we used language proficiency measures from both Weber and Cutler (2004) and FitzPatrick and Indefrey (2010; Chapter 2 of this thesis). To ascertain whether language proficiency influences the amount of cross-linguistic lexical activation we correlated each of our proficiency measures with our measure of cross-linguistic competitor activation. Participants participated in both parts of the experiment on separate days. To avoid potential order effects the order of the experiments was counterbalanced.

	Current Study	*Weber & Cutler*
Age	22.8 (3.3)	n/a
Age of Acquisition (English)	10.4 (1.7)	11.25
Duration of English lessons in years	8.2 (2.7)	7.45
20 noun test	98% (6.8%)	97%
ΔM	0.47 (0.36)	n/a
Oxford Placement test	44.1 (3.8)	n/a

Table 3.1: Participant characteristics (mean values) from the current study as well as from Weber & Cutler (2004). Standard deviations (where available) given in parentheses.

3.2 Experiment 1

Methods

Participants

Twenty-five right-handed, highly proficient, Dutch-English bilinguals participated in the experiment. Data from five participants were lost due to technical malfunctions, leaving 20 in the final analysis. The participants' English proficiency was assessed using 50 grammaticality judgement items of the Oxford Placement Test (Allan, 1992), a non-speeded lexical decision test (Meara, 1996; Lemhöfer, Dijkstra & Michel, 2004) and a 20 noun English multiple-choice test (for a full description see: Weber & Cutler, 2004). Table 2.1 outlines the characteristics of the participants in the current study as well as the participants in Weber and Cutler (2004).

Materials

We used the same picture stimuli as Weber and Cutler (2004). As in their study, we had 20 experimental trials and 20 filler trials with pictures that did not appear in experimental trials. Because our participants would see the same target-competitor pairings in both experiments, we created 20 additional filler trials in which target-competitor pairings or pairings of pictures from filler trials were recombined with other items. These additional fillers always occurred after the corresponding experimental trials and, in these trials, neither picture from the original target-competitor pairing was the intended target to avoid cueing the participants to the relevance of the target-competitor pairings.

	Invariant context	*Sentences*	*Weber & Cutler*
Context	549 (43)	1085 (945)	451
Target word	558 (120)	520 (130)	576
Overlap	298 (140)	341 (99)	270

Table 3.2: Durations of sentence context, target word, and between language overlap (mean values) in ms from the current study and corresponding values from Weber & Cutler (2004). Standard deviations (where available) given in parentheses.

The 20 experimental items and 40 filler trials constituted one stimulus set. To ensure that participants were not presented with identical stimulus displays across experiments, we created an additional stimulus set in which all target-competitor pairings were recombined with two other pictures drawn from the filler items. We made sure that neither the English nor the Dutch names of these new distractors shared phonemes with the English or Dutch names of the target or competitor pictures. Half the participants were first presented with stimuli from set 1, the other half were first presented with stimuli from set 2.

All stimulus materials were spoken by a male English native speaker at a normal speaking rate and with normal intonation. The materials were digitally recorded and equalised to eliminate any differences in sound level. Table 3.2 outlines the characteristics of the stimuli of Experiments 1 and 2 in the current study as well as the corresponding values from Weber and Cutler (2004).

Procedure

Participants were exclusively addressed in English by an English native speaker to make certain they were in a monolingual L2 language mode (Grosjean, 1982). Participants' eye movements were monitored using a SMI EyeLink- Hispeed 2D eye-tracking system at a sampling rate of 250 Hz. Only data from the dominant (right) eye were analyzed. The participants' task (i.e., to click on one of the four pictures using the mouse and then drag it to one of four geometric shapes), stimulus displays (Figure 3.1), and presentation settings were identical to Weber and Cutler (2004).

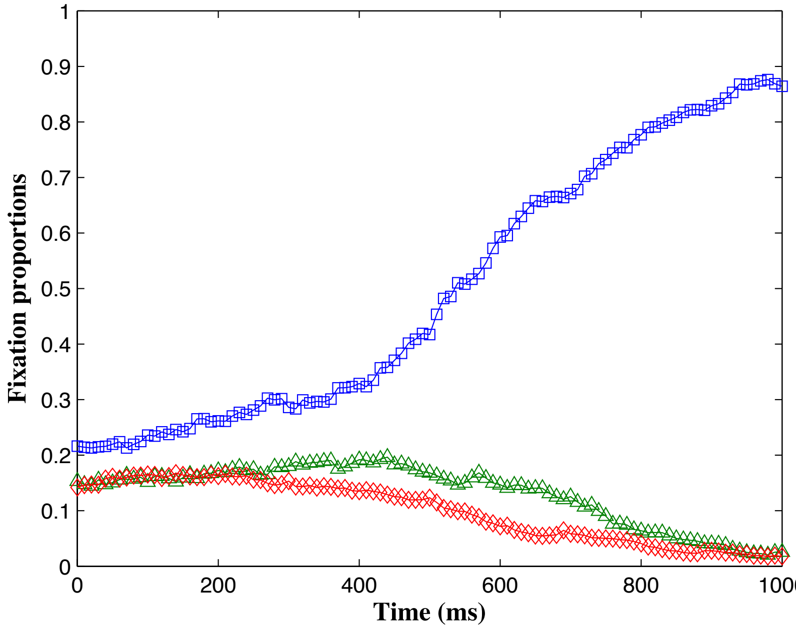


Figure 3.2: Fixation proportions over time for participants listening to invariant instructions: targets (blue squares), interlingual competitors (green triangles), and averaged distractors (red diamonds).

Results and Discussion

Trials in which participants did not fixate the target item or clicked on a picture other than the target were removed. Total trial loss in Experiment 1 amounted to 15% of experimental trials. Figure 3.2 shows the proportion of fixations averaged over participants. A repeated measures ANOVA was conducted on the mean proportion of fixations in the 300-800 ms time window, with condition (three levels: ‘target’, ‘competitor’ and ‘unrelated distractors’) as the within-participants factor. The omnibus ANOVA revealed a significant main effect of condition (F_2 (2,38) = 23.06; F_2 (2,38) = 18.02; min-F’ (2,50) = 10.1, p<0.001). A priori contrasts revealed that the target was fixated significantly more often than the competitor and unrelated distractors (F_1 (1,19) = 27.34; F_2 (1,19) = 19.41; min-F’ (1,37) = 11.3, p<0.01) and the competitor was fixated significantly more often than the unrelated distractors (F_1 (1, 19) = 10.86; F_2 (1, 19) = 11.07; min-F’ (1,38) = 5.13, p<0.05). This result replicates Weber and Cutler (2004) and confirms earlier findings of cross-linguistic lexical activation in L2 spoken word recognition (Marian & Spivey, 2003a; 2003b; Marian, et al., 2003; Spivey & Marian, 1999).

In the 0-300 ms time window there was also a significant main effect of condition (F_1 (2,38) = 8.94; F_2 (2, 38) = 5.14; min-F' (2,37) = 3.26, $p<0.05$), however there was no significant difference between fixations to the competitor and unrelated distractors (F_1 (1, 19) = 0.46; F_2 (1, 19) = 0.37; min-F' (1,38) = 0.23, p = *n.s.*). The increased number of fixations to the target picture could plausibly be attributed to visual properties of the target pictures (i.e., the target pictures may have been more visually salient) or co-articulatory information from the preceding word in the speech stream. Given that the same visual materials in Weber and Cutler (2004) did not reveal a target preference in the 0-300 ms range we consider the latter account most likely. That is, the speaker of our experimental materials may have unintentionally produced a greater amount of co-articulation than Weber and Cutler's speaker.

A significant negative correlation (r = -0.51, $p<0.05$) held between the proportion of fixations on the competitor and participants' averaged self-rated proficiency (Figure 3.3). There was also a trend toward a negative correlation (r = -0.41, $p<0.08$) between the proportion of fixations on the competitor and participants' score on the Oxford Placement Test. These data suggest that the more proficient one is in one's second language the less likely one is to experience cross-linguistic lexical activation.

3.3 Experiment 2

Methods

Participants

Experiment 2 used the same participants as Experiment 1.

Materials

We used the same sets of stimulus pictures and target words as in Experiment 1. We created sentence frames that provided no information about the target word for each of 20 experimental and 40 filler trials. For both experimental and filler trials half of the target words were embedded early in the sentence (e.g., "My *desk* is at the window") and the other half were embedded late in the sentence (e.g.,"My grandma has an ugly *desk*") to avoid cueing the subject to the relevance of a particular (i.e., the sentence final) word. Items that occurred early in one stimulus

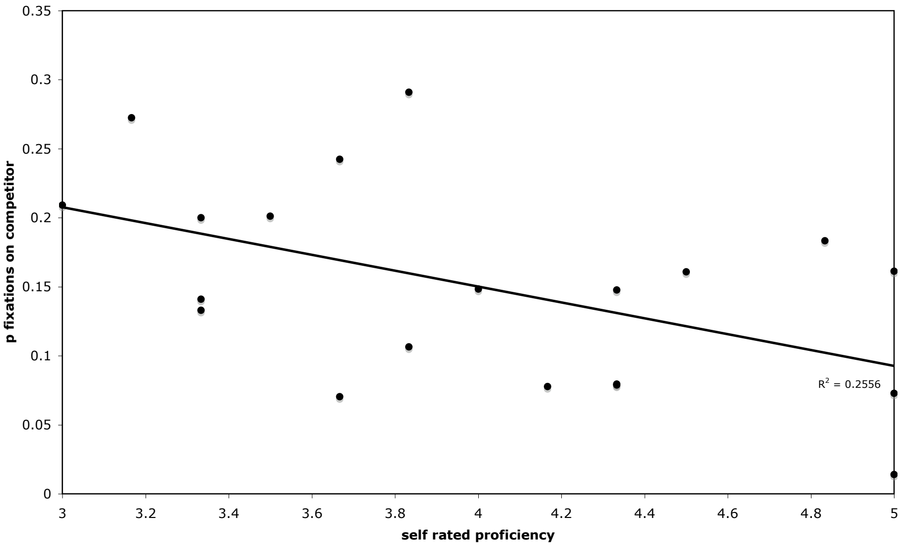


Figure 3.3: Correlation between proportions of competitor fixations (vertical axis) and averaged self- rated L2 proficiency (horizontal axis).

set occurred late in the other, and vice versa. To test the sentence contexts for a possible bias towards the target, competitor, or distractors, we presented an independent group of participants (n=24) with the experimental stimuli truncated before the onset of the target word. They were instructed to click on the object that best fit the sentence fragment. There were no significant differences in the proportion of times the target, competitor or distractors were selected either in sentences with an early target ($F(2,38) = 2.95$, $p = n.s.$) or with a late target ($F(2,38) = 1.13$, $p = n.s.$). A full list of experimental materials is available in Appendix B, Table B.1.

Procedure

Participants were instructed to click on any picture that was mentioned in the sentence. In all other respects the procedure was identical to Experiment 1. Having confirmed that cross-linguistic activation occurs in invariant sentence contexts, we next set out to investigate whether variable sentence contexts would modulate the extent of cross-linguistic lexical activation. In Experiment 2 we therefore embedded our target items in semantically richer sentence contexts.

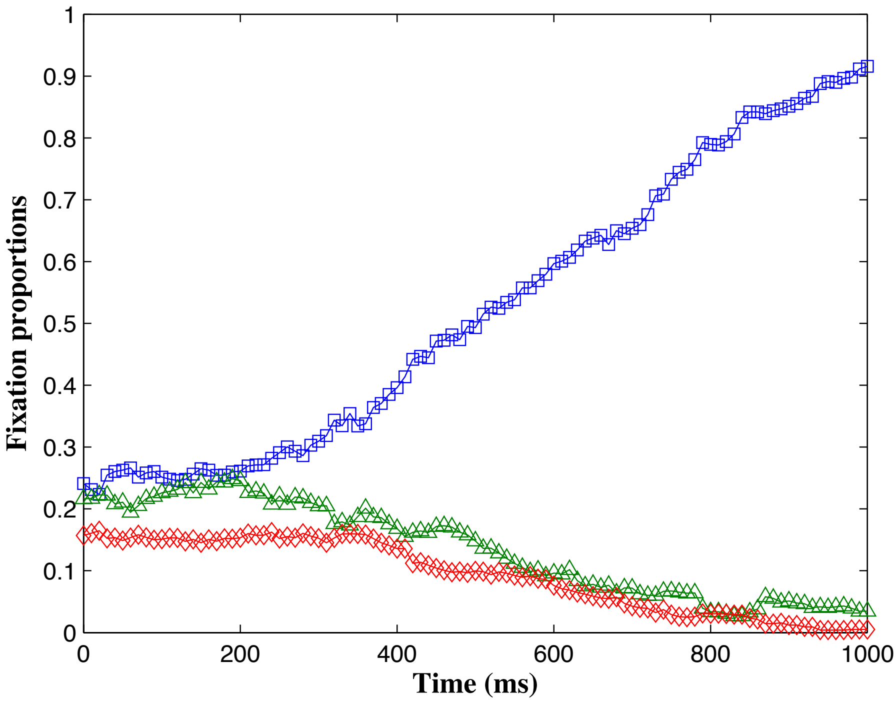


Figure 3.4: Fixation proportions over time for participants listening to semantically rich sentences with targets late in the sentence: targets (blue squares), interlingual competitors (green triangles), averaged distractors (red diamonds)

Results and Discussion

Total trial loss in Experiment 2 amounted to 16% of experimental trials. Figures 3.4 and 3.5 show the proportion of fixations averaged over participants in the early and late target conditions, respectively. In the 300-800 ms time window the omnibus ANOVA yielded a significant main effect of target position (F_1 (1,19) = 11.80, p<0.01; F_2 (1,9) = 9.93; min-F' (1,23) = 5.39, p<0.05), reflecting the fact that there were more fixations when the target appeared in the late position (mean prop = 0.25, SD = 0.01) than when it appeared in the early position (mean prop = 0.21, SD = 0.01). There was also a significant main effect of condition (F_1 (2,38) = 87.50; F_2 (2,18) = 293.08; min-F' (2,54) = 67.3, p<0.001). Contrasts revealed that the target was fixated significantly more often than the competitor and unrelated distractors (F_1 (1,19) = 101.22; F_2 (1, 9) = 767.70; min-F' (1,23) = 89.4, p<0.001), however there was no significant difference between fixations

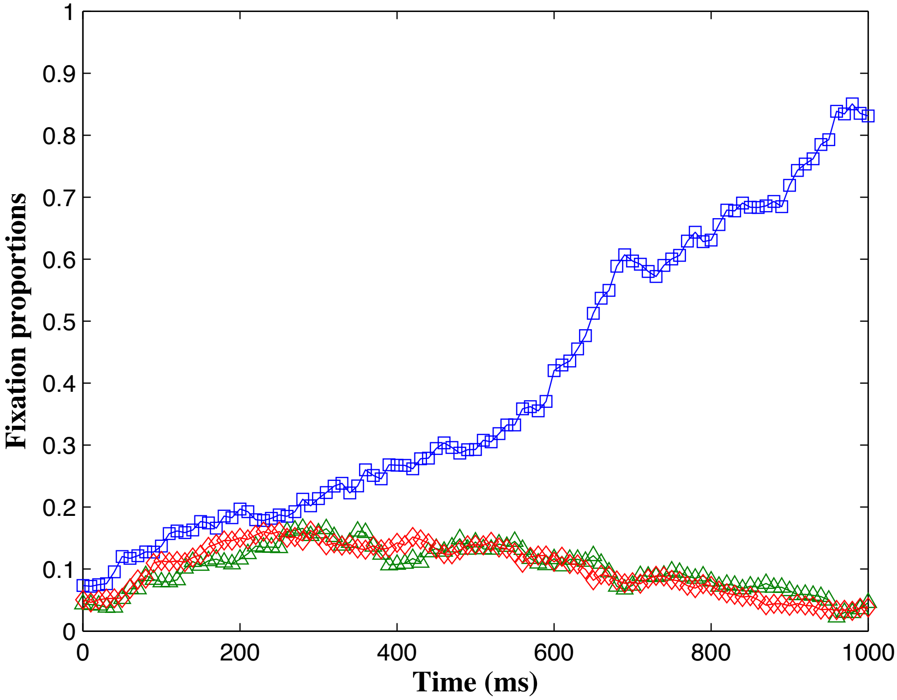


Figure 3.5: Fixation proportions over time for participants listening to semantically rich sentences with targets early in the sentence: targets (blue squares), interlingual competitors (green triangles), averaged distractors (red diamonds)

to the competitor and unrelated distractors (F_1 (1, 19) = 0.50; F_2 (1, 9) = 0.14; min-F' (1,14) = 0.10, p = $n.s.$).

There was also a significant interaction between condition and target position (F_1 (2,38) = 8.49; F_2 (2,18) = 7.23; min-F' (2,46) = 3.9, $p<0.05$). Contrasts revealed that this was due to the fact that the target was fixated more often (F_1 (1,19) = 11.62; F_2 (1,9) = 9.63; min-F' (1,23) = 5.26, $p<0.05$) when it was presented late in the sentence than when it was presented early in the sentence. Target position did not interact with the difference between looks to the competitor and the unrelated distractor (F_1 (1, 19) = 0.58; F_2 (1, 19) = 1.12; min-F' (1,28) = 0.38, p = $n.s.$). We thus find no evidence of a competitor effect in either our early or our late target conditions, suggesting that no cross-linguistic activation occurred.

In the 0-300 ms time window there was a significant main effect of target $p<0.05$), however there was no significant difference between fixations to the competitor and unrelated distractors (F_1 (1, 19) = 2.15; F_2 (1, 9) = 0.73; min-F' (1,15) = 0.54, p = $n.s.$). Finally, no significant correlations emerged between the proportion of fixations on the competitor and any of the language proficiency measures.

3.4 General Discussion

This study investigated the influence of sentence context and language proficiency on cross-linguistic lexical activation. In Experiment 1, bilinguals fixated more often on cross-linguistic phonological competitors than on unrelated distractor objects, thereby replicating earlier findings (e.g., Marian & Spivey, 2003a; Marian & Spivey, 2003b; Marian, et al., 2003; Spivey & Marian, 1999; Weber & Cutler, 2004). There is, thus, ample reason to believe bilinguals experience cross-linguistic lexical activation in spoken word recognition. Interestingly, the extent of cross-linguistic lexical activation was negatively correlated with language proficiency, suggesting that more proficient bilinguals are more able to "zoom in" (cf., Elston-Guettler, 2005) to the language at hand. This interpretation accords well with the Revised Hierarchical Model of the bilingual lexicon (Kroll & Stewart, 1994) that assumes that lexical access relies less on the L1 in highly proficient, compared with less proficient bilinguals.

Results from Experiment 2 reveal a further restriction to cross-linguistic lexical activation. When the target item is embedded in even a minimally elaborated sentence context, the competitor effect is greatly attenuated. These results are consistent with observations of reduced cross-linguistic lexical activation in written sentence comprehension (Duyck, et al. 2007; Schwartz & Arêas Da Luz Fontes, 2008; Schwartz & Kroll, 2006). A tentative account for these findings is that accessing non-target language words requires cognitive resources, and the availability of such resources is modulated by the sentence context. Invariant instructions make less demand on such resources than richer sentence contexts, leaving comparatively more resources available for alternative processes (such as access to the L1 lexicon).

In summary, the present study shows that cross-linguistic lexical activation is subject to modulation by both language proficiency and sentence context. Proficient bilinguals experience less between-language interference than their less proficient counterparts, and such interference is more likely when the language context does not place great demands on the processing system.

3.5 References

Allan, D. (1992). *Oxford placement test.* Oxford: Oxford University Press.

Broersma, M. E. & Cutler A.(in press). Competition dynamics of second-language listening. *Quarterly Journal of Experimental Psychology.*

Cooper, R. M. (1974). The control of eye fixation by the meaning of spoken language. A new methodology for the real-time investigation of speech perception, memory, and language processing. *Cognitive Psychology*, *6*(1), 84-107.

Duyck, W., Van Assche, E., Drieghe, D., & Hartsuiker, R. J. (2007). Visual word recognition by bilinguals in a sentence context: Evidence for nonselective lexical access. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *33*(4), 663-679.

Elston-Guettler, K. E., Gunter, T. C., & Kotz, S. A. (2005). Zooming into L2: global language context and adjustment affect processing of interlingual homographs in sentences. *Brain Research: Cognitive Brain Research*, *25*(1), 57-70.

Fischer, B. (1992). Saccadic reaction time: Implications for reading, dyslexia and visual cognition. In K. Rayner (Ed.), *Eye movements and visual cognition: Scene perception and reading* (pp. 31-45). New York: Springer-Verlag.

FitzPatrick I., & Indefrey P. (2010). Lexical Competition in Nonnative Speech Comprehension. *Journal of Cognitive Neuroscience*, *22*(6), 1165-1178.

Grosjean, F. (1982). *Life with two languages: An introduction to bilingualism.* Cambridge, MA: Harvard University Press.

Kroll, J. F., & Stewart, E. (1994). Category interference in translation and picture naming: Evidence for asymmetric connections between bilingual memory representations. *Journal of Memory and Language*, *33*(2), 149-174.

Kutas, M., & Hillyard, S. A. (1980). Reading senseless sentences - Brain potentials reflect semantic incongruity. *Science*, *207*(4427), 203-205.

Lemhöfer, K., Dijkstra, T., & Michel, M. C. (2004). Three languages, one ECHO: Cognate efects in trilingual word recognition. *Language and Cognitive Processes*, *19*(5), 585-611.

Marian, V., & Spivey, M. J. (2003a). Bilingual and monolingual processing of competing lexical items. *Applied Psycholinguistics*, *24*(2), 173-193.

Marian, V., & Spivey, M. J. (2003b). Competing activation in bilingual language processing: Within- and between-language competition. *Bilingualism: Language and Cognition*, *6*(2), 97-115.

Marian, V., Spivey, M. J., & Hirsch, J. (2003). Shared and separate systems in bilingual language processing: Converging evidence from eyetracking and brain imaging. *Brain and Language*, *86*(1), 70-82.

McClelland, J., & Elman, J. (1986). The TRACE model of speech perception. *Cognitive Psychology*, *18*(1), 1-86.

McQueen, J. M., Norris, D., & Cutler, A. (1994). Competition in spoken word recognition: Spotting words in other words. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *20*(3), 621-638.

Meara, P. M. (1996). *English vocabulary tests: 10k.* Swansea, UK: Centre for Applied Language Studies.

Moss, H. E., & Marslen-Wilson, W. D. (1993). Access to word meanings during spoken language comprenhension: effects of sentential semantic context. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *19*(6), 1254-1276.

Norris, D. (1994). Shortlist - A connectionist model of continuous speech recognition. *Cognition*, *52*(3), 189-234.

Norris, D., McQueen, J. M., & Cutler, A. (1995). Competition and segmentation in spoken-word recognition. *Journal of Experimental Psychology: Human Perception and Performance*, *21*(5), 1209-1228.

Schulpen, B., Dijkstra, T., Schriefers, H. J., & Hasper, M. (2003). Recognition of interlingual homophones in bilingual auditory word recognition. *Journal of Experimental Psychology: Human Perception and Performance*, *29*(6), 1155-1178.

Schwartz, A. I., & Kroll, J. F. (2006). Bilingual lexical activation in sentence context. *Journal of Memory and Language*, *55*(2), 197-212.

Schwartz, A.I., & Arêas Da Luz Fontes, A. B. (2008). Cross-language mediated priming: Effects of context and lexical relationship. *Bilingualism: Language and Cognition*, *11*(1), 95-110.

Spivey, M. J., & Marian, V. (1999). Cross talk between native and second languages: Partial activation of an irrelevant lexicon. *Psychological Science*, *10*(3), 281-284.

Tabossi, P. (1988). Accessing lexical ambiguity in different types of sentential contexts. *Journal of Memory and Language*, *27*(3), 324-340.

Tanenhaus, M.K., Spivey-Knowlton, M.J., Eberhard, K.M., & Sedivy, J.C. (1995). Integration of visual and linguistic information in spoken language comprehension. *Science*, *268*(5217), 1632-1634.

Weber, A., & Cutler, A. (2004). Lexical competition in non-native spoken-word recognition. *Journal of Memory and Language*, *50*(1), 1-25.

Head Start For Target Language in Bilingual Listening

CHAPTER 4

Ian FitzPatrick and Peter Indefrey

Abstract

The current study investigated the availability of first language (L1) semantic features in second language (L2) speech processing. We recorded EEG from 30 Dutch-English bilinguals who listened to spoken sentences in their L2 (English). In Experiment 1 the critical word in the sentence was an L1-L2 interlingual homophone. In separate conditions: (a) the L2 meaning, (b) the L1 meaning, or (c) neither meaning was congruent with the sentence context. Whenever the L1 meaning was congruent with the sentence context we observed an N400 with an earlier offset than the N400 to incongruent homophones. When the L2 meaning of the homophone was congruent a negativity emerged, but substantially later than the N400 to incongruent homophones. Experiment 2 used sentences in which the critical word was a: (a) semantically congruent L2 word, (b) semantically incongruent L2 word, (c) congruent L1 word, or (d) an incongruent L1 word. Incongruent L1 and L2 words elicited a canonical N400 effect. The N400 to congruent L1 words had a substantially earlier offset than the N400 to incongruent L1 and L2 words. Additionally both congruent and incongruent L1 words exhibited a late positive ERP component (LPC). Taken together these results show that target language semantics become available earlier than non-target language semantics when processing language switches or interlingual homophones.

Submitted for publication

4.1 Introduction

Spoken language is fraught with ambiguity. Words with different meanings often sound identical (e.g., *mail* and *male*) leaving the listener with the task to determine which meaning ('post' or 'man') is contextually appropriate. The ambiguity problem is compounded in bilingual listeners who may additionally be faced with words that sound the same between their languages. The Dutch word *meel* ('flour'), for instance, sounds similar to the English word *mail*. Although words of two different languages are seldom phonologically identical, initial investigations of non-native word comprehension nevertheless show concurrent activation of first (L1) and second (L2) language words in bilinguals (Marian & Spivey, 2003a; 2003b; Marian, et al., 2003; Spivey & Marian, 1999; Weber & Cutler, 2004). Whether or not this is a problem for second language comprehension depends on the extent to which words from the non-target (i.e., native) language compete for recognition and at which point in time the target (i.e., second) language word emerges as the winner.

Comprehension of homophones has received much attention in studies of monolingual reading and listening. Models of word ambiguity resolution generally fall into one of three categories (for a review see: Simpson, 1994): (1) context dependent models that assume that only the contextually appropriate meaning of the ambiguous word is accessed at any given moment (e.g., Glucksberg Kreuz & Rho, 1986; Simpson, 1981), (2) exhaustive access models that assume that every meaning of the ambiguous word is activated irrespective of the context (Swinney, 1979), or (3) ordered access models that assume that meanings are accessed sequentially from most to least frequent (e.g., Hogaboam & Perfetti, 1975). Although the exhaustive access accounts have, in the past, enjoyed a great deal of popularity, an increasing number of studies have emphasized the influence of context on access to ambiguous word meanings. Prominent among these are studies that demonstrated that balanced ambiguous words (i.e., words with two or more equally frequent meanings) are read as fast as matched control words in neutral contexts but biased ambiguous words (i.e., words with a dominant and one or more subordinate meanings) are read slower than matched control words in sentences that bias towards the subordinate interpretation of the ambiguous word (e.g., Pacht & Rayner, 1993; Rayner, Pacht & Duffy, 1994). In other words, lexical frequency determines the order of meaning activation in neutral contexts, however a context biasing toward a subordinate meaning can speed up the activation of a subordinate meaning. The resulting simultaneous activation of the dominant and subordinate meanings leads to meaning competition, and the corresponding slowed processing is referred to as the subordinate bias effect. These findings are considered to be strong support of so-called re-ordered access models (Duffy, Morris & Rayner, 1988) of ambiguous word comprehension that advocate a prominent influence of both context and lexical frequency on access to ambiguous word meanings.

There have also been Event-Related Potential (ERP) studies of ambiguous word processing in both written (Van Petten & Kutas, 1987) and spoken (Swaab, Brown & Hagoort, 2003) sentence contexts. Both these studies employed an N400 priming approach. Ambiguous prime words in the final position of sentences biasing towards either their dominant or subordinate meaning were followed by concordant (i.e., consistent with the contextual bias), discordant (i.e., inconsistent with the contextual bias), or unrelated target words. Both studies report effects of discordant targets compared to unrelated targets especially at short inter-stimulus intervals (ISIs; 100-200 ms). In Van Petten and Kutas (1987), the ERPs to discordant targets initially mirrored the ERPs to unrelated targets but diverged after 500 ms. In Swaab et al. (2003) discordant targets elicited reduced N400 (Kutas & Hillyard, 1980) responses compared to unrelated targets suggesting that the meaning that was not contextually supported was still activated. This N400 reduction was most pronounced for the dominant meaning of the ambiguous word and, in contrast to subordinate biased targets, was even observed at long ISIs (1250 ms).

Taken together these findings support the idea of multiple access to ambiguous word meanings in monolingual word recognition, and suggest an important role of context and word frequency in determining the time course and relative activation levels of these meanings. In light of this, two important questions are raised with respect to bilingual language comprehension: is there multiple access to between-language ambiguous word meanings? And if so: to what extent is this cross-linguistic activation modulated by context?

There is a great deal of evidence that suggests that bilinguals are not capable of restricting their language processing to a single (target) language. The vast majority of this evidence comes from studies of bilingual visual word recognition. Among the most replicated results are findings of a processing advantage for between language cognates (i.e., words that share form and meaning) and a processing cost for interlingual homographs (for an overview see: Dijkstra, 2005). These findings have leant weight to models of bilingual language processing that assume that the bilingual language comprehension system is fundamentally language non-selective in nature, such as the Bilingual Interactive Activation (BIA) and BIA+ models (Dijkstra & Van Heuven, 1998; 2002; Grainger & Dijkstra, 1992). Beyond visual word recognition there are also reports of cross-linguistic lexical activation in bilingual speech comprehension. Schulpen, Dijkstra, Schriefers and Hasper (2003), for example, showed that both pronunciations of a Dutch-English interlingual near homophone (e.g., /li:f/ - English: *leaf*, Dutch: *lief* 'sweet') could prime both orthographic forms of the word (LEAF, LIEF). More strikingly, a number of studies that employed the visual world paradigm (e.g., Tanenhaus, et al., 1995) have shown cross-linguistic lexical activation based solely on word-initial (i.e., incomplete) phonological overlap. Initial phonological overlap of a spoken target word with a visual referent's non-target language translation causes bilinguals to look more often at that referent than at a distractor object with no phonological relation to the target (e.g., Spivey & Marian, 1999; Weber & Cutler 2004). For example, when tasked to "Click on the *desk*" Dutch-English bilinguals tended to fixate on a picture of a lid (Dutch: 'deksel') more often than on a control object such as a swing (Dutch: 'schommel') (Weber & Cutler, 2004; FitzPatrick, Cutler & Indefrey, 2010; Chapter 3 of this thesis).

Although there is mounting evidence for cross-linguistic lexical activation in bilinguals faced with words in isolation or invariant sentence contexts, investigations of bilingual visual word recognition using semantically rich contexts showed marked reductions of cross-linguistic activation (Duyck, Van Assche, Drieghe & Hartsuiker, 2007; Schwartz & Arêas Da Luz Fontes, 2008; Schwartz & Kroll, 2006). Duyck et al. (2007) presented bilinguals with between language cognates, near-cognates, and non-cognate control words in isolation and in sentences presented word-by-word. Recognition of both cognates and near-cognates was facilitated compared to control words, however the near-cognate effect disappeared when the full sentence was presented while the cognate effect remained. The authors concluded that the presence of a sentence context "may influence, but does not nullify" cross-linguistic lexical activation. This assertion is supported by observations by Schwartz and Arêas Da Luz Fontes (2008) who investigated the role of context on between language mediated form priming and -semantic priming. Using Spanish-English bilinguals, in an English (L2) only task, they obtained priming when the prime (bark) had a form mediated relationship via the L1 (*barco*; Spanish for 'boat') to the target (BOAT) for isolated words, but not when the words were embedded in sentence contexts (e.g., "The baby woke up every time the dog would *bark*"). Further evidence suggests an effect of semantic constraint on cross-linguistic lexical activation. Schwartz and Kroll (2006) observed a cognate facilitation effect for the reading of cognates in low constraining sentences, but this effect was substantially reduced when the cognates were presented in high constraining sentence contexts.

Thus, the picture emerging from bilingual visual word recognition studies is that cross-linguistic lexical activation is not eliminated in bilingual sentence processing, but may require a greater amount of interlingual lexical overlap compared to isolated word processing.

The majority of studies that demonstrated cross-linguistic lexical activation in bilingual speech comprehension used target words embedded in invariant contexts (e.g., "Click on the *desk*"). However, those few studies that investigated bilingual speech comprehension in semantically rich sentences seem to suggest a similar reduction of cross-linguistic lexical activation as observed in studies of bilingual reading. FitzPatrick and Indefrey (2010; Chapter 2 of this thesis), found evidence of within-, but not between language lexical competition in bilingual spoken sentence comprehension. The study focused on the N400, an extensively researched ERP component. The amplitude of the N400 is widely held to index the ease of semantic integration (Brown & Hagoort, 1993; Kutas & Hillyard, 1984), and the peak and onset latency of the N400 component have been shown to be sensitive to the point at which a semantic incongruity is detected (O'Rourke & Holcomb, 2002; Praamstra, Meyer & Levelt, 1994). FitzPatrick and Indefrey (2010; Chapter 2 of this thesis) presented Dutch-English bilinguals with English (i.e., second language) sentences that terminated in a word that was: a) semantically fitting, b) semantically incongruent, or c) semantically incongruent, but initially congruent due to sharing initial phonemes with the most probable sentence completion within the L2 or d) the L1 translation equivalent of the most probable sentence completion. The authors reasoned that, if the target word would be initially perceived as congruent, the N400 would be delayed in comparison to non-overlapping semantically incongruent target words. Whereas intralingual (i.e., within L2) phonemic overlap led to a significantly delayed N400, interlingual phonemic overlap did not, suggesting that within-, but not between-language lexical competitors are available for semantic integration. Another study by Li and Yip (1998) suggested bilinguals may be able to utilize contextual constraint to limit between language lexical competition. They investigated the processing of interlingual near homophones in Chinese-English bilinguals. The homophones were pronounced according to Chinese phonetics and embedded in semantically biasing or neutral Chinese sentences. The contextual bias was towards the non-context (English) language meaning of the homophone. The bilinguals' task was to identify visual probes that could be the (contextually appropriate) English version of the homophone or the (contextually inappropriate) Chinese version of the homophone. Identification latencies of the English version of the homophone were significantly faster in contextually biasing sentences compared to neutral sentences, while identification latencies of the contextually inappropriate Chinese version of the homophone were only marginally faster in semantically biasing compared to neutral sentences. In summary these findings suggest that lexical items can be activated across languages in bilingual comprehension and that the presence of a semantically rich, target language sentence context may reduce the non-target language activation. The question, however, remains whether the sentence context forces the bilingual into a language selective processing mode, or whether given enough between-language overlap we can still observe cross-linguistic lexical activation in bilingual auditory sentence comprehension.

The present study aims to investigate the processing of cross-linguistic semantics in spoken sentence contexts. As in our previous study (FitzPatrick & Indefrey, 2010; Chapter 2 of this thesis) we will exploit the sensitivity of the N400 to the moment at which a semantic incongruity becomes apparent to the listener. In Experiment 1 of the present study, Dutch native speakers listened to spoken sentences in their second language (English). The sentences included an interlingual near-homophone (e.g., *pet*, meaning 'hat' in Dutch). In different conditions either the English (L2) meaning but not the Dutch (L1) meaning was congruent with the English sentence context (L2-congruent/L1-incongruent), the Dutch meaning but not the English meaning was congruent with the context (L2 incongruent/L1-congruent) or neither the English nor the Dutch meaning were congruent with the context (L2-incongruent/L1-incongruent). For comparison we also included a control condition with a non-homophonic English word (e.g., kite) that was congruent with the sentence context (L2-congruent). We reasoned that if cross-linguistic semantics were activated, the presence of non-target language congruent (L2-incongruent/L1-congruent) semantic features would lead to an attenuation of the N400 effect, whereas the presence of non-target language incongruent (L2-congruent/L1-incongruent) semantic features would lead to an increased N400. If no cross-linguistic semantics were activated, only the L2 congruity would determine the magnitude of the N400 effect.

The potential activation of cross-linguistic semantics in Experiment 1 raises a caveat for our interpretation, as it has been shown that language switches can have a substantial effect on the electrophysiological waveform. Moreno et al. (2002) observed that semantically congruent language switches (e.g., "He heard a knock at the *puerta*") did not result in an N400 effect compared to semantically congruent control sentences (e.g., "He heard a knock at the *door*") whereas lexical switches (e.g., "He heard a knock at the *entrance*") did. Instead the language switches elicited a Late Positive Component (LPC). The absence of an N400 effect to semantically congruent code-switched words relative to semantically congruent non-switched words would seem to suggest that bilinguals have no trouble semantically integrating a fitting language-switched item. Additionally the authors speculate that the LPC may be a reflection of the perception of a language switch. In our Experiment 1, a modulation of the N400 could potentially be attributable to an LPC effect that temporally overlaps with the N400. We therefore considered it important to compare results from Experiment 1 to a situation in which the activation of cross-linguistic semantics was explicit in the task, namely by using language switched critical words instead of homophones.

Our aim in Experiment 2 was thus to uncover the electrophysiological correlates of perceived language switches in spoken word contexts. We used the same experimental participants as Experiment 1 to maximise comparability of the results. To avoid potential order effects the order of Experiments 1 and 2 were counterbalanced across participants. In a 2 x 2 design (language switch vs. no switch x semantically congruent vs. semantically incongruent) we had the participants listen to L2 sentences that included a critical word that was: (a) congruent with the sentence context, (b) incongruent with the sentence context, (c) an L1 lexical item that was congruent with the sentence context, or (d) an L1 lexical item that was incongruent with the sentence context. We expected incongruent words to elicit a greater N400 irrespective of whether they are language switched or not. Additionally we predicted that language switches would elicit a greater positivity (LPC) compared to non-switched words in late time windows. Finally, we expected that the morphology of the ERP waveforms and scalp topographies of the various components would inform us whether the observed modulations of the N400 from Experiment 1 could be attributed to an LPC effect.

4.2 Experiment 1

Methods

Participants

Thirty right-handed Dutch-English bilinguals (5 males; average age: 21.3 years) participated in the experiment. The participants' English proficiency was assessed using the average z-scores on 50 grammaticality judgement items of the Oxford Placement Test (Allan, 1992) (mean score: 43.03, "advanced level", $SD = 4.05$; maximum score: 50) and a non-speeded lexical decision test (60 items), created by Meara (1996) and later adapted by Lemhöfer, Dijkstra and Michel (2004) (mean

$\Delta M = 0.47$, $SD = 0.29$; maximum score: 1.0). Additionally participants completed an extensive language history questionnaire, which included a self-reported English proficiency measure (mean score: 3.9 out of 5). Participants were either paid a small fee or they received study credits. None of the participants had any neurological impairment. All participants gave their written informed consent.

Materials

All experimental materials were in the subjects' second language (English). The experimental sentences, fillers, and practice items were spoken by one of the authors (a male, English-Dutch balanced bilingual) with normal intonation and at a normal speaking rate. The materials were digitally recorded in a sound-attenuating booth and digitised at a rate of 44.1 kHz. Sound files were later equalised to eliminate any differences in sound level.

We chose 56 monosyllabic English-Dutch non-cognate interlingual homophones based on their phonetic transcriptions. For each of the homophones we created three sentence frames. The first sentence frame was semantically congruent with the English meaning of the homophone, the second was semantically congruent with the Dutch meaning of the homophone, and the third was semantically incongruent both in English and in Dutch. We created one further sentence frame paired with a non-homophonic semantically congruent critical word. We thus ended up with four conditions, each with 56 items. We additionally included 112 semantically congruent filler sentences. Ten practice sentences were created half of which were semantically congruent and half included a semantically incongruent word. All sentence frames were cloze tested by an independent group of Dutch-English bilinguals (cloze probabilities: L2-congruent control = 0.72, L2-congruent/L1-incongruent = 0.60, L2-incongruent/L1-congruent=0.00). Sentence frames in the L2-incongruent/L1-congruent condition were also cloze tested for Dutch completions (cloze probability = 0.56). Across both Experiment 1 and Experiment 2 each condition was controlled with respect to cloze probability (English and Dutch where applicable) and word frequency (average frequency per million: L2-congruent control = 40.14, English homophone meaning = 40.47, Dutch homophone meaning = 34.34). Word frequencies were taken from the CELEX lemma database (Baayen, Piepenbrock & van Rijn, 1993). Within each sentence frame the critical word was either the direct or indirect object of the verb and across conditions all sentence materials preceding the critical word were of equal length. To ensure experimental data were not influenced by end-of-sentence wrap-up effects critical words never occurred in a sentence-final position. Due to design constraints each participant heard each interlingual homophone in three different sentence contexts. To minimize potential order effects we created six pseudo randomised stimulus lists across which the order in which each homophone token occurred was balanced. Each stimulus list was presented to an equal number of participants. A full list of experimental materials is available in Appendix C, Table C.1.

To make certain that the homophones were not unintentionally uttered with a more Dutch sounding accent in any of the conditions, an independent group of participants (n=10) judged 3 tokens of each homophone (56 homophones x 3 conditions) with respect to whether they could perceive any trace of a Dutch accent. The homophones were spliced out of the original stimulus materials and were presented in isolation. Participants heard each homophone token once and made a non-speeded judgement on a five-point scale (1=weak accent, 5=strong accent) 1600 ms after stimulus offset. 'Weak accent' was intentionally chosen as the lowest point on the scale in order to bias participants towards hearing an accent. A Kruskal-Wallis Test (Kruskal & Wallis, 1952) on each homophone utterance ranked by the sum of judgement scores across all participants, revealed no significant differences per condition (L2-incongruent/L1-incongruent: Mdn = 2, Range = 1-5; L2-incongruent/L1-congruent: Mdn = 2, Range = 1-5; L2-congruent/L1-incongruent: Mdn = 2, Range = 1-5; $H(2)$ = .556, p>.05).

Procedure

The same participants were used in both Experiment 1 and Experiment 2 in separate sessions, and on separate days. To minimize order effects half the participants first participated in Experiment 1 the other half first participated in Experiment 2. Participants were exclusively addressed in English by an English native speaker, both preceding and during the experiment, in order to make certain they were in a monolingual L2 language mode (Grosjean, 1982). Participants were placed in a sound-attenuating booth and were instructed to listen attentively to the sentences, which were played over two loudspeakers at a distance of roughly 1.5 m, and to try to understand them. The sound level was kept constant over participants. The experimental session was split into 3 blocks of approximately equal duration. In between blocks participants had an optional 5-10 minute break. To ensure that participants remained focused on the task, they were prompted to make an animacy decision regarding the previous sentence on three occasions per block. They could respond by means of a button press. On average participants answered 93% of these questions correctly, suggesting that they had attentively listened to the stimulus materials. Each trial began with a 300 ms warning tone, followed by

1200 ms of silence, then a spoken sentence. The next trial began 4100 ms after the sentence offset. To ensure that participants did not blink during and shortly after presentation of the sentence, 1000 ms prior to the beginning of the sentence a fixation point was displayed. Participants were instructed not to blink while the fixation point was on the screen. The fixation point remained until 1600 ms after the offset of the spoken sentence. Participants had a practice session with ten sentences to familiarize themselves with the experimental setting followed by three experimental blocks with short breaks in between.

After the EEG recording the participants completed a word translation test on the critical items to verify that they were known. On average the participants scored 92% for Experiment 1 and 87% for Experiment 2.

EEG Recording and Analysis

The EEG was recorded continuously from 63 sintered Ag/AgCl electrodes, each referred to an electrode on the nose of the participant. The electrodes were mounted in an equidistant elastic cap (`http://www.easycap.de`). The EEG and EOG recordings were amplified with a BrainAmp DC amplifier (Brain Products, München, Germany) using a high-cutoff of 200 Hz, a time constant of 10 s (0.016 Hz), and a sampling rate of 500 Hz. Impedances were kept below 20 kΩ with the amplifier impedance set to 10 MΩ (Ferree, Luu, Russell & Tucker, 2001). Trials with deflections exceeding 70 μV were rejected. Data from six participants were excluded from further analysis because too few trials remained after artefact rejection. Residual blinks and eye movements were removed from the data using a procedure based on Independent Component Analysis (ICA) as described by Jung et al. (2000).

The data were analysed using the FieldTrip (`http://fieldtrip.fcdonders.nl`) toolbox for Matlab (`http://www.mathworks.com`). EEG data were time-locked to critical word onset. Average waveforms were calculated for each participant using a 150 ms pre-stimulus baseline. Statistical analysis was performed by taking the mean amplitude per site (see Figure 4.1) from the grand averaged data in three latency ranges (250-450 ms, 450-650 ms, and 650-850 ms relative to critical word onset) based on Moreno, et al. (2002). In each latency range we used an omnibus analysis of variance (ANOVA) with condition (4 levels) and site (9 levels) as within subject factors. Seven electrodes were excluded from the analysis in order to have an equal number of electrodes in each site (see Figure 4.1). All p values are reported after Greenhouse-Geisser correction (Greenhouse & Geisser, 1959). Contrasts between pairs of conditions were tested using a randomization

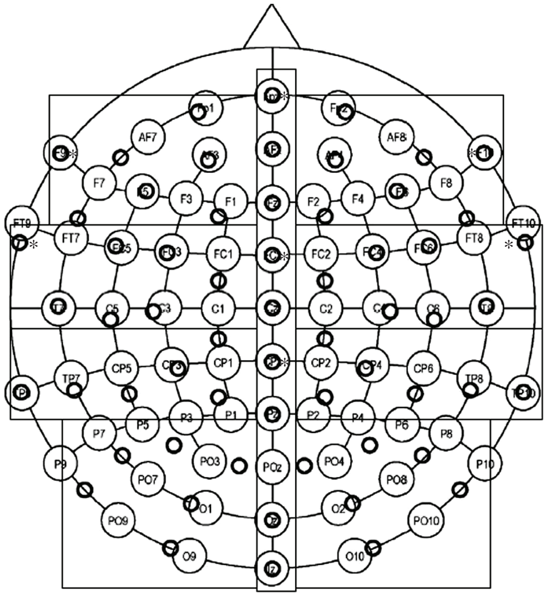


Figure 4.1: Radial projection of electrode positions of the equidistant placement system (small black circles) relative to the 10-20 system. Boxes denote regions for statistical analyses. Asterisks denote electrodes excluded from analysis.

approach that corrects for multiple comparisons (Maris, 2004; for a brief description see: Takashima, et al., 2006; Tuladhar, et al., 2007). Cluster randomization was performed, in the latency range between 200 ms and 2000 ms, on the following pairs of conditions: L2-incongruent/L1-incongruent versus control, L2-incongruent/L1-congruent versus control, and L2-congruent/L1-incongruent versus control.

Results

250-450 ms

The ANOVA yielded only a significant main effect of condition ($F(3,78) = 5.802$, $p<0.01$, $\eta^2=0.182$). A priori contrasts revealed significant differences between the L2-congruent control condition and the L2-incongruent/L1-incongruent ($F(1,26) = 5.104$, $p<0.05$, $\eta^2=0.164$), and L2-incongruent/L1-congruent ($F(1,23) = 11.506$, $p<0.01$, $\eta^2=0.307$) conditions.

450-650 ms

The ANOVA yielded a significant main effect of condition ($F(3,78) = 9.673$, $p<0.001$, $\eta^2 = 0.271$). A priori contrasts revealed significant differences between the L2-congruent control condition and the L2-incongruent/L1-incongruent ($F(1,26) = 16.506$, $p<0.001$, $\eta^2=0.388$) condition.

650-850 ms

The ANOVA yielded a significant main effect of condition ($F(3,78) = 2.885$, $p<0.05$, $\eta^2 = 0.100$). A priori contrasts revealed significant differences between the L2-congruent control condition and the L2-congruent/L1-incongruent ($F(1,26) = 3.792$, $p<0.01$, $\eta^2=0.232$) condition.

Cluster Randomisation Statistics

The contrast between the L2-incongruent/L1-incongruent condition and the L2-congruent control condition yielded a significant negative effect ($p<0.001$) emerging at 424 ms after critical word onset and lasting until 716 ms. Contrasting L2-incongruent/L1-congruent words with L2-congruent control words yielded a significant negative effect ($p<0.05$) starting at 374 ms after critical word onset. However, different from L2-incongruent/L1-incongruent homophones, the negativity to L2-incongruent/L1-congruent homophones offset nearly 300 ms earlier at 440 ms. Contrasting L2-congruent/L1-incongruent words with L2 congruent control words yielded a significant negativity ($p<0.05$) at 742 ms lasting until 834 ms.

Discussion

Experiment 1 investigated the time course of cross-linguistic semantic activation in spoken sentence contexts by manipulating the semantic fit of interlingual homophones. As expected, results revealed a canonical N400 effect between L2-incongruent/L1-incongruent homophones and L2 congruent control words (Figure 4.2). Additionally, significant negative effects emerged between firstly, the L2-incongruent/L1-congruent condition and the control condition, and secondly the L2-congruent/L1-incongruent condition and the control condition. The latter effects exhibited different time-courses from the N400 effect to L2-incongruent/L1-incongruent words. Specifically the L2-incongruent/L1-congruent words elicited a negative effect in the early time window (250-450 ms), which was absent in later time windows. Conversely, the L2-congruent/L1-incongruent condition elicited a negative effect in the late time window (650-850 ms), which was absent in earlier time windows. Taken together these results seem to show cross-linguistic semantic activation of homophone meanings. If only the semantic features of the target language meaning of the homophone would have been considered, the L2-incongruent/L1-congruent condition would have elicited a canonical N400 effect, and the L2-congruent/L1-incongruent condition would not have elicited a negative effect. Interestingly, the time course of the negative effect seems to suggest a target language priority for homophone meaning activation. The semantic features of the non-target language seem not to be initially available (cf., FitzPatrick & Indefrey, 2010; Chapter 2 of this thesis) leading to an initial incongruity in the L2-incongruent/L1-congruent condition, and initial congruity in the L2-congruent/L1-incongruent condition. But when the non-target language semantics assert themselves after a short delay this then leads to an attenuation of the negative effect in the L2-incongruent/L1-congruent condition due to the congruity of the non-target language semantics, and an increased negative effect in the L2-congruent/L1-incongruent condition due to the incongruity of the non-target language semantics.

Results

In summary, results from experiment 1 show differential effects of interlingual homophones on the amplitude of the N400 depending on the semantic fit of their L1 and/or L2 meanings with the sentence context. In order to properly interpret these results, it is important to establish whether these data reflect a modulation of the N400 component or could otherwise be attributed to superposition of an N400 and an LPC (e.g., Moreno, et al., 2002). Thus, our aim for experiment 2 was to compare results from experiment 1 to a situation in which activation of cross-linguistic semantics to target words is a given, namely when using language switches.

4.3 Experiment 2

Methods

Participants

Experiment 2 used the same participants as Experiment 1 in separate sessions, and on separate days.

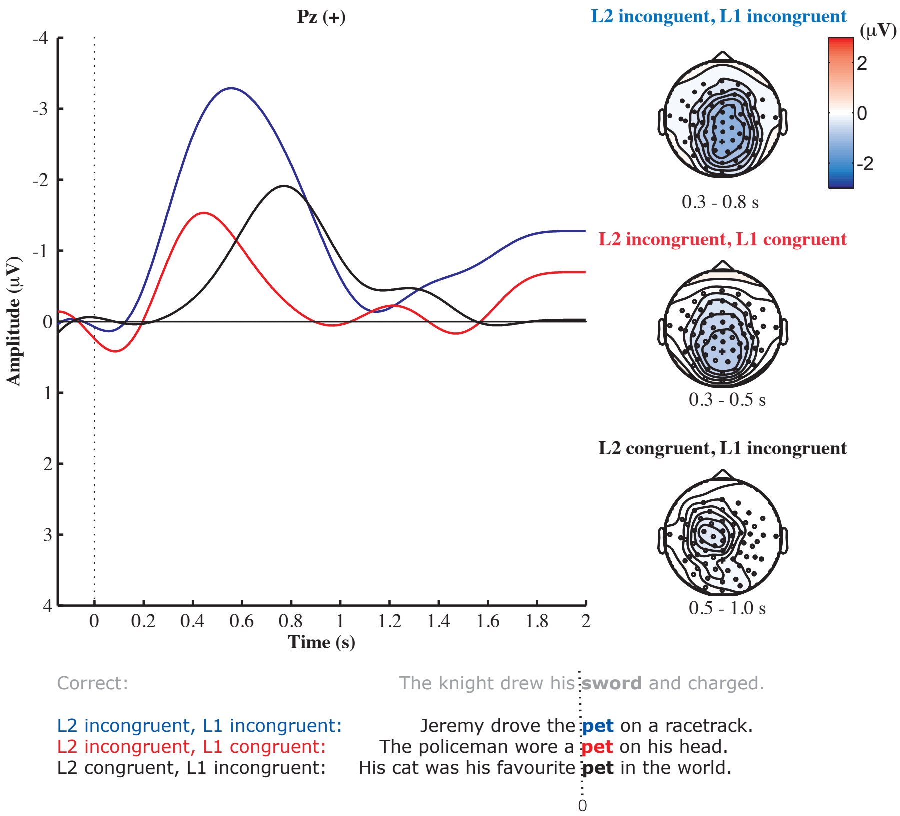


Figure 4.2: Grand average ERPs for the centro-parietal electrode Pz (left panel) time-locked to the onset of the critical word (below, printed in bold) and iso-voltage topographical plots (right panel). Plots and waveforms represent differences between the correct condition (grey sentence) and: the L2-incongruent/L1-incongruent condition (blue), the L2-incongruent/L1-congruent condition (red), and the L2 congruent/L1-incongruent condition (black). + denotes Pz electrode in topographical plots. For unfiltered waveforms see Appendix C, Figure C.1

Materials

The speaker and recording procedure for the stimulus materials were identical to Experiment 1. We created four sentence frames for each of 238 monosyllabic non-homophonic critical words spanning four experimental conditions (56 items per condition). These four frames were split over four stimulus lists such that each critical word occurred only once per list. Each stimulus list was presented to an equal number of participants. Critical words were either: (a) congruent with the

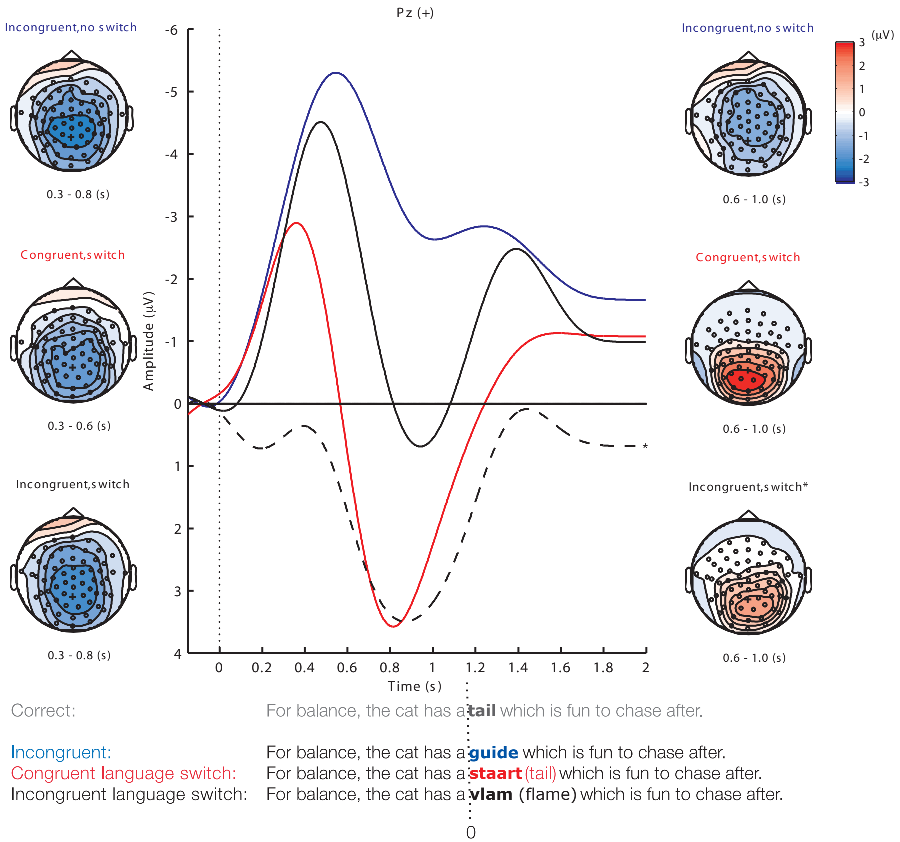


Figure 4.3: Grand average ERPs for the centro-parietal electrode Pz (centre panel) time-locked to the onset of the critical word (below, printed in bold) and isovoltage topographical plots for the N400 time window (left panel) and LPC time window (right panel). Plots and waveforms represent differences between the correct condition (grey sentence) and: incongruent condition (blue), the congruent, language switch condition (red), and the incongruent, language switch condition (black). + denotes Pz electrode in topographical plots. * indicates waveform (black, dashed) and topographical plot (right panel, bottom) for the contrast between the incongruent condition and the incongruent, language switch condition, provided for comparison. For unfiltered waveforms see Appendix C, Figure C.2

sentence context, (b) incongruent with the sentence context, (c) L1 lexical items that were congruent with the sentence context, or (d) L1 lexical items that were incongruent with the sentence context. We additionally added 112 semantically congruent filler sentences to each stimulus list. Aside from the L1 critical words all other materials were in English (L2). A full list of experimental materials is available in Appendix C, Table C.2.

The cloze testing (average English cloze probability: 0.74, average Dutch cloze probability: 0.79) and frequency matching procedures (average frequency per million: Correct control = 51.04; Incongruent = 44.12; Congruent, language switch = 69.16; Incongruent, language switch = 47.50) were identical to Experiment 1.

Procedure

The experimental procedure, was identical to Experiment 1. In Experiment 2, participants answered 85% of the animacy questions correctly, suggesting that they had attentively listened to the stimulus materials.

EEG Recording and Analysis

The EEG recording procedure was identical to Experiment 1. Statistical analysis was performed by taking the mean amplitude per site (see Figure 4.1) from the grand averaged data in same latency ranges as Experiment 1 (250-450 ms, 450-650 ms, and 650-850 ms relative to critical word onset). In each latency range we used an omnibus analysis of variance (ANOVA) with congruity (2 levels), switching (2 levels) and site (9 levels) as within subject factors. All p values are reported after Greenhouse-Geisser correction (Greenhouse & Geisser, 1959). Cluster randomization was performed on the following pairs of conditions: Incongruent, no switch versus control; Congruent, switch versus control; Incongruent, switch versus control; Incongruent, switch versus Incongruent; in the latency range between 200 ms and 2000 ms.

250-450 ms

The ANOVA yielded a significant main effect of switching ($F(1,24) = 14.058$, $p<0.01$, $\eta^2 = 0.369$), a significant interaction between congruity and switching ($F(1,24) = 5.437$, $p<0.05$, $\eta^2 = 0.185$) reflecting a greater difference between congruent and incongruent critical words when they were not language switched. There was also a significant interaction between switching and site ($F(8,192) = 4.763$, $p<0.01$, $\eta^2 = 0.244$), reflecting the fact that most sites showed an increased negativity to switched versus non-switched words with the exception of the left occipital site.

450-650 ms

The ANOVA yielded a significant main effect of congruity ($F(1,24) = 46.727$, $p<0.001$, $\eta^2 = 0.661$), with semantically incongruent words showing a greater negativity than semantically congruent words.

650-850 ms

The ANOVA yielded a significant main effect of congruity ($F(1,24) = 24.182$, $p<0.001$, $\eta^2 = 0.502$), with semantically incongruent words showing a greater negativity than semantically congruent words. There was also a significant main effect of switching ($F(1,24) = 18.510$, $p<0.001$, $\eta^2 = 0.435$), with language switched words showing a greater positivity than non-switched words.

Cluster Randomisation Statistics

Semantic incongruity led to a negative effect irrespective of whether the critical word was a language switch ($p<0.001$; onset 296 ms; offset 754 ms) or not ($p<0.001$; onset 278 ms; offset 876 ms). Language switched, semantically congruent words led to a transient negativity ($p<0.001$; onset 202 ms; offset 560 ms). Language switches additionally elicited a late positive effect irrespective of whether they were semantically congruent ($p<0.001$; onset 572 ms; offset 1112 ms) or semantically incongruent ($p<0.05$; onset 598 ms; offset 1178 ms). The isovoltage topographical plots (Figure 4.3) of the negative effect show it to have a centro-parietal distribution, whereas the positive effect had a largely parieto-occipital distribution. The semantically incongruent words do not exhibit the positive effect.

Discussion

In Experiment 2 we investigated the electrophysiological correlates of perceived language switching in spoken language comprehension using semantically congruent and incongruent language switches. Processing of semantically incongruent words led to an N400 effect compared to semantically congruent words, irrespective of whether the words were language switched or not. When the language switch was semantically congruent with the sentence context an initial negativity emerged, thereby providing support for our assertion from Experiment 1 that cross-linguistic semantics are initially unavailable (cf., FitzPatrick & Indefrey, 2010; Chapter 2 of this thesis). The initial negativity was followed by an LPC with a mostly posterior scalp distribution. This LPC also emerged in the semantically incongruent language switch condition but was not observed in the non-switched conditions.

In light of these results we now return to the question of whether the N400 modulation, which was observed in Experiment 1, could be attributable to an LPC effect, due to cross-language semantic activation to homophones. A number of different observations render this particular interpretation unlikely. Firstly, the magnitude of the LPC to language switches in Experiment 2 was far greater ($\sim$6 μV) compared to the positive deflection of the waveform in the L2-incongruent/L1-congruent condition of Experiment 1 ($\sim$1.5 μV). Secondly, the LPC showed a largely posterior scalp topography (Figure 4.3) whereas the effect in the L2-incongruent/L1-congruent condition was broadly similar to the N400 effect in the L2-incongruent/L1-incongruent condition. Finally, the semantically incongruent, language switched condition in Experiment 2 was indicative of a superposition of an LPC onto an on-going N400 effect. In this condition the positive deflection starts to emerge around 600 ms post stimulus, whereas the negativity in the L2-incongruent/L1-congruent condition of Experiment 1 had already offset around 440 ms post stimulus. In summary, the results from Experiment 2 show a, largely posterior LPC effect to language switches irrespective of their semantic congruity. This effect seems to be distinct from the observed modulation of the N400 in Experiment 1. We therefore consider it unlikely that the N400 modulation in Experiment 1 is the result of co-occurring N400 and LPC effects, owing to the activation of cross-linguistic semantics.

4.4 General Discussion

The present study investigated processing of interlingual homophones and L2 to L1 language switches in non-native spoken language comprehension. In Experiment 1, Dutch-English bilinguals listened to sentences in which we had manipulated the semantic congruity of a Dutch-English interlingual homophone. The homophone could be semantically incongruent with respect to both its English (L2) and Dutch (L1) meanings (L2-incongruent/L1-incongruent), congruent with respect to its L1 but not its L2 meaning (L2-incongruent/L1-congruent), or congruent with respect to its L2 but not its L1 meaning (L2-congruent/L1-incongruent). These conditions were each compared to a semantically congruent control condition with a non-homophone target word (control condition).

As expected we firstly obtained a significant N400 effect between the control condition and the condition in which neither meaning of the homophone made sense within the context (L2-incongruent/L1-incongruent condition). Interestingly, we further found a transient N400 effect between the control condition and the L2-incongruent/L1-congruent condition that offset earlier than the effect in the contrast between the L2-incongruent/L1-incongruent condition and the control condition. This divergent pattern of the N400 effect between the L2-incongruent/L1-incongruent condition and the L2-incongruent/L1-congruent condition seems remarkably similar to the ERP waveforms obtained by Van Petten & Kutas (1987; their Figure 1) and Swaab et al. (2003; their Figure 2) to targets following intralingual homophone/homograph primes at early ISIs (100-200 ms). In their studies the N400 to targets related to the contextually inappropriate meaning of the ambiguous prime offset earlier than the N400 to targets that were semantically unrelated to the prime. Targets related to the contextually appropriate meaning of the prime exhibited substantially lower N400 components. These results showed activation of the contextually appropriate and contextually inappropriate homophone/homograph meanings, although Van Petten & Kutas (1987) attributed their results to backward priming (e.g., Kiger & Glass, 1983; but see: Swaab, et al., 2003). In our study, the earlier offset of the N400 in the L2-incongruent/L1-congruent condition thus suggests delayed availability of (in this case congruent) cross-linguistic semantics attenuating the incongruity effect. Supporting this assertion we also obtained a negative effect in the contrast between L2-congruent/L1-incongruent and the control condition. This negativity, however, emerged later than the transient negative effect in the L2-congruent/L1-incongruent condition suggesting that, in this case, the later activation of incongruent semantic features from the L1 led to an increased incongruity response. We purposefully refrain from referring to the latter negativity as an N400 as, while the scalp topography of the N400 effect in the L2-incongurent/L1-congruent condition was almost identical to that in the L2-incongruent/L1-incongruent condition, the negativity in the L2-congruent/L1-incongruent condition had a more left-frontal distribution (Figure 4.2). These differences could either signify a separate ERP component, part of a multiphasic N400 component, or an N400 effect that has been modulated by processes that would otherwise have been obscured by the main N400 effect. However, the present data cannot distinguish between these accounts.

Taken together these findings suggest that when processing interlingual homophones, semantic features of the target (context) language become available to the bilingual earlier than semantic features of the non-target language. Our results also have implications for our understanding of the nature of between language interactions. Although a constraining sentence context has been shown to attenuate between-language lexical activation (e.g., Duyck, et al., 2007; FitzPatrick & Indefrey, 2010; Chapter 2 of this thesis; Schwartz & Arêas Da Luz Fontes, 2008), the present data suggest that given enough interlingual overlap lexical candidates can be elicited across languages, even in semantically constraining sentence contexts.

At first glance, the sequential nature of target, and non-target language semantic activation to interlingual homophones is reminiscent of (re)ordered access accounts of ambiguous word processing (e.g., Duffy, et al., 1988; Hogaboam & Perfetti, 1975). However, our data cannot be explained solely by the interplay of contextual semantic constraint and relative lexical frequency, but rather suggest an additional influence of language context. The bilinguals in our study were highly proficient, however all had vastly more language experience in Dutch than in English (on average, 20 years vs. 8 years). This would suggest that the L1 meaning of the homophone should have a subjectively higher frequency than the L2 meaning of the homophone. In essence, this would predict that the L1 meaning of the homophone should be accessed first unless the context biases towards the L2 meaning of the homophone. Our data, however, suggest that the target language (i.e., L2) meaning of the homophone is accessed first regardless of the contextual bias. The contextual independence of the order of meaning activation is thus more suggestive of an exhaustive access account for interlingual homophone processing whereby the target language meaning has a head start. In other words, this could be taken to suggest that language membership information supersedes contextual bias and lexical frequency during processing of interlingual homophones. A possible avenue for future studies would be to establish whether contextual bias and/or relative frequency of the homophones affect the time course of between language meaning activation. The present data suggest that such contextual bias and/or frequency effects may not override the target language priority we observe here, but could nevertheless lead to speeding up or slowing down of non-target language meaning activation. Outcomes of this line of investigation may shed further light on how interlingual homophones processing relates to intralingual homophone processing.

An alternative way of looking at this pattern of results would be that the homophone, which has form features that best match the L2 meaning, activates the L2 meaning first and the L1 meaning is only elicited due to spread of activation at the word form level (due to phonological overlap of L1 and L2 word forms). Such an account would set interlingual homophony apart from intralingual homophony as it would always entail delayed activation of the less-well matching homophone meaning. We cannot fully discount this possibility, however the fact that, in our study, language switches also showed delayed availability of cross-linguistic semantics goes against an activation spreading account. Future studies will have to investigate whether the same sequential pattern of target and non-target language meaning activation also occurs when the interlingual homophone is pronounced according to non-target language phonology. If, in this case, the sequence of meaning activation still shows a target language priority this would constitute evidence against an activation spreading account of interlingual homophone processing.

In Experiment 2 we investigated whether the observed modulation of the N400 from Experiment 1 could be attributable to the co-occurrence of the N400 with an LPC effect, triggered by activation of cross-linguistic semantics. We therefore performed a replication of Moreno et al. (2002) who had observed an LPC effect to language switches compared to control words. In contrast to Moreno et al. (2002) we used auditory stimulus materials and included a semantically incongruent/language switched condition. Our results showed that language switches elicited a substantial LPC effect irrespective of whether the language switch was semantically congruent or Ðincongruent, thereby replicating Moreno et al.'s finding (2002). We further obtained a transient negative effect in the contrast between the semantically congruent/language switch and the semantically congruent control condition. This effect was similar in time-course but not in scalp topography to the negative effect reported in Moreno et al. (2002) to semantically congruent language switches. Moreno et al. (2002) speculate that the early effect might reflect a Left Anterior Negativity (LAN) which arises due to working memory demands resulting from syntactically integrating the language switched word into the base language context. In our data the scalp distribution of the transient negative effect was identical to that of the N400 and we thus consider this effect to be a reflection of the initial unavailability of the language switched semantics. Such an account would be compatible with FitzPatrick & Indefrey (2010; Chapter 2 of this thesis) who showed that between-language initial phonemic overlap did not influence the time-course of the N400. The morphology, scalp topography, and latency of the LPC effect (Figure 4.3) seem to be distinct from the N400 modulation we observed in Experiment 1. This interpretation is strengthened by the fact that we did not observe an LPC to L2-congruent/L1-incongruent homophones despite evidence of cross-language activation in this condition. These results thus verify our interpretation of the N400 modulations observed in Experiment 1 as indicative of the relative time course of within and between language semantic activation. This also begs the question of how to interpret the LPC effect.

The functional relevance of the LPC (or P300/ P3 as it is sometimes referred to) in studies of language switching is as yet unclear. There is, however a rich body of literature pertaining to late positive ERP effects (a full discussion of which is beyond the scope of the present article) in both linguistic and non-linguistic tasks and settings (For a review see: Polich, 2007). The amplitude of the LPC is purportedly determined by three separate factors (Johnson, 1986): (1) improbability, with more improbable stimuli eliciting larger positivities, (2) meaning, encompassing task complexity and stimulus valence, and (3) transfer, referring to in how much detail the stimulus is evaluated and how much attention is paid to it. Indeed, results from those studies that showed late positivities to language switches (Moreno, et al., 2002; Martin, Dering, Thomas & Thierry, 2009) can easily be interpreted within this framework. As Moreno et al. (2002) point out, the language switches in their study could be considered highly improbable events for their participants and thus not very ecologically valid. The improbability thus explains why the LPC emerged to the language switches but not lexical switches in their study. Martin et al. (2009) found that the amplitude of the late positivity was dependent on whether the language switch was task-relevant or not. In their study, Welsh-English bilinguals judged the number of characters of written prime-target pairs in either English or Welsh while ignoring the other language. When attending to English words there was a significant LPC effect between switches and non-switches when the language switches were from Welsh to English, but not when the switches were from English to Welsh. When attending to Welsh, the pattern was reversed. In the present study, the language switches were always into the bilinguals' native language (Dutch). One might speculate that it is more common for the Dutch-English bilinguals to hear English words in Dutch discourse than the reverse, as it is improbable that an English native speaker would use Dutch words. Thus, similar to Moreno et al. (2002) the LPC effect in our study could be explained in terms of the improbable nature of the language switches. On the basis of this interpretation one might derive the following prediction for future studies, namely that Dutch-English bilinguals will exhibit a smaller LPC effect when processing Dutch-to-English language switches or when processing English-to-Dutch switches in Dutch accented English contexts (where switches into Dutch may be more expected).

4.5 Conclusions

The present study demonstrates that the bilingual cannot help but activate both meanings of cross-linguistic homophones, irrespective of whether they make sense within the current context or not. Our data also suggest how bilinguals may avoid comprehension problems in this situation: The bilingual's comprehension system gives the target language meaning a head start that likely reduces the competitive strength of the inappropriate alternative, thereby negating the ambiguity.

4.6 References

Allan, D. (1992). *Oxford placement test.* Oxford: Oxford University Press.

Baayen, R. H., Piepenbrock, R., & van Rijn, H. (1993). *The CELEX lexical database.* Philadelphia, PA: University of Pennsylvania, Linguistic Data Consortium.

Binder, K. S., & Rayner, K. (1999). Does contextual strength modulate the subordinate bias effect? A reply to Kellas and Vu. *Psychonomic Bulletin & Review*, *6*(3), 518-5223.

Brown, C. M., & Hagoort, P. (1993). The processing nature of the N400 - Evidence from masked priming. *Journal of Cognitive Neuroscience*, *5*(1), 34-44.

Dijkstra, T. (2005). *Bilingual Visual Word Recognition and Lexical Access.* In J. F. Kroll & A. M. B. de Groot (Eds.), *Handbook of bilingualism: Psycholinguistic approaches* (pp. 179-201). New York: Oxford University Press.

Dijkstra, T., & Van Heuven, W. J. B. (1998). The BIA model and bilingual word recognition. In J. Grainger & A. Jacobs (Eds.), *Localist connectionist approaches to human cognition* (pp. 189-225). Mahwah, NJ: Erlbaum.

Dijkstra, T., & Van Heuven, W. J. B. (2002). The architecture of the bilingual word recognition system: From identification to decision. *Bilingualism: Language and Cognition*, *5*(3), 175-197.

Duffy, S. A., Morris, R. K., & Rayner, K. K. (1998). Lexical ambiguity and fixation times in reading. *Journal of Memory and Language*, *27*(4), 429-446.

Duyck, W., Van Assche, E., Drieghe, D., & Hartsuiker, R. J. (2007). Visual word recognition by bilinguals in a sentence context: Evidence for nonselective lexical access. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *33*(4), 667-679.

Ferree, T.C., Luu, P., Russell, G.S., & Tucker, D.M. (2001). Scalp electrode impedance, infection risk, and EEG data quality. *Clinical Neurophysiology*, *112*(3), 536-544.

FitzPatrick, I., Culter, A., & Indefrey P. (2010). Context and proficiency effects on cross-linguistic lexical activation. *Manuscript submitted for publication.*

FitzPatrick I., & Indefrey P. (2010). Lexical Competition in Nonnative Speech Comprehension. *Journal of Cognitive Neuroscience*, *22*(6), 1165-1178.

Glucksberg, S., Kreuz, R. J., & Rho, S. H. (1986). Context can constrain lexical access: Implications for models of language comprehension. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *12*(3), 323-335.

Grainger, J., & Dijkstra, T. (1992). On the representation and use of language information in bilinguals. In R. J. Harris (Ed.), *Cognitive Processing in*

Bilinguals (pp. 207-220). Amsterdam: Elsevier Science Publishers.

Greenhouse, S. W., & Geisser, S. (1959). On methods in the analysis of profile data. *Psychometrika*, *24*(2), 95-112.

Grosjean, F. (1982). *Life with two languages: An introduction to bilingualism.* Cambridge, MA: Harvard University Press.

Hogaboam, T. W., & Perfetti, C. A. (1975). Lexical ambiguity and sentence comprehension. *Journal of Verbal Learning and Verbal Behavior*, *14*(3), 265-274.

Johnson R. (1986). A triarchic model of P300 amplitude. *Psychophysiology*, *23*(4), 367-384.

Jung, T. P., Makeig, S., Humphries, C., Lee, T. W., McKeown, M. J., Iragui, V., & Sejnowski, T. J. (2000). Removing electroencephalographic artefacts by blind source separation. *Psychophysiology*, *37*(2), 163-178.

Kellas, G., & Vu, H. (1999). Strength of context does modulate the subordinate bias effect: A reply to Binder and Rayner. Psychonomic Bulletin & Review, 6(3), 511-517.

Kiger, J. I., & Glass, A. L. (1983). The facilitation of lexical decisions by a prime occurring after the target. *Memory & Cognition*, *11*(4), 356-365.

Kruskal, W. H., & Wallis, W.A. (1952). Use of ranks in one-criterion variance analysis. *Journal of the American Statistical. Association*, *47*(260), 583-621.

Kutas, M., & Hillyard, S. A. (1980). Reading senseless sentences - Brain potentials reflect semantic incongruity. *Science*, *207*(4427), 203-205.

Kutas, M., & Hillyard, S. A. (1984). Brain potentials during reading reflect word expectancy and semantic association. *Nature*, *307*(5947), 161-163.

Lemhöfer, K., Dijkstra, T., & Michel, M. C. (2004). Three languages, one ECHO: Cognate efects in trilingual word recognition. *Language and Cognitive Processes*, *19*(5), 585-611.

Li, P. & Yip, M. C. (1998). Context effects and the processing of spoken homophones. *Reading and Writing*, *10*(3-5), 223-243.

Marian, V., & Spivey, M. J. (2003a). Bilingual and monolingual processing of competing lexical items. *Applied Psycholinguistics*, *24*(2), 173-193.

Marian, V., & Spivey, M. J. (2003b). Competing activation in bilingual language processing: Within- and between-language competition. *Bilingualism: Language and Cognition*, *6*(2), 97-115.

Marian, V., Spivey, M. J., & Hirsch, J. (2003). Shared and separate systems in bilingual language processing: Converging evidence from eyetracking and brain imaging. *Brain and Language*, *86*(1), 70-82.

Maris, E. (2004). Randomization tests for ERP topographies and whole spatiotemporal data matrices. *Psychophysiology*, *41*(1), 142-151.

Martin, C.D., Dering, B.R., Thomas, E.M., & Thierry, G. (2009). Brain potentials reveal semantic priming in both the 'active' and the 'non-attended' language of early bilinguals. *Neuroimage*, *47*(1) 326-333.

Meara, P. M. (1996). *English vocabulary tests: 10k.* Swansea, UK: Centre for Applied Language Studies.

Moreno, E. M., Federmeier, K. D., & Kutas, M. (2002). Switching languages, switching palabras (words): An electrophysiological study of code switching. Brain and Language, 80(2), 188-207.

O'Rourke, T. B., & Holcomb, P. J. (2002). Electrophysiological evidence for the efficiency of spoken word processing. *Biological Psychology*, *60*(2-3), 121-150.

Pacht, J. M., & Rayner, K. (1993). The processing of homophonic homographs during reading: Evidence from eye movement studies. *Journal of Psycholinguistic Research*, *22*(2), 251-271.

Polich, J. (2007). Updating P300: An integrative theory of P3a and P3b. *Clinical Neurophysiology*, *118*(10), 2128-2148.

Praamstra, P., Meyer, A. S., & Levelt, W. J. M. (1994). Neurophysiological manifestations of phonological processing - Latency variation of a negative ERP component timelocked to phonological mismatch. *Journal of Cognitive Neuroscience*, *6*(3), 204-219.

Rayner, K., Pacht, J. M., & Duffy, S. A. (1994). Effects of prior encounter and global discourse bias on the processing of lexically ambiguous words: Evidence from eye fixations. *Journal of Memory and Language*, *33*(4), 527-544.

Schulpen, B., Dijkstra, T., Schriefers, H. J., & Hasper, M. (2003). Recognition of interlingual homophones in bilingual auditory word recognition. Journal of Experimental Psychology: Human Perception and Performance, 29(6), 1155-1178.

Schwartz, A. I., & Kroll, J. F. (2006). Bilingual lexical activation in sentence context. *Journal of Memory and Language*, *55*(2), 197-212.

Schwartz, A.I., & Arêas Da Luz Fontes, A. B. (2008). Cross-language mediated priming: Effects of context and lexical relationship. *Bilingualism: Language and Cognition*, *11*(1), 95-110.

Simpson, G.B. (1981). Meaning dominance and semantic context in the processing of lexical ambiguity. *Journal of Verbal Learning and Verbal Behavior*, *20*(1), 120-136.

Simpson, G. B., & Kang, H. (1994). *Inhibitory processes in the recognition of homograph meanings.* In: Dagenbach, D., & Carr, T. H. (Eds.), Inhibitory Processes in Attention, Memory, and Language (pp. 359-378). Academic Press, San Diego, CA.

Spivey, M. J., & Marian, V. (1999). Cross talk between native and second languages: Partial activation of an irrelevant lexicon. *Psychological Science*, *10*(3), 281-284.

Swaab, T. Y., Brown, C. M., & Hagoort, P. (2003). Understanding words in sentence contexts: The time course of ambiguity resolution. *Brain and Language*, *86*(2), 326-343.

Swinney, D. A. (1979). Lexical Access during Sentence Comprehension: (Re) Consideration of Context Effects. *Journal of Verbal Learning and Verbal Behavior*, *18*(6), 645-659.

Tabossi, P. (1988). Accessing lexical ambiguity in different types of sentential contexts. *Journal of Memory and Language*, *27*(3), 324-340.

Takashima, A., Jensen, O., Oostenveld, R., Maris, E., van de Coevering, M., & Fernández, G. (2006). Successful declarative memory formation is associated with ongoing activity during encoding in a distributed neocortical network related to working memory: A magnetoencephalography study. *Neuroscience*, *139*(1), 291-297.

Tanenhaus, M.K., Spivey-Knowlton, M.J., Eberhard, K.M., & Sedivy, J.C. (1995). Integration of visual and linguistic information in spoken language comprehension. *Science*, *268*(5217), 1632-1634.

Tuladhar, A. M., Ter Huurne, N., Schoffelen, J. M., Maris, E., Oostenveld, R., & Jensen, O. (2007). Parieto-occipital sources account for the increase in alpha activity with working memory load. *Human Brain Mapping*, *28*(8), 785-792.

Van Heuven, W. J. B., Dijkstra, T., & Grainger, J. (1998). Orthographic neighborhood effects in bilingual word recognition. *Journal of Memory and Language*, *39*(3), 458-483.

Van Petten, C., & Kutas, M. (1987). Ambiguous words in context: An event-related potential analysis of the time course of meaning activation. *Journal of Memory and Language*, *26*(2), 188Đ208.

Weber, A., & Cutler, A. (2004). Lexical competition in non-native spoken-word recognition. *Journal of Memory and Language*, *50*(1), 1-25.

ENCODING OF LANGUAGE MEMBERSHIP INFORMATION IN THE BILINGUAL BRAIN

CHAPTER 5

Ian FitzPatrick and Peter Indefrey

Abstract

The present study investigated the representation of language membership information in the bilingual mental lexicon by examining the processing of language switches and interlingual homophones (e.g., *pet*, which is also Dutch for 'hat') in a spoken, second-language sentence context. In two separate experiments we manipulated the language membership and semantic fit of target words within the sentence. Semantic incongruity led to greater involvement of especially left BA45 likely reflecting a greater demand on semantic unification for incongruent lexical items compared to congruent lexical items. Language switches, on the other hand, led to activation of primarily left dorsolateral prefrontal cortex (DLFPC; BA 46). This DLPFC activity was observed irrespective of whether the critical word had native-language form features (language switches) or not (homophones). These results suggest that language switch related brain activation in comprehension does not depend on form-level cues, but must be triggered by more abstract (lemma or concept level) language membership representations.

Submitted for publication

5.1 Introduction

Bilinguals often demonstrate a remarkable capacity to keep their languages separate in daily use. Depending on the situation they are able to restrict their production to one of their languages to suit language competences of their interlocutor(s), or rapidly switch between languages with seemingly little effort. They accomplish all this, for the most part, without unintentionally producing mixed language utterances. Bilinguals must, therefore, have a mechanism of rapidly selecting words or word meanings based on their language membership. Indeed, bilinguals have been shown to be able to accurately judge language membership of spoken words based on their initial phonemes alone (Grosjean, 1988). This means that language membership information must be intricately linked to words in the bilingual lexicon. Little is known about how this linkage is accomplished, thus the aim of the present study is to investigate how language membership information is encoded in the bilingual mental lexicon.

One way of effectuating word-to-language mapping is by relying on form level differences between languages. In most cases, words are pronounced or written differently across languages, giving the bilingual a powerful cue with which to filter out non-target language items during language production or distinguish between interlingual lexical neighbours during comprehension. Alternatively, language membership may be encoded at a more abstract level linked to lemmas or even concepts. Such abstract language representations have been conceptualised as language tags (e.g., Poulisse & Bongaerts, 1994) or language nodes in models such as the Bilingual Interactive Activation (BIA; Grainger & Dijkstra, 1992) and BIA+ (Dijkstra & Van Heuven, 1998) models. A possible way for us to distinguish between these two accounts is by examining how the bilingual brain responds to language switching.

A number of functional imaging studies have focussed on language switching, and the majority of those have done so in using speech production paradigms (for extensive reviews see: Abutalebi, 2008; Abutalebi & Green, 2007, 2008). Typically these studies involve blocks of experimental trials in which pictures had to be named in one language (non-switch) or alternating between languages (switch) (Hernandez, 2009; Hernandez, Dapretto, Mazziotta & Bookheimer. 2001; Hernandez, Martinez & Kohnert, 2000; Wang, Kuhl, Chen & Dong, 2009; Wang, G. Xue, Chen, F. Xue & Dong, 2007). A consistent finding when comparing switch to non-switch tasks is activation in the dorsolateral prefrontal cortex (DLPFC) predominantly on the left side, which is thought to reflect greater reliance on top-down executive control (Hernandez, et al., 2000, 2001; Rodriguez-Fornells, et al., 2005; Wang, et al., 2007) or more specifically attentional control (Wang, et al., 2009) when switching between languages. DLPFC involvement was also evident in bilinguals when between-language information conflicted during response selection in a go/no-go paradigm (Rodriguez-Fornells, et al., 2005). In addition, certain parietal (Hernandez, 2009; Price, Green & Von Studnitz, 1999; Wang, et al., 2009) and medial frontal areas (Hernandez, 2009; Rodriguez-Fornells, et al., 2005; Wang, et al., 2007; 2009) have been implicated as important substrates for producing language switches. While there is a large body of literature regarding production of language switches, there are surprisingly few functional imaging studies that have looked at comprehension of language switches.

One such study (Abutalebi, et al., 2007) found that bilinguals recruited bilateral Inferior Prefrontal Cortex and Superior Temporal Cortex when comprehending switches embedded in spoken utterances. Additionally the left-caudate nucleus and Anterior Cingulate Cortex (ACC) were involved when bilinguals heard switches into their less proficient language (for a similar finding in language production see: Wang, et al., 2007). Another study by Crinion et al. (2006) revealed a potential role of the head of the left caudate nucleus in language control. Their data showed a repetition priming effect in the left caudate for language switched related word pairs (*trout* - LACHS 'salmon'), whereas this effect was absent for within language word pairs (*trout* - SALMON). These findings could suggest a role for the caudate nucleus in monitoring and controlling the language currently in use (Crinion, et al., 2006), but may also reflect a more general supportive function of the left caudate when the system cannot solely rely on automatic processing (Friederici, 2006). Studies using Event-Related Potentials (ERPs) have also shown effects of language switching in comprehension (Moreno, Federmeier & Kutas, 2002; Martin, Dering, Thomas & Thierry, 2009). Moreno et al. (2002) found that, relative to control words, language switches elicited a late positive ERP component (LPC). The amplitude of the LPC was later found by Martin et al. (2009) to be dependent on whether the language switch was task-relevant or not. In their study, Welsh-English bilinguals judged the number of characters of written prime-target pairs in either English or Welsh while ignoring the other language. When attending to English words there was a significant LPC effect between switches and non-switches when the language switches were from Welsh to English, but not when the switches were from English to Welsh. When attending to Welsh, the pattern was reversed. The functional relevance of the LPC (or P300/ P3 as it is sometimes referred to) in studies of language switching is as yet unclear, however the pattern of results suggests that the LPC may not constitute a language switch effect but could be a reflection of the improbability of language switch trials and/or task relevance of the language switch stimulus dimension (for a similar view see: Moreno, et al., 2002). This interpretation would be in line with Johnson's (1986) triarchic model of the P300 effect in studies beyond the linguistic domain.

Taken together, previous studies highlight an important contribution of predominantly left inferior and dorsolateral frontal cortex and, potentially, the left caudate nucleus in comprehending and producing language switches. But although evidence pertaining to the neural substrates of language switching in the bilingual brain is steadily accumulating, the question remains at what representational level the language mismatch is detected. In other words, is a form level language mismatch necessary to produce a language switch response or can we also observe this response when only abstract lemma (or even conceptual) features signal the language change?

The present study aims to investigate the level at which language membership is represented in bilinguals by exploiting what we know about the language switch response in the brain. We contrasted activation to language switched words to activation to stimuli for which the form level gives no information about language membership: that is, interlingual homophones. Homophones (e.g., *pet*, which in Dutch means 'hat') are ideally suited to the purposes of this experiment as there is some evidence that bilinguals cannot avoid activating multiple meanings of these words, even across languages (e.g., Schulpen, Dijkstra, Schriefers & Hasper, 2003). Because interpreting language switches may also cause problems for semantic unification (and indeed some studies show that language switches elicit activation in brain regions thought to be involved in the semantic unification process e.g., Price, et al., 1999) we additionally manipulated the semantic fit of the homophones and language switches within the sentence.

In two experiments Dutch-English bilinguals listened to spoken sentences in their L2 (English). These participants took part in both Experiment 1 and Experiment 2. To minimize potential order effects the order of the experiments was counterbalanced across participants. In Experiment 1, stimulus sentences (see Table 5.1, for examples) included a critical word that was: congruent with the sentence context (control), incongruent with the sentence context (incongruent, no switch), an L1 lexical item that was congruent with the sentence context (congruent, language switch), or an L1 lexical item that was incongruent with the sentence context (incongruent, language switch). We expected the contrast between incongruent words and congruent control words to show a semantic incongruity effect in BA45. Additionally, we expected a language switch effect possibly including caudate nucleus, DLPFC, and Inferior Parietal Lobule (IPL), between the congruent, language-switch condition and the control condition. Lastly, we expected the incongruent, language-switch condition to exhibit both these effects.

In Experiment 2, the same group of Dutch-English bilinguals listened to L2 sentences (see Table 5.1, for examples) that included an interlingual near-homophone (e.g., *pet*, meaning 'hat' in Dutch). In different conditions either the English (L2) meaning but not the Dutch (L1) meaning was congruent with the English sentence context (L2-congruent/L1-incongruent), the Dutch meaning but not the English meaning was congruent with the context (L2 incongruent/L1-congruent) or neither the English nor the Dutch meaning were congruent with the context (L2-incongruent/L1-incongruent). For comparison we also included a control condition with a non-homophonic English word (e.g., *kite*) that was congruent with the sentence context (L2-congruent). If the form-level information is necessary for the language switch response we should not see switch related brain activation to homophones. If, on the other hand, language membership is encoded in language tags or language nodes we should see similar switch related brain activation for both language switches and homophones.

5.2 Experiment 1

Methods

Participants

Twenty-four right-handed Dutch-English bilinguals participated in the experiment, 22 of which were included in the final analysis (5 males; average age: 21.0 years). The participants' English proficiency was assessed using the average z-scores on 50 grammaticality judgement items of the Oxford Placement Test (Allan, 1992) (mean score: 43.7, "advanced level", $SD = 4.05$; maximum score: 50) and a non-speeded lexical decision test (60 items), created by Meara (1996) and later adapted by Lemhöfer, Dijkstra, and Michel (2004) (mean $\Delta M = 0.48$, $SD = 0.32$; maximum score: 1.0). Additionally participants completed an extensive language history questionnaire, which included a self-reported English proficiency measure (mean rating: 3.8 out of 5). Participants were either paid a small fee or they received study credits. None of the participants had any neurological impairment. All participants gave their written informed consent.

Conditions and stimulus examples		
Experiment 1: language switches involving form features not corresponding to context language		
Sentence context	*Critical word*	*Condition*
Pork is a kind of É	*meat*	Congruent/no switch
	shoe	Incongruent, no switch
	vlees (‘meat’)	Congruent, switch
	schoen (‘shoe’)	Incongruent, switch
Experiment 2: between language homophones (Dutch *pet* = kind of hat)		
Sentence context	*Critical word*	*Condition*
His cat was his favorite	*pet*	L2-congruent/L1-incongruent
The policeman wore a	*pet*	L2-incongruent/L1-congruent
Jeremy drove the	*pet*	L2-incongruent/L1-incongruent
We went to the Vatican to see the	*Pope*	Congruent

Table 5.1: Examples of stimulus materials.

Materials

With the exception of language switched critical words all experimental materials were in the subjects' second language (English). The experimental sentences, fillers, and practice items were spoken by one of the authors (a male, English-Dutch balanced bilingual) with normal intonation and at a normal speaking rate. The materials were digitally recorded in a sound-attenuating booth and digitised at a rate of 44.1 kHz. Sound files were later equalised to eliminate any differences in sound level.

We created four sentence frames for each of 224 monosyllabic non-homophonic critical words spanning four experimental conditions (56 items per condition). These four frames were split over four stimulus lists such that each critical word occurred only once per list. Each stimulus list was presented to an equal number of participants. Critical words were either: (a) congruent with the sentence context (control condition), (b) incongruent with the sentence context, (c) L1 lexical items that were congruent with the sentence context, or (d) L1 lexical items that were incongruent with the sentence context. A full list of experimental materials is available in Appendix C, Table C.2.

Twenty practice sentences were created (10 for each experiment) half of which were semantically congruent and half included a semantically incongruent word. None of the practice sentences included language switches or homophones. For both Experiment 1 and 2 separately, 112 semantically congruent filler items were constructed such that the number of regular and anomalous sentences was equal.

All sentence frames were cloze tested by an independent group of Dutch-English bilinguals (average English cloze probability: 0.74). Sentence frames in the language switched conditions were also cloze tested for Dutch completions (average Dutch cloze probability: 0.79). Additionally, each condition was controlled with respect to word frequency (average frequency per million: Correct control = 51.04; Incongruent = 44.12; Congruent, language switch = 69.16; Incongruent, language switch = 47.50). Word frequencies were taken from the CELEX lemma database (Baayen, Piepenbrock & van Rijn, 1993). Within each sentence frame the critical word was either the direct or indirect object of the verb and across conditions each critical word was preceded by an approximately equal amount of lexical content (see Table 5.1, for examples of stimulus materials). Critical words never occurred in a sentence-final position.

Ten items from each experimental condition as well as 6 additional filler items were converted to signal correlated noise (cf., Schroeder, 1968; Rodd, Davis & Johnsrude, 2005) to act as a low-level baseline. The experiment thus consisted of 46 items per experimental condition (4 conditions plus baseline) and 112 semantically congruent filler items.

Procedure

Participants were exclusively addressed in English by an English native speaker, both preceding and during the experiment, in order to make certain they were in a monolingual L2 language mode (Grosjean, 1982). To ensure that participants remained focussed on the task, they were prompted to make an animacy decision regarding the previous sentence on three occasions per block. These questions were always preceded and followed by filler items. Participants could respond by means of a button press. On average the participants answered 92% of these questions correctly, showing that they had attentively listened to the sentences. Each trial began with a 300 ms warning tone, followed by 1200 ms of silence, then a spoken sentence. The next trial began 4100 ms after the sentence offset. 1000 ms prior to the beginning of the sentence a fixation point was displayed. The fixation point remained until 1600 ms after the offset of the spoken sentence. Participants had a practice session with ten sentences to familiarize themselves with the experimental setting followed by three experimental blocks with short breaks in between.

After the experiment the participants completed a word translation test on the critical items to verify that they were known. On average the participants scored 87% on this translation test.

fMRI Recording and Anaysis

We acquired T2*-weighted EPI-BOLD fMRI data with a SIEMENS Trio 3T MR scanner using an ascending slice acquisition sequence (TR = 2.4 s, TE= 30 ms, 90° flip-angle, 35 slices, slice-matrix size = 64 x 64, slice thickness = 3.5 mm, slice gap = 0.5 mm, field of view = 224 mm, isotropic voxel size = 3.5 x 3.5 x 3.5 mm^3). At the end of the scanning session, a structural MR image volume was acquired for which a high- resolution T1-weighted 3D MP–RAGE sequence was used (TE = 3.93 ms, 8° flip-angle, 192 sagittal slices, slice thickness = 1.0 mm, voxel size = 1 x 1 x 1 mm^3). Image preprocessing and statistical analysis were performed using Statistical Parametric Mapping (SPM5; `http://www.fil.ion.ucl.ac.uk/spm`). The first 6 image volumes were discarded in order to avoid transient non-saturation effects. The functional EPI-BOLD images were realigned, slice-time corrected, and normalized to a Montreal Neurological Institute (MNI) T1 template image.

The normalized images were spatially filtered with a 10 mm FWHM 3D Gaussian kernel.

The fMRI data were proportionally scaled to account for global blood flow effects, and analyzed statistically using the general linear model and statistical parametric mapping (Friston, Holmes, Poline, Price, Frith & Frackowiak, 1995) in a 2-step mixed design procedure. At the first-level, single-subject fixed effect analyses were conducted. The linear model included mini-block regressors to model the sentence presentation from the onset of the critical word to the offset of the sentence. The beginnings of sentences and filler items were modelled together as a separate regressor of no interest. We included the realignment parameters for movement artifact correction and a temporal high-pass filter (cut-off 128 s) to account for low-frequency effects as effects of no interest. We temporally convolved the explanatory variables with the canonical hemodynamic response function provided by SPM5. Results were rendered onto an inflated average brain as provided by FreeSurfer (CorTechs Labs; `http://surfer.nmr.mgh.harvard.edu`) with the help of SPM SurfRend toolbox (`http://spmsurfrend.sourceforge.net`).

Low-level Baseline

Our intention was to use the signal correlated noise as a low-level baseline to account for acoustic processing of stimuli. Compared to an implicit baseline the signal-correlated noise yielded activation in left inferior parietal cortex (BA 40, x = -46, y = -60, z = 35) but no discernible activity in primary auditory areas. We consider it likely that scanner noise obscured activity in primary auditory cortex (cf., Moelker & Pattynama, 2003; Gaab, Gabrieli & Glover, 2007; Scarff, Dort, Eggermont & Goodyear, 2004). Because the low level baseline was not central to our research questions we excluded the condition from further analyses and treated the condition as a regressor of no interest.

Results and Discussion

Table 5.2 shows the foci of activation in contrasts between our conditions of interest and the control condition. Activations passing a voxel level threshold of $P<0.001$ (uncorrected) and a cluster extent threshold of 50 contiguous voxels are reported as significant. All coordinates are reported in MNI space. As in previous studies (For a recent review see: Hagoort, Baggio & Willems, 2009) semantic incongruity led to greater involvement of pars triangularis (BA 45) of Broca's complex relative to control. This activation was evident in the contrast between

Region	*BA*	*Cluster size*	*T-value*	*x*	*y*	*z*
Incongruent, no-switch >control						
Right prefrontal cortex		110				
R MFG	9		5.72	42	28	21
Left prefrontal cortex		62				
LIFG pars triangularis	45		5.08	-52	21	24
Congruent, switch >control						
Left prefrontal cortex		200				
L IFG	46		5.37	-46	46	4
L MFG	9,46		5.2	-46	21	28
Incongruent, switch >control						
Occipital cortex		370				
L Cuneus	17,18		6.15	-10	-88	14
L Posterior Cingulate	30		5.39	-18	-66	7
R MOG	18		4.43	14	-91	14
R Cuneus	18		3.9	14	-70	18
L Lingual Gyrus	18		3.58	-24	-74	-10
Right prefrontal cortex		55				
R IFG	45		4.78	38	24	21
Left prefrontal cortex		64				
L IFG	45		4.65	-49	35	4
L MFG	46		4.23	-52	28	21

Table 5.2: Significant clusters of activation thresholded at $P<0.001$ (uncorrected). Only foci of activation (8 mm apart) with a spatial extent greater than 50 voxels are shown here. Multiple peaks within a single activation cluster are shown indented. Coordinates are reported in MNI space. Abbreviations: L = left, R = right, IFG = inferior frontal gyrus, MFG = middle frontal gyrus.

the incongruent/no switch condition and the control condition (Figure 5.1) and between the incongruent/switch and the control condition. Additionally, these contrasts yielded activation of the right prefrontal cortex (BA 9 for incongruent/no switch; BA 45 for incongruent/switch).

The contrast between the congruent/language switch condition and the control condition (Figure 5.2) yielded significant activation in the Left Inferior Frontal Gyrus (IFG; BA 46) extending into the Left Medial Frontal Gyrus (BA 9/46). This activation is consistent with the DLPFC activation found in earlier studies of language switching in production (e.g., Hernandez, 2009; Hernandez, et al., 2000, 2001; Rodriguez-Fornells, 2005; Wang, et al., 2009). Further activation in this

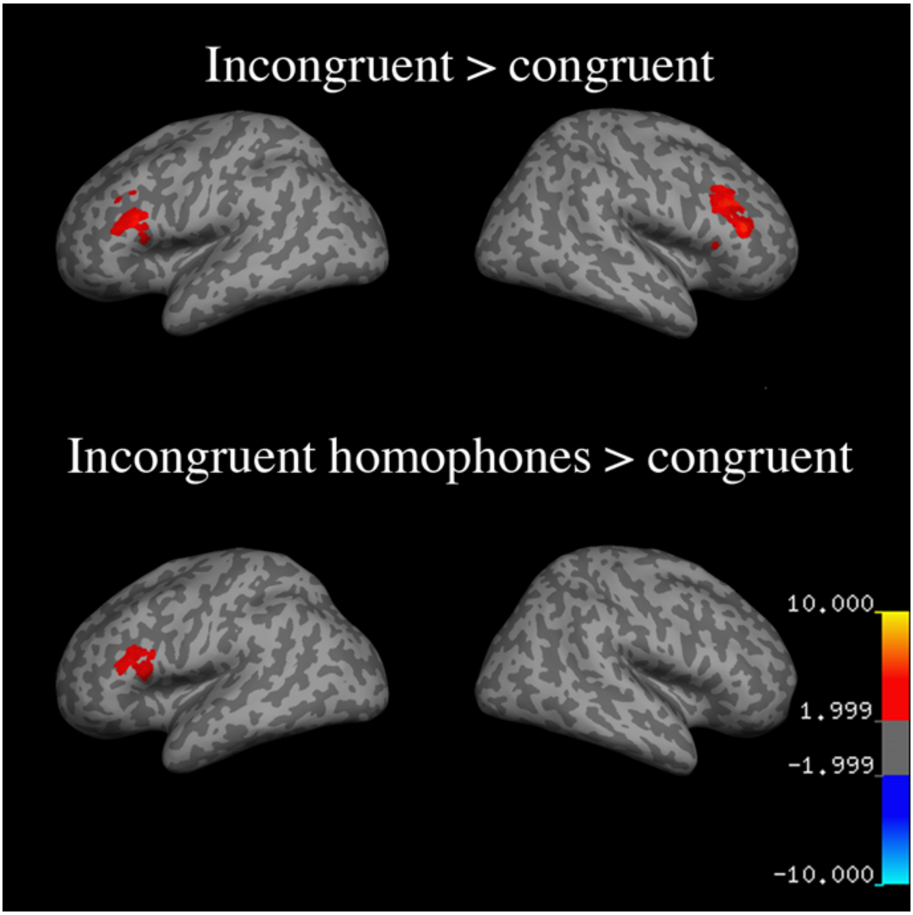


Figure 5.1: Semantic incongruity effect overlaid on inflated cortical surface for: (top) within language semantically incongruent items versus congruent control items and (bottom) L2-incongruent/L1-incongruent homophones versus congruent control items. Images thresholded at $P<0.001$ (uncorrected).

contrast was observed in the left Supplementary Motor Area (SMA; BA 6, x = -7, y = 18, z = 52; Figure 5.2), which had earlier been observed in Rodriguez-Fornells et al. (2005) and Van Heuven et al. (2008) and was taken to reflect response-based language conflict. However this activation did not reach the 50 voxel extent threshold.

As predicted, the contrast between the incongruent/language switch and the control condition showed a superposition of the language switch (Left MFG, BA46) and semantic incongruity effects (bilateral IFG, BA45). In addition, the contrast yielded a large cluster of activation bilaterally in the occipital cortex (see Table 5.1 for details). This cluster of activation was not predicted and we will further discuss this issue in the general discussion.

In summary, the results of Experiment 1 suggest that processing of L1 lexical items embedded in L2 spoken sentence contexts has a distinct pattern of activation from semantic unification and primarily involves the DLPFC on the left side. These, and converging data from studies of language switching in production (e.g., Hernandez, et al., 2000; 2001; 2009; Wang, et al., 2009) and comprehension (e.g., Abutalebi, et al., 2007), thus seem to confirm that the left-prefrontal cortex plays an important role in bilingual language switching. We can now turn our attention to the question at which level the language switch is detected. The critical words used in Experiment 1 were actual L1 lexical items produced according to L1 phonology, and thus established that left-inferior frontal regions were sensitive to language switches in comprehension when there was an overt form-level language mismatch. In Experiment 2, we sought to establish whether we could observe the same switching response when the language switches were not discernible from non-switches at the form level, namely by using interlingual homophones produced according to English phonology.

5.3 Experiment 2

Methods

Participants

Experiment 2 used the same participants as Experiment 1.

Materials

We chose 56 monosyllabic English-Dutch non-cognate interlingual homophones based on their phonetic transcriptions. For each of the homophones we created three sentence frames. The first sentence frame was semantically congruent with the English meaning of the homophone, the second was semantically congruent with the Dutch meaning of the homophone, and the third was semantically incongruent both in English and in Dutch. We created one further sentence frame paired with a non-homophonic semantically congruent critical word (control condition). We thus ended up with four conditions, each with 56 items. All sentence frames were cloze tested by an independent group of Dutch-English bilinguals (cloze probabilities: L2-congruent control = 0.72, L2-congruent/L1-incongruent = 0.60, L2-incongruent/L1-congruent = 0.00). Sentence frames in the L2-incongruent, L1-congruent condition were also cloze tested for Dutch completions (cloze probability = 0.60). Additionally, each condition was controlled with respect to word frequency (average frequency per million: L2-congruent control = 40.14, English homophone meaning = 40.47, Dutch homophone meaning = 34.3; see Table 5.1, for examples of stimulus materials).

Due to design constraints each participant heard each interlingual homophone in three different sentence contexts. To minimize potential order effects we created six pseudo randomised stimulus lists across which the order in which each occurred was balanced. Each stimulus list was presented to an equal number of participants. A full list of experimental materials is available in Appendix C, Table C.1.

To make certain that the homophones were not unintentionally uttered with a more Dutch sounding accent in any of the conditions, an independent group of participants (n=10) judged 3 tokens of each homophone (56 homophones x 3 conditions) with respect to whether they could perceive any trace of a Dutch accent. The homophones were taken from the original stimulus materials and were presented in isolation. Participants heard each homophone token once and made a non-speeded judgement on a five-point scale (1=weak accent, 5=strong accent) 1600 ms after stimulus offset. A Kruskal-Wallis Test (Kruskal & Wallis, 1952) on each homophone utterance ranked by the sum of judgement scores across all participants, revealed no significant differences per condition (L2-incongruent/L1-incongruent: Mdn = 2, Range = 1-5; L2-incongruent/L1-congruent: Mdn = 2, Range = 1-5; L2-congruent/L1-incongruent: Mdn = 2, Range = 1-5; $H(2) = .556$, $p>.05$).

Procedure

The experimental procedure was identical to Experiment 1. In Experiment 2 the participants answered (on average) 85% of the animacy judgment questions correctly, showing that they had attentively listened to the sentences. As in Experiment 1, the participants completed a word translation test on the critical items after the experiment. On average the participants scored 92% on this translation test.

fMRI Recording and Analysis

fMRI acquisition and analysis procedures were identical to Experiment 1.

Region	*BA*	*Cluster size*	*T-value*	*x*	*y*	*z*
L2-incongruent/L1-incongruent >control						
Left prefrontal cortex		50				
L IFG pars triangularis	45		5.01	-49	24	18
L2-congruent/L1-incongruent >control						
no significant clusters						
L2-incongruent/L1-congruent >control						
Left Prefrontal Cortex		1664				
L IFG pars triangularis	44,45		9.54	-38	24	21
LIFG	46		7.28	-42	35	6
LIFG pars orbitalis	47		6.54	-42	21	-9
L insula			6.38	-28	21	-3
L MFG	8,9,10		6.25	-46	7	33
L Thalamus			5.23	-10	-14	3
L Putamen			5.15	-21	0	12
Left Parietal Cortex		461				
L IPL	40		7.17	-46	-42	42
L precuneus	7		4.35	-28	-66	33
Medial Frontal Cortex		447				
R Medial FG	8		7.05	4	24	45
L SFG	8		6.61	0	32	45
L Cingulate Gyrus	24,32		5.18	-4	7	27
L ACC	24		4.04	-10	21	24
Occipital Cortex		1100				
R Cuneus	17		6.89	10	-88	9
L Cuneus	18		5.99	-14	-94	18
R Uvula	18		5.71	14	-74	-33
R Cuneus	18		5.64	18	-77	15
R Lingual Gyrus	18		5.26	18	-74	-3
L Lingual Gyrus	18		4.16	-21	-74	-6
Right prefrontal cortex		968				
R IFG	47		6.76	38	21	-6
R MFG	46		6.75	49	35	21
R IFG	46		6.63	46	28	15

Table 5.3 – continued on next page.

Region	*BA*	*Cluster size*	*T-value*	*x*	*y*	*z*
R IFG	10		6.46	49	49	0
R IFG	9		5.66	60	14	24
R MFG	9		5.3	46	10	36
Left temporal cortex		158				
L fusiform gyrus	37		5.34	-42	-63	-12
L ITG	37		5.07	-56	-56	-9
Right parietal cortex		164				
R IPL	40		5.13	38	-49	45

Table 5.3 Significant clusters of activation thresholded at $P<0.001$ (uncorrected). Only foci of activation (8 mm apart) with a spatial extent greater than 50 voxels are shown here. Multiple peaks within a single activation cluster are shown indented. Coordinates are reported in MNI space. Abbreviations: L = left, R = right ,IFG = inferior frontal gyrus, MFG = middle frontal gyrus, SFG = superior frontal gyrus, ACC = Anterior Cingulate Cortex, ITG = inferior temporal gyrus, IPL = inferior parietal lobule.

Results and Discussion

We used the same thresholding criteria as in Experiment 1. Table 5.3 shows the foci of activation in contrasts between our conditions of interest and the control condition. As in Experiment 1, we found increased activation in left BA 45 in the contrasts between the L2-incongruent/L1-incongruent condition and the control condition (Figure 5.1), and L2-incongruent/L1-congruent and control, likely attributable to a semantic incongruity effect. In the latter contrast we found an extensive pattern of additional activations (Figure 5.2; See Table 5.3 for more details). This included activation of Left DLPFC (BA 46), medial frontal cortex involving the left Anterior Cingulate Cortex (ACC), right prefrontal cortex (BA 9, 10, 46, 47), left inferior temporal cortex (BA 37) and bilateral inferior parietal cortex (BA 40). Similar to the incongruent/switch condition in Experiment 1, the contrast between the L2-incongruent/L1-congruent condition and the control condition also yielded a large cluster of activation bilaterally in the occipital cortex (see below for a more extensive discussion). No significant differences emerged between the L2-congruent/L1-incongruent condition and the control condition.

In summary, results from Experiment 2 seem to firstly, reveal an effect of semantic incongruity, particularly in left BA 45, and secondly suggest a switching effect similar to Experiment 1 in left DLPFC (BA 9, 46), but also possibly involving Left ACC (BA 24), and bilateral IPL (BA 40). Implications of these results are discussed below.

5.4 General Discussion

The present study investigated the representation of language membership information in the bilingual mental lexicon. In Experiment 1, Dutch(L1)-English(L2) bilinguals listened to English (L2) sentences that contained a critical word, which was either semantically congruent or incongruent with the sentence and either language-switched or not. Results revealed an effect of semantic incongruity in left IFG pars triangularis (BA 45) and an effect of language switching in left DLPFC (BA 46). In Experiment 2, the critical words were Dutch-English homophones and, in different conditions, their English but not their Dutch meaning (L2-congruent/L1-incongruent), their Dutch but not their English meaning (L2-incongruent/L1-congruent) or neither English nor Dutch meaning (L2-incongruent/L1-incongruent) was semantically congruent with the context. Relative to non-homophone control words we observed an effect of semantic incongruity in BA 45 in the L2-incongruent/L1-incongruent condition and the L2-incongruent/ L1-congruent condition. The L2-incongruent/L1-congruent condition elicited an extensive pattern of additional activations including: left DLPFC (BA 9,46), left ACC (BA 24), and bilateral IPL (BA 40). There were no significant differences in the comparison between the L2-congruent/L1-incongruent condition and the control condition. This may suggest that the bilinguals treated the L2-congruent/L1-incongruent homophones as they would any other L2 congruent item and did not process the (incongruent) L1 semantic features, however this result should be interpreted with caution as it constitutes a negative finding. Furthermore, FitzPatrick and Indefrey (2010a; Chapter 4 of this thesis) did obtain a significant difference between the exact same experimental conditions in an Event-Related Potential (ERP) design with an independent group of Dutch-English bilinguals.

The activation of inferior temporal and/or occipital areas to L2-incongruent/L1-congruent homophones and semantically incongruent language switches relative to control sentences was surprising. We had no a-priori reason to expect differential activation of areas primarily involved in visual processing in any of our contrasts of interest. A tentative and highly speculative account for these results could be that, to resolve the language conflict in the L2-incongruent/L1-congruent and Incongruent, switch conditions the bilingual retrieves every conceivable cue that could help determine the language membership of the incoming lexical item. Such cues might include visualized orthographic word representations, which are not necessarily identical even in the case of homophones (e.g., *leaf* is a homophone of *lief* 'sweet').

By visual inspection, the pattern of activation for L2-incongruent/L1-congruent homophones seemed more extensive than the pattern of activation to language switches. This was not expected and could reflect additional processing requirements for L1 congruent homophones compared to language switches. To test this, we performed an extra analysis contrasting the L2-incongruent/L1-congruent homophones from Experiment 2 with the semantically congruent, language switches from Experiment 1 (Table 5.4) inclusively masked with previously established clusters of activation (Tables 5.2 & 5.3). This analysis revealed that L2-incongruent/L1-congruent homophones more strongly recruited the IFG including left BA 44 and 46, and bilateral BA 47. Additionally the left Cingulate Gyrus (BA 24, 32), left IPL (BA 40), and a number of left-sided subcortical areas (see Table 5.4, for more details) were more strongly activated for homophones than language switches. A tentative account for these results would be that the conflicting semantic, and language information for the L2-incongruent/L1-congruent homophones was the most demanding for our bilinguals' processing systems. In other words, this condition comparatively required the most effort on the part of the bilinguals in terms of arriving at an interpretation of the utterance.

Taken together these results suggest that both language switches (that have non-context language form features) and homophones (that have only context-language form features) induce language-switch related brain activation in especially left DLPFC. This activation is distinct from Left IFG (BA 45) activation attributable to semantic unification processes (e.g., Hagoort, et al., 2009). This pattern of results can be taken as evidence for the encoding of language membership information at the lemma/ conceptual level rather than at the form level.

Compared to the only previous functional imaging study on language switching in bilingual auditory language comprehension, Abutalebi, et al. (2007), our language-switch related activation foci in inferior prefrontal cortex were slightly more dorsal and we did not find superior temporal cortex activation. This seeming disparity may reflect differences in the nature of language switches employed in our studies. In our study there was only one switched noun, whereas in Abutalebi, et al. (2007) the language was switched either between language constitutents (e.g., "Il

Region	*BA*	*Cluster size*	*T-value*	*x*	*y*	*z*
L2-incongruent/L1-congruent homophone >congruent, language switch						
Right prefrontal cortex		131				
R IFG	47		6.42	35	21	-4
Left prefrontal cortex		362				
L IFG	47		5.96	-32	21	-4
L Putamen			4.4	-24	4	14
L Medial Globus Pallidus			4.31	-14	-7	0
L Thalamus			4.07	-10	-21	10
L Precentral Gyrus	44		3.93	-52	10	10
Bilateral medial cortex		198				
L Cingulate Gyrus	32,24		5.4	-10	24	42
R MFG	8		4.07	7	28	42
Left parietal cortex		191				
L IPL	40		4.95	-32	-52	38
Left prefrontal cortex		68				
L IFG	46		4.15	-46	38	10
Left occipital cortex		52				
L Cuneus	18		3.97	-14	-91	21
Congruent, language switch >L2-incongruent/L1-congruent homophone						
no significant clusters						

Table 5.4: Significant clusters of activation thresholded at P <0.001 (uncorrected). Only foci of activation (8 mm apart) with a spatial extent greater than 50 voxels are shown here. Multiple peaks within a single activation cluster are shown indented. Coordinates are reported in MNI space. Abbreviations: L = left, R = right, IFG = inferior frontal gyrus, MFG = middle frontal gyrus.

piccolo principe_est allé?": Italian-"The little prince"_French-"was going") or within language constituents (e.g., "j'ai_risposto": French-"I have"_Italian-"answered") and carried on in the switched language for the rest of the sentence. We also find no evidence of caudate nucleus activation in any of our language switch contrasts. While a number of other studies that employed language switching paradigms also failed to show caudate nucleus activation (Hernandez, 2009; Hernandez, et al., 2000, 2001; Wang, et al., 2009), those that did, showed caudate nucleus involvement when comprehending (Abutalebi, et al., 2007) or producing (Wang, et al., 2007) language switches into the bilingual's less-proficient language. The notable exception to this is Crinion, et al. (2006), however their data were collapsed across both directions of language switching (i.e., more to less proficient and vice versa)

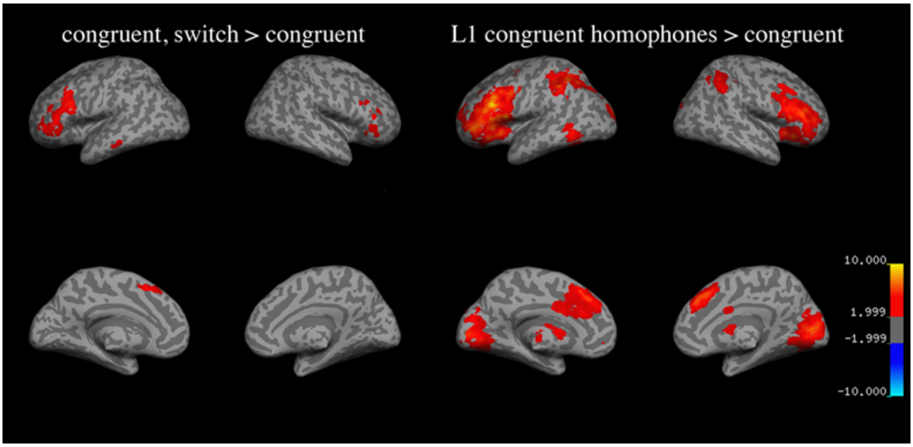


Figure 5.2: Language switch effect overlaid on inflated cortical surface for: (left) semantically congruent, language switched items versus congruent control items and (right) L2-incongruent/L1-congruent homophones versus congruent control items. Images thresholded at $P < 0.001$ (uncorrected).

and their use of repetition suppression could arguably have been more sensitive to caudate activation than our whole brain approach. In the present study the language switches were always into the bilingual's more proficient (native) language and thus may not have necessitated the involvement of the caudate nucleus.

Language Membership Information and Bilingual Lexical Access

The results of the present study suggest the encoding of language membership information at an abstract (lemma/conceptual) level rather than at the word form level. These results thus validate the inclusion of language tags or language nodes in models of bilingual comprehension and production such as the BIA (Grainger & Dijkstra, 1992) and BIA+ models (Dijkstra & Van Heuven, 1998). In the BIA model the language nodes served to: (1) indicate language membership, (2) accrue activation from lexical representations to account for between-trial language priming effects (e.g., Grainger and O'Regan, 1992), (3) Modulate relative language activation, and (4) provide a mechanism for pre-activation of a certain language, based on the non-linguistic context (e.g., bilinguals' expectations about the relevant language for a given situation). However, in the BIA+ model the functionality of the language nodes was restricted to being just language membership indicators (for a more elaborate discussion see: Dijkstra & Van Heuven, 2002).

Although language nodes or tags could theoretically allow bilinguals to restrict their processing to one language, language selective lexical access (e.g., McNamara, 1967; McNamara & Kushnir, 1971) is not necessarily implied. A number of studies have shown language non-selective lexical access in bilingual speech comprehension (e.g., Marian & Spivey, 2003a; Marian & Spivey, 2003b; Marian, et al., 2003; Spivey & Marian, 1999; Weber & Cutler, 2004), although there are also reports that cross-linguistic lexical activation may be restricted when between-language overlap occurs when words are presented in a sentence context (FitzPatrick & Indefrey, 2010b; Chapter 2 of this thesis). The present study reveals evidence of cross-linguistic lexical activation despite the presence of a sentence context. The activation in the L2-incongruent/L1-congruent condition shows not only an incongruity response in BA 45, but also a language switch response in left DLPFC. The latter response could only be present if the homophone activates both its L1 and L2 representations.

Functional Significance of the Switch Response

The current data support the assertion that language switching is accomplished by a network of interacting brain regions (Abutalebi, 2009; Abutalebi & Green 2007, 2008). Abutalebi and Green (2008), identify a number of areas thought to be important for producing and (to a lesser extent) comprehending language switches. In their view left prefrontal cortex is important for updating the language in use and inhibiting the irrelevant language, bilateral supramarginal gyri help bias lexical selection away from the non-target language, the ACC is responsible for detecting response-based language conflict, and the Caudate Nucleus is ascribed a supervisory role for language selection (cf., Crinion, et al., 2006). Our findings can easily be understood within this framework. The DLPFC activation in our study showed up both for language switches and (even more strongly) for L2-incongruent/L1-congruent homophones. Both these conditions require language updating, however only in the latter case is inhibition of non-target language semantics (cf., Green, 1998) necessary. This could also explain the additional recruitment of the ACC for detecting the conflicting semantics and bilateral IPL for disambiguating towards the target language, that we observed for L2-incongruent/ L1-congruent homophones.

5.5 Conclusions

The present study reveals that bilinguals have abstract representations of language membership. These representations may enable the bilingual to rapidly recognise to which language incoming words belong and could potentially help to resolve language ambiguities when their languages come into conflict, for example when processing interlingual homophones, or spuriously embedded words across languages (e.g., the Dutch *lief* 'sweet' in the English word *belief*). The present study has also shown that these conflicts can arise even in the presence of a strong monolingual sentence context.

5.6 References

Abutalebi, J. (2008). Neural aspects of second language representation and language control. *Acta Psychologica*, *128*(3), 466-478.

Abutalebi, J., Brambati S., Annoni J., Moro A., Cappa S., & Perani D. (2007). The neural cost of the auditory perception of language switches: An event-related functional magnetic resonance imaging study in bilinguals. *The Journal of Neuroscience*, *27*(50), 13762-13769.

Abutalebi, J., Cappa, S. F., & Perani, D. (2001). The bilingual brain as revealed by functional neuroimaging. *Bilingualism: Language and Cognition*, *4*(2), 179-190.

Abutalebi, J., & Green, D. W. (2007). Bilingual language production: The neurocognition of language representation and control. *Journal of Neurolinguistics*, *20*(3), 242-275.

Abutalebi, J., & Green, D. W. (2008). Control mechanisms in bilingual language production: Neural evidence from language switching studies. *Language and Cognitive Processes*, *23*(4), 557-582.

Allan, D. (1992). *Oxford placement test.* Oxford: Oxford University Press.

Baayen, R. H., Piepenbrock, R., & van Rijn, H. (1993). *The CELEX lexical database.* Philadelphia, PA: University of Pennsylvania, Linguistic Data Consortium.

Crinion, J., Turner, R., Grogan, A., Hanakawa, T., Noppeney, U., Devlin, J. T., Aso, T., Urayama, S., Fukuyama, H., Stockton, K., Usui, K., Green, D. W., & Price, C. J., (2006). Language control in the bilingual brain. *Science*, *312*(5779), 1537-1540.

Dijkstra, T., & Van Heuven, W. J. B. (1998). *The BIA model and bilingual word recognition.* In J. Grainger & A. Jacobs (Eds.), Localist connectionist approaches to human cognition (pp. 189-225). Mahwah, NJ: Erlbaum.

Dijkstra, T., & Van Heuven, W. J. B. (2002). The architecture of the bilingual word recognition system: From identification to decision. *Bilingualism: Language and Cognition*, *5*(3), 175-197.

FitzPatrick I., & Indefrey, P. (2010a). Head start for target language in bilingual listening. *Manuscript submitted for publication*.

FitzPatrick I., & Indefrey, P. (2010b). Lexical competition in nonnative speech comprehension. *Journal of Cognitive Neuroscience*, *22*(6), 1165-1178.

Friederici, A. D. (2006). What's in control of language? *Nature Neuroscience*, *9*(8), 991-992.

Friston K. J., Holmes A. P., Worsley K. J., Poline J. B., Frith C., & Frackowiak R. S. J. (1995). Statistical parametric maps in functional imaging: a general linear approach. *Human Brain Mapping*, *2*(4), 189-210.

Gaab, N., Gabrieli, J. D. E., & Glover, G. H. (2007). Assessing the influence of scanner background noise on auditory processing. II. An fMRI study comparing auditory processing in the absence and presence of recorded scanner noise using a sparse design. *Human Brain Mapping*, *28*(8), 721-732.

Grainger, J., & Dijkstra, T. (1992). On the representation and use of language information in bilinguals. In R. J. Harris (Ed.), *Cognitive Processing in Bilinguals* (pp. 207-220). Amsterdam: Elsevier Science Publishers.

Grainger, J., & O'Regan, J. K. (1992). A psychophysical investigation of language priming effects in two English-French bilinguals. *European Journal of Cognitive Psychology*, *4*(4), 323-339.

Green, D. W. (1998). Mental control of the bilingual lexico-semantic system. Bilingualism: *Language and Cognition*, *1*(2), 67-81.

Grosjean, F. (1982). *Life with two languages: An introduction to bilingualism*. Cambridge, MA: Harvard University Press.

Grosjean, F. (1988). Exploring the recognition of guest words in bilingual speech. *Language and Cognitive Processes*, *3*(3), 233-274.

Hagoort, P., Baggio, G., & Willems, R. M. (2009). Semantic Unification. In M. S. Gazzaniga (Ed.), *The Cognitive Neurosciences, 4th Edition* (pp. 819-836). Cambridge, MA: The MIT Press.

Hernandez, A. E. (2009). Language switching in the bilingual brain: What's next? *Brain and Language*, *109*(3), 133-140.

Hernandez, A. E., Dapretto, M., Mazziotta, J., & Bookheimer, S. (2001). Language switching and language representation in Spanish-English bilinguals: An fMRI study. *NeuroImage*, *14*(2), 510-520.

Hernandez, A. E., Martinez, A., & Kohnert, K. (2000). In search of the language switch: An fMRI study of picture naming in Spanish-English bilinguals. *Brain and Language*, *73*(3), 421-431.

Hernandez, A. E., & Meschyan, G. (2006). Executive function is necessary to enhance lexical processing in a less proficient L2: Evidence from fMRI during picture naming. *Bilingualism: Language and Cognition*, *9*(2), 177-188.

Johnson R. (1986). A triarchic model of P300 amplitude. *Psychophysiology*, *23*(4), 367-384.

Kruskal, W. H., & Wallis, W.A. (1952). Use of ranks in one-criterion variance analysis. *Journal of the American Statistical Association*, *47*(260), 583-621.

Lemhöfer, K., Dijkstra, T., & Michel, M. C. (2004). Three languages, one ECHO: Cognate efects in trilingual word recognition. *Language and Cognitive Processes*, *19*(5), 585-611.

Marian, V., & Spivey, M. J. (2003a). Bilingual and monolingual processing of competing lexical items. *Applied Psycholinguistics*, *24*(2), 173-193.

Marian, V., & Spivey, M. J. (2003b). Competing activation in bilingual language processing: Within- and between-language competition. *Bilingualism: Language and Cognition*, *6*(2), 97-115.

Marian, V., Spivey, M. J., & Hirsch, J. (2003). Shared and separate systems in bilingual language processing: Converging evidence from eyetracking and brain imaging. *Brain and Language*, *86*(1), 70-82.

Martin, C.D., Dering, B.R., Thomas, E.M., & Thierry, G. (2009). Brain potentials reveal semantic priming in both the 'active' and the 'non-attended' language of early bilinguals. *Neuroimage*, *47*(1) 326-333.

McNamara, J. (1967). The bilingual's linguistic performance. *Journal of Social Issues*, *23*(2), 58-77.

McNamara, J., & Kushnir. S. (1971). Linguistic independence of bilinguals: The input switch. *Journal of Verbal Learning and Verbal Behavior*, *10*(5), 480-87.

Meara, P. M. (1996). *English vocabulary tests: 10k*. Swansea, UK: Centre for Applied Language Studies.

Moelker, A., & Pattynama, P. M. T. (2003). Acoustic noise concerns in functional magnetic resonance imaging. *Human Brain Mapping*, *20*(3), 123-141.

Moreno, E. M., Federmeier, K. D., & Kutas, M. (2002). Switching languages, switching palabras (words): An electrophysiological study of code switching. *Brain and Language*, *80*(2), 188-207.

Poulisse, N., & Bongaerts, T. (1994). First language use in second language production. *Applied Linguistics*, *15*(1), 36-57.

Price, C. J., Green, D. W., & Von Studnitz, R. (1999). A functional imaging study of translation and language switching. *Brain*, *122*(12), 2221-2235.

Rodd, J. M., Davis, M. H., & Johnsrude, I. S. (2005). The neural mechanisms of speech comprehension: fMRI studies of semantic ambiguity. *Cerebral Cortex*, *15*(8), 1261-1269.

Rodriguez-Fornells, A., Rotte, M., Heinze, H., Noesselt, T., & Muente, T. F., (2002). Brain potential and functional MRI evidence for how to handle tow languages with one brain. *Nature*, *415*(6875), 1026-1029.

Rodriguez-Fornells, A., Van Der Lugt, A., Rotte, M., Britti, B., Heinze, H., & Muente, T. F. (2005). Second language interferes with word production in fluent bilinguals: Brain potential and functional imaging evidence. *Journal of Cognitive Neuroscience*, *17*(3), 422-433.

Scarff, C. J., Dort, J. C., Eggermont, J. J., & Goodyear, B. G. (2004). The effect of MR scanner noise on auditory cortex activity using fMRI. *Human Brain Mapping*, *22*(4), 341-349.

Schroeder, M. R. (1968) Reference signal for signal quality studies. *Journal of the Acoustical Society of America*, *44*(6), 1735-1736.

Schulpen, B., Dijkstra, T., Schriefers, H. J., & Hasper, M. (2003). Recognition of interlingual homophones in bilingual auditory word recognition. *Journal of Experimental Psychology: Human Perception and Performance*, *29*(6), 1155-1178.

Spivey, M. J., & Marian, V. (1999). Cross talk between native and second languages: Partial activation of an irrelevant lexicon. *Psychological Science*, *10*(3), 281-284.

Van Heuven, W. J. B., Dijkstra, T., & Grainger, J. (1998). Orthographic neighborhood effects in bilingual word recognition. *Journal of Memory and Language*, *39*(3), 458-483.

Van Heuven, W. J. B., Schriefers, H., Dijkstra, T., & Hagoort, P. (2008). Language conflict in the bilingual brain. *Cerebral Cortex*, *18*(11), 2706-2716.

Wang, Y., Kuhl, P. K., Chen, C., & Dong, Q. (2009). Sustained and transient language control in the bilingual brain. *NeuroImage*, *47*(1), 414-422.

Wang, Y., Xue, G., Chen, C., Xue, F., & Dong, Q. (2007). Neural bases of asymmetric language switching in second-language learners: An ER-fMRI study. *NeuroImage*, *35*(2), 862-870.

Weber, A., & Cutler, A. (2004). Lexical competition in non-native spoken-word recognition. *Journal of Memory and Language*, *50*(1), 1-25.

Summary and Conclusions

CHAPTER 6

In this thesis I investigated instances in which the bilingual's languages come into conflict, more specifically, when a bilingual is challenged to arrive at a coherent interpretation of a spoken utterance in the presence of conflicting information between his languages. In Chapter 2 of this thesis we set out by investigating whether we could find evidence for within and/or between language lexical competition in spoken L2 sentence contexts. The role of these sentence contexts was the explicit focus of our investigation in Chapter 3. Specifically, we were interested in whether the sentence context has a modulatory influence on between language lexical activation. Chapter 4 looked at whether we could see cross-linguistic lexical activation despite the presence of a sentence context by maximising the degree of between language overlap (i.e., by using interlingual homophones). Furthermore, we compared the processing of interlingual homophones to actual language switches into the participants' native language. Finally, in Chapter 5 we attempted to lift the veil on the mechanism by which bilinguals are able to separate their two languages by looking at whether they encode language membership information using form level (e.g., orthographic, phonological) cues or alternatively have more abstract (lemma or conceptual) level representations of language membership.

6.1 Summary of Results

The results we obtained in Chapter 2 constitute an interesting point of departure towards investigating between language lexical interactions. In this chapter we exploited the sensitivity of one particular Event-Related Potential (ERP) component, called the N400 (Kutas & Hillyard, 1980), to the moment at which semantic incongruity becomes apparent to the listener. The N400 component has a negative polarity and is more negative to words that are semantically incongruent within the current context than to words that are semantically congruent. The amplitude of the N400 is therefore taken to reflect the relative difficulty of the semantic integration process (i.e., making sense of a word within a broader sentence context; Brown & Hagoort, 1993; Kutas & Hillyard, 1984). In our study, we firstly obtained an N400 effect between semantically incongruent and congruent sentence words (e.g., "When we moved house I had to put all my books in a *towel*" versus *box*). Secondly, we observed a significant latency shift in the N400 when the semantically incongruent critical word shared its initial phonemes with a congruent sentence continuation (e.g., "When we moved house I had to put all my books in a *bottle*"). We took this latency shift as evidence that the non-native listeners were sensitive to the semantic congruity of the word-initial phonemes, thus must have started the semantic integration process before the critical word could be uniquely identified based on the input. This in turn meant that non-native listeners indeed experience within language lexical competition in non-native speech comprehension. Interestingly, we observed no such latency shift when the semantically incongruent critical words shared their initial phonemes with the translation equivalent of a congruent sentence continuation (e.g., "When we moved house I had to put all my books in a *doughnut*" which starts the same as the Dutch word *doos*" 'box'). These data did not allow us to rule out activation of cross linguistic lexical items, but did at least suggest to us that L1 items may not be available for semantic integration in L2 speech comprehension. We speculated that a possible account for the absence of a cross-linguistic effect in our study lay in the influence of the sentence context.

The possible modulatory influence of sentence context on cross-linguistic lexical activation was the subject of our studies in Chapter 3 of this thesis. We conducted two eye-tracking experiments in which we initially replicated the finding of cross-linguistic lexical activation (i.e., more looks to an interlingual competitor *deksel* 'lid' than to an unrelated distractor *flower*) for target words (e.g., *desk*) in invariant sentence contexts (e.g., "Click on the *desk*"), but subsequently found the effect to be markedly attenuated when target words were embedded in semantically rich sentence contexts (e.g., "My grandma has an ugly *desk*"). Strikingly, we also obtained a significant negative correlation between the proportion of looks to the interlingual competitor and participants' self reported L2 language proficiency. We thus obtained evidence that two important factors may constrain the amount of cross-linguistic lexical activation: the richness of the semantic context and the bilingual's second language proficiency. That is, the richer the sentence context or the more proficient one is in one's second language, the less likely it is that one experiences between language interference.

Chapter 4 shows us that despite the presence of a sentence context, a large amount of between language phonological overlap (as is the case for interlingual homophones) can still elicit between-language lexical activation. We observed that interlingual homophones embedded in a sentence context (e.g., "His cat was his favourite *pet*", where *pet* is also Dutch for 'hat') activated their context language (in this case L2) meaning first followed by their non-context language (in this case L1) meaning. This occurred irrespective of whether the non-context language meaning was beneficial or detrimental to the understanding of the sentence. The relative latencies of meaning activation were evidenced by N400 time-course differences. When the homophone was congruent with the non-context language but not the context language an N400 effect emerged that offset earlier than the N400 effect to a semantically incongruent word. Conversely, when the homophone was congruent with the context language but not with the non-context language a negative effect emerged but at a longer latency than the N400 to semantically incongruent words. That non-target language semantics are initially unavailable was also evident when we looked at language switches. When the language switches were semantically congruent with the context an initial negativity emerged that, again, offset earlier than the N400 effect between a semantically incongruent word and a semantically congruent control. Language switches (both semantically congruent and incongruent) also exhibited a Late Positive Component (LPC), which was not elicited by interlingual homophones. Following Moreno, Federmeier, and Kutas (2002) we speculate that this effect is due to the improbable nature of hearing language switches. The emergence of a transient negativity to both L2-incongruent/L1-congruent homophones and semantically congruent, language switches can be taken as evidence of a target-language priority in L2 speech comprehension. Furthermore, the early offset of this effect as well as the emergence of a negative effect to L2-congruent/L1-incongruent homophones suggest that non-target language semantics are nevertheless accessed following a short delay. These results necessarily imply that the bilingual's language comprehension system possesses a mechanism by which to instantiate the observed target language priority. In other words, language membership information must be intricately linked to words in the bilingual lexicon.

Chapter 5 investigated two possible ways for language membership to be represented in the bilingual brain. One way of effectuating word-to-language mapping is by relying on form level (e.g., pronunciation, orthography) differences between languages. Alternatively, language membership may be encoded at a more abstract level linked to lemmas or concepts. To distinguish between these two alternatives we examined bilingual's neural responses to (a) perceiving language switches involving the form level (i.e., form features not corresponding to the context language), and (b) perceiving language switches not involving the form level induced by a manipulation of the semantic congruity of between-language homophones. Compared to semantically congruent controls, the semantically incongruent critical words (irrespective of whether they were language switches or not) led to greater involvement of especially left BA45, in line with earlier results and likely reflecting a greater demand on semantic unification (e.g., Hagoort, Baggio & Willems, 2009) for semantically incongruent compared to control words. Language switches led to activation of primarily left dorsolateral prefrontal cortex (DLPFC, BA 46). This DLPFC activity was also observed in the contrast between L2-incongruent/ L1-congruent homophones and control words. No significant differences emerged in the contrast between L2-congruent/ L1-incongruent homophones and control words. Our results thus showed that left DLPFC was activated for language switches in L2 speech comprehension, irrespective of whether these switches contained non-context language form features or not. These results suggest that language membership is represented at an abstract (lemma or conceptual) level in the bilingual mental lexicon rather than at a form level.

6.2 Discussion

When comparing the pattern of results in Chapter 5 with those obtained in Chapter 4 an interesting difference comes to light. Chapter 4 showed us that L2-congruent/L1-incongruent homophones elicited a short-lived negativity with a left frontal topographic distribution, however the same contrast yielded no significant differences in our fMRI study in Chapter 5. Comparisons between functional imaging data and electrophysiological data are not straightforward, as both methods have vastly differing temporal resolutions and can be said to reflect different aspects of neuronal activation/communication. Whereas Blood Oxygen Level Dependent (BOLD) activations are likely the result of changes in Local Field Potentials (LFPs) and to a lesser extent Multi-Unit spiking Activity (MUA) (e.g., Logothetis, 2001), EEG is said to arise from excitatory and inhibitory post-synaptic potentials (for a recent review see: Laufs, 2008). Thus, three possibilities emerge to account for the discrepant results between Chapters 4 and 5: (1) they could be due to the temporal shift in the ERP effect leading to lowered correspondence with the predicted BOLD response in that condition, (2) the neuronal recruitment underlying the observed ERP effect could be too weak to bring about changes in local oxygen metabolism, or (3) the ERP response may simply reflect neuronal processes that do not correspond well with BOLD measurements. The present data, however, do not allow us to discriminate between these three accounts. In any case, the emergence of a negative ERP effect in the comparison between L2-congruent/L1-congruent homophones and control words (Chapter 4) suggests activation of the L1 homophone meaning, despite the absence of an effect in the corresponding fMRI contrast (Chapter 5).

Taken together, the studies presented here paint an intricate picture of the bilingual speech comprehension process. We have seen that bilinguals activate multiple lexical candidates in non-native speech comprehension (Chapter 2), but that the activation of between-language lexical candidates is restricted by the richness of the sentence context (Chapters 2 and 3), the bilingual listener's language proficiency (Chapter 3), and the degree of between language overlap (Chapter 4). We have also seen that the bilingual is able to prioritise the processing of target language semantics during non-native listening (Chapter 4) likely by using abstract language membership representations (Chapter 5). These findings support a model of bilingual speech comprehension in which language context and proficiency are assigned prominent roles. We will outline the basics of such a model below and discuss how the present data fit with existing models of bilingual comprehension.

One way of accounting for the pattern of results would be to assume that words belonging to one or other of a bilingual's languages are interconnected. As each word in a given speech signal is recognised, language membership information accrues and incrementally either raises the threshold of activation for words from the non-target language, or lowers the threshold for words from the target language. One possible way of realising such a mechanism would be that when a word from the target language is recognised it sends a tiny amount of activation to all other candidates from the same language, thus when the next word from the target language arrives in the input it more easily reaches the recognition threshold. In the context of the present data this would imply that, in sparse or single word contexts, initial phonological overlap is enough to elicit cross-linguistic activation, however in semantically rich contexts (where the extent of activation in the language network is larger) a greater degree of between-language overlap (e.g., homophones, language switches) is necessary for between language lexical candidates to cross the recognition threshold. This account is largely compatible with interactive activation models of bilingual comprehension such as the BIA (Dijkstra & Van Heuven, 1998; Grainger & Dijkstra, 1992), BIA+ (Dijkstra & Van Heuven, 2002), and BIMOLA (Grosjean, 1997) models.

The BIA and BIA+ models, although primarily intended for the bilingual visual word recognition domain could conceivably be extrapolated to account for the present data. These models assume integration of the bilingual processing system at each level of representation, which allows for concurrent activation of words from multiple languages based on word form similarity. The degree of between language similarity, as well as lexical characteristics of the target words (e.g., subjective frequency), are determining factors in how strongly words are activated. A fundamental difference between the BIA and BIA+ models lies in the role assigned to the language nodes. Whereas in the BIA model the language nodes can influence the word recognition process, in the BIA+ model the flow of information between language nodes and lexical items has been tempered based on observations that language membership information becomes available relatively late in the (visual) word recognition process (for a full discussion see: Dijkstra & Van Heuven, 2002). BIA+ does not preclude effects of language context, however the authors argue that these effects are more likely due to the bilingual's expectations operating at the task/decision level, which does not affect the lexical activation process. The present data suggest a direct influence of language context on the word recognition process and are thus more in line with the proposed role of language nodes as formulated in the BIA model. It cannot be excluded however, that the influence of language membership information on bilingual comprehension is dependent on the input modality. Different from the written modality, it has been shown that language membership information is available at an early stage during auditory word recognition (e.g., Grosjean, 1988), and could therefore presumably affect the word recognition process at an earlier stage.

One model that was intended to account for findings in bilingual auditory word recognition is the BIMOLA model by Grosjean (1997). This model holds that the bilingual speech processing system is integrated at the level of phonetic-phonological features but functional separation occurs at higher levels of representation where phonemes and words are organised within language-defined subsets. Activation of a phoneme or word within such a subset sends a small amount of activation to other members of the subset while simultaneously inhibiting close competitors by means of lateral inhibition. The model also assigns a role to top down modulation of activation within this language network permeating down to the phonemic level. This top-down modulation serves to bias activation in the network towards one or other of the languages. When considering the present data within this framework, the top-down modulation would seem to be necessary to account for the target language priority (Chapter 4) as well as the diminished availability of between language competitors when they are embedded in semantically rich sentence contexts (Chapters 2 & 3).

A subtly different account for the present findings that does not involve modulatory activation from either language nodes (BIA) or the non linguistic context, which acts at a task/decision level (BIA+) or directly at the lexical level (BIMOLA), involves suppression of non-target language words in line with the Inhibitory Control (IC) model (Green, 1998). Besides allowing for top down influences on the bilingual lexico-semantic system by means of task-schema driven control processes, the IC model also postulates that activation of lexical items in one language leads to reactive inhibition of all the lexical items in the other language. The present data cannot help us decide whether the lesser availability of non-target language semantics is due to lowering of the recognition threshold of target-language words or reactive inhibition of non-target language words. Indeed, the two proposals need not be mutually exclusive, however it is worthwhile to note that, in light of the present data, purported reactive inhibition cannot be considered an all or nothing process. Rather, inhibitory effects become stronger as more target language lexical items emerge in the speech stream. Consistent with this notion are observations that cross-linguistic lexical activation can diminish over the course of an experiment. For example, Elston-Guettler, Gunter, and Kotz (2005) observed cross-linguistic lexical activation in non-native reading, but only after participants had been exposed to non-target language material prior to the experiment. Moreover, they showed that the cross-linguistic lexical activation was only present in the first experimental block. Elston-Guettler et al. (2005) attribute these findings to bilinguals gradually "zooming in" to the target language. Borrowing this analogy, the absence of cross-linguistic effects in Chapters 2 and 3 (Experiment 2) and the target language priority which we observed in Chapter 4 could all be understood as resulting from a bilingual language comprehension system which is already "zoomed in" to the L2.

All in all, the present data are consistent with the existence of bilingual language modes (Grosjean, 1982) in which the relative availability of a bilingual's languages varies on a continuum between active and suppressed. That said, the present data hardly speak to the controversy surrounding the existence of the two extremes of the continuum. Although the results from Chapter 3 suggest a semantically rich sentence context may effectively reduce the availability of cross-linguistic lexical candidates, we also observed clear evidence of cross-linguistic lexical activation in Chapter 4 despite measures to ensure participants were in a monolingual L2 language mode. It could, however, also be argued that the presence of homophones or language switches in the experiments in Chapter 4 effectively brought the participants into a more interactive language mode. The issue, thus, remains unresolved although, on the basis of our findings in Chapter 3 and previous work by Elston-Guettler et al. (2005), one might speculate that extreme monolingual language modes are more likely to be found in highly proficient bilinguals. This assertion is consistent with the Revised Hierarchical Model (Kroll & Stewart, 1994), which assumes that as bilinguals become more proficient in their second language they start to rely less on L1-L2 lexical links to access semantics and start to gain more direct access to concepts from L2 words (thus eliminating the need for L1 mediation).

Broadly speaking data from the present thesis are, thus, compatible with existing models of bilingual language processing. However, although each of the models discussed above allow for some measure of cross-linguistic lexical activation, these models invariably predict simultaneous activation of cross-linguistic lexical candidates (albeit to a lesser extent than within-language lexical competitor activation) and thus cannot account for the delayed availability of non-target language semantics observed here (Chapter 4). The data from this thesis provide qualitatively new evidence on the dynamics of within- and between language meaning activation which are brought about by a tug of war between such factors as the bilingual's language proficiency, processing resources, and the degree of between language correspondence. These data, therefore, constitute an important challenge for models of bilingual processing, as it is apparent that not only the extent of between language lexical activation but also its time course can greatly influence the bilingual language comprehension process.

6.3 Conclusions

In conclusion, the present thesis has shown that between language lexical interactions are not inevitable by-products of between language overlap. Rather, they only occur when the bilingual has sufficient processing resources available (e.g., when words are heard in isolation) or in the face of a great deal of between-language overlap. Furthermore, these interactions are likely to diminish as the bilingual becomes more proficient in his second language. Even when we consider the most extreme case of between-language overlap, namely processing words that sound very similar between languages, we have shown that the bilingual's speech comprehension system gives priority to the language at hand, thereby minimising any between language ambiguity. Finally, we have demonstrated that words in the bilingual lexicon are linked to abstract language membership features (e.g., language nodes/

language tags), which allow the bilingual to distinguish between words of different languages. Overall, the bilingual listener can rest easily in the knowledge that his language comprehension system is well equipped to deal with spurious between language overlap. The results in this thesis may, however, constitute less good news for those bilinguals who frequently switch between languages, as it seems the switches may incur a processing cost for their interlocutors.

6.4 References

Dijkstra, T., & Van Heuven, W. J. B. (1998). The BIA model and bilingual word recognition. In J. Grainger & A. Jacobs (Eds.), *Localist connectionist approaches to human cognition* (pp. 189-225). Mahwah, NJ: Erlbaum.

Dijkstra, T., & Van Heuven, W. J. B. (2002). The architecture of the bilingual word recognition system: From identification to decision. *Bilingualism: Language and Cognition*, *5*(3), 175-197.

Elston-Guettler, K. E., Gunter, T. C., & Kotz, S. A. (2005). Zooming into L2: global language context and adjustment affect processing of interlingual homographs in sentences. *Brain Research: Cognitive Brain Research*, *25*(1), 57-70.

Grainger, J., & Dijkstra, T. (1992). On the representation and use of language information in bilinguals. In R. J. Harris (Ed.), *Cognitive Processing in Bilinguals* (pp. 207-220). Amsterdam: Elsevier Science Publishers.

Green, D. W. (1998). Mental control of the bilingual lexico-semantic system. *Bilingualism: Language and Cognition*, *1*(2), 67-81.

Grosjean, F. (1988). Exploring the recognition of guest words in bilingual speech. *Language and Cognitive Processes*, *3*(3), 233-274.

Grosjean, F. (1997). Processing mixed language: Issues, findings and models. In A. M. B. De Groot & J. F. Kroll (eds.), *Tutorials in Bilingualism: Psycholinguistic Perspectives* (pp. 225-254). Mahwah, NJ: LEA.

Hagoort, P., Baggio, G., & Willems, R. M. (2009). *Semantic Unification.* In M. S. Gazzaniga (Ed.), The Cognitive Neurosciences, 4th Edition (pp. 819-836). Cambridge, MA: The MIT Press.

Kroll, J. F., & Stewart, E. (1994). Category interference in translation and picture naming: Evidence for asymmetric connections between bilingual memory representations. *Journal of Memory and Language*, *33*(2), 149-174.

Laufs, H. (2008). Endogenous brain oscillations and related networks detected by surface EEG-combined fMRI. *Human Brain Mapping*, *29*(7), 762-769.

Logothetis, N. K., Pauls, J., Augath, M., Trinath, T. & Oeltermann, A. (2001). Neurophysiological investigation of the basis of the fMRI signal. *Nature*, *412*(6843), 150Ð157.

Moreno, E. M., Federmeier, K. D., & Kutas, M. (2002). Switching languages, switching palabras (words): An electrophysiological study of code switching. *Brain and Language*, *80*(2), 188-207.

Nederlandse Samenvatting

HOOFDSTUK 7

Het leren van een nieuwe taal kan erg lonend zijn, maar kent ook de nodige moeilijkheden. Tijdens het verwerven van een nieuwe woordenschat en grammatica, en het onder de knie krijgen van subtiele nuances in de uitspraak, moet de nieuwe taal een plaats zien te krijgen in een brein dat reeds een uitgebreide infrastructuur heeft ontwikkeld om de moedertaal te verstaan en produceren. Bij het leren van de tweede taal (L2) zou het dan ook logisch zijn om in het brein geen compleet nieuw taalsysteem te ontwikkelen, maar om aanspraak te maken op die hersengebieden, die voorheen uitsluitend voor de moedertaal (L1) bestemd waren. Dat dit ook daadwerkelijk het geval is, blijkt uit de vele studies die tweetaligheid onderzoeken met functionele beeldvormingstechnieken, zoals Positron Emissie Tomografie (PET) en functionele Magnetische Resonantie Imaging (fMRI; voor een overzicht van deze studies zie: Indefrey, 2006). Dit deelgebruik van cognitieve capaciteit is echter niet zonder gevolg. De vraag dient zich namelijk aan hoe een tweetalig persoon in staat kan zijn om zijn talen van elkaar gescheiden te houden.

Het empirisch onderzoek naar deze vraag is grotendeels afkomstig van onderzoek naar visuele woordherkenning in tweetaligen (zie: Dijkstra, 2005) en tweetalige woord-productie (bijv., Costa, Colomé, Gómez & Sebastián-Gallés, 2003). De vraag is echter evenzeer van belang – hoewel tot op heden minder uitgebreid onderzocht – in het domein van de gesproken woordherkenning alwaar potentiële bronnen van crosslinguïstische verwarring (d.w.z. klank-overlap tussen de talen) alom aanwezig zijn. De klankcombinatie /meɫ/ zou bijvoorbeeld overeen kunnen komen met het Nederlandse woord *meel*, maar lijkt ook bijzonder veel op de Engelse woorden *mail* 'post' of *male* 'mannelijk'. Om antwoord te kunnen geven op de vraag hoe de talen in het tweetalige brein van elkaar gescheiden zijn dienen we eerst de aard van het probleem te onderzoeken. Daarom stellen we de volgende vragen: in hoeverre treedt er interactie op tussen de talen in het tweetalige brein? Is deze interactie automatisch en onvermijdelijk? Onder welke omstandigheden treedt interactie op en is deze onafhankelijk van de vaardigheid in de tweede taal? Deze onderzoeksvragen vormen de kern van dit proefschrift.

Een belangrijk concept, dat centraal staat in ons onderzoek naar interacties tussen talen, is *meervoudige lexicale activatie*. In essentie betekent dit dat wanneer men een woord hoort of leest, in het brein meerdere opties ten aanzien van de mogelijke identiteit van het bewuste woord geactiveerd worden. Neem bijvoorbeeld het woord *kapitaal*; de eerste fonemen van dit woord klinken hetzelfde als die in *kapitein*. Wanneer men tijdens het horen van het woord *kapitaal* de opdracht krijgt om geschreven woorden te herkennen (Zwitserlood, 1989), blijkt het eenvoudiger om de woorden *geld* (qua betekenis verwant aan *kapitaal*) of *schip* (qua betekenis verwant aan *kapitein*) te herkennen dan een woord als *neus* (qua betekenis noch verwant aan *kapitaal* noch aan *kapitein*). Dit voorbeeld laat zien dat wanneer men een gesproken fragment hoort (bijv. /kɑp/) vergelijkbaar klinkende woorden (bijv. *kapitaal* en *kapitein*) en hun betekenisverwanten (bijv. *geld* en *schip*) kortstondig in het mentale lexicon geactiveerd worden. Met andere woorden, het brein houdt zijn opties open en overweegt (korte tijd) meerdere mogelijke woordkandidaten (Goldinger, Luce & Pisoni, 1989; Marslen-Wilson & Tyler, 1980; McClelland & Elman, 1986; Norris, 1994). Deze eigenschap van het woordherkenningsproces roept een aantal interessante vragen op, namelijk: wat gebeurt er als men meer dan één taal spreekt? Heeft de L2 luisteraar, gegeven de moeilijkheden van het verstaan van een vreemde taal, afdoende cognitieve verwerkingscapaciteit om meerdere woordkandidaten te overwegen? Zo ja, worden die kandidaten dan tussen talen geactiveerd? Deze vragen vormen het beginpunt van ons onderzoek naar lexicale interacties in tweetalige spraakherkenning.

In Hoofdstuk 2 van dit proefschrift onderzochten we of er binnen- en/of tussen talen lexicale activatie plaatsvindt tijdens het luisteren naar gesproken L2 zinnen. De rol van de zinscontext stond centraal in Hoofdstuk 3, waarin we specifiek onderzochten of de complexiteit van de zinscontext een modulerende werking kon hebben op crosslinguïstische lexicale activatie. In Hoofdstuk 4 werd onderzocht of we crosslinguïstische activatie konden vinden ondanks de aanwezigheid van een rijke zinscontext. We gebruikten hiervoor interlinguale homofonen (woorden die tussen talen qua klank grotendeels overeenkomen, maar qua betekenis verschillen). Ook vergeleken we het verwerken van homofonen in L2 zinscontexten met het verwerken van woorden afkomstig uit de moedertaal van de proefpersonen (*taalswitches*). Tenslotte trachtten we in Hoofdstuk 5 het mechanisme te achterhalen waarmee tweetalige personen hun talen uit elkaar kunnen houden. We onderzochten of tweetaligen taallidmaatschap van woorden (d.w.z. kennis over tot welke taal ze behoren), ofwel bepaalden met behulp van *cues* (aanwijzingen) gerelateerd aan de woordvorm (d.w.z. orthografische of fonologische *cues*) danwel over meer abstracte (lemma- of conceptniveau) representaties van taallidmaatschap beschikken.

7.1 Experimentele Technieken

In dit proefschrift benaderden we de vraag over de aanwezigheid en aard van cross-linguïstische lexicale interacties vanuit verschillende invalshoeken en door middel van uiteenlopende experimentele technieken. In het onderzoek in Hoofdstukken 2 en 4 registreerden we Elektro-encefalogrammen (EEG's) bij tweetalige proefpersonen terwijl ze naar spraak luisterden in hun tweede taal. EEG's geven de simultane activatie weer van een groot aantal parallel geordende neuronen (voornamelijk in de neocortex). Activiteit in deze neuronenbundels wekt een elektrisch veld op, welke zich naar de hoofdhuid verspreidt, alwaar het door elektroden wordt geregistreerd. Elk van deze elektroden wordt vergeleken met een gemeenschappelijke referentie-elektrode die verondersteld wordt een minimale hoeveelheid breinactiviteit te registreren (in dit geval op de neus van de proefpersoon). Hierdoor wordt achtergrondruis uit de omgeving van de proefpersoon weggefilterd. *Epochs* (tijdsintervallen) van EEG data van één of twee seconden worden gesynchroniseerd aan een stimulus; in ons geval de akoestische aanvang van een bepaald woord. Vervolgens wordt een groot aantal van deze *epochs* voor elke experimentele conditie gemiddeld. Deze procedure minimaliseert ruis en stelt ons in staat om in elke afzonderlijke conditie met een nauwkeurigheid in de orde van enkele milliseconden tot een breinsignatuur te komen van het te onderzoeken cognitieve proces. In dit geval betreft het het verwerken van semantisch congruente en incongruente woorden. Statistische vergelijkingen tussen de verschillende condities werden gemaakt op basis van de individuele gemiddelden van elke proefpersoon.

In de experimenten in Hoofdstuk 3 gebruikten we een camerasysteem, dat op het hoofd van de proefpersoon bevestigd werd, om de positie van zijn/haar ogen te registreren terwijl hij/zij naar afbeeldingen keek op een computermonitor. Vanuit het oogpunt van de camera veranderen de positie van de pupil en de reflectieve eigenschappen van het hoornvlies van de proefpersoon als hij/zij naar verschillende delen van de visuele scène kijkt. Door de registratie van de oogbewegingen per proefpersoon te kalibreren kunnen we (met een temporele resolutie van 250 Hz) inschatten op welk deel van het computerscherm de proefpersoon zijn/haar blik richt. De bruikbaarheid van deze procedure om lexicale activatie van woordkandidaten te onderzoeken is afkomstig van de observatie (bijv. Allopenna, Magnuson &

Tanenhaus, 1998;Tanenhaus, et al., 1995) dat proefpersonen die luisteren naar gesproken taal hun blik richten op het visuele object waarvan de naam overeenkomt met (een deel van) het gesproken signaal. Als proefpersonen bijvoorbeeld het woord /blɪk/ horen zouden ze vaker kijken naar de afbeeldingen voor *blik* of *bliksem* dan naar de afbeelding voor *wortel*.

In de experimenten in Hoofdstuk 5 maakten we gebruik van fMRI. Hoewel deze techniek, in tegenstelling tot EEG of oogbewegingsregistratie, een temporele resolutie heeft in de orde van seconden (in plaats van milliseconden), stelt fMRI ons wel in staat om breinactivatie te detecteren met een spatiële resolutie van 3 mm. Proefpersonen nemen plaats in de scanner waarbinnen een sterk magnetisch veld heerst met magnetische gradiënten in drie verschillende spatiële oriëntaties. Het is bekend dat waterprotonen in het lichaam van de proefpersoon zich onder deze omstandigheden gaan gedragen als kleine magneten. Het merendeel van deze protonen oriënteert zich in de richting van het statische magnetische veld (lage energietoestand), terwijl een minderheid zich in de tegengestelde richting oriënteert (hoge energietoestand). De protonen wentelen om de ruimtelijke as van het statische magnetische veld in een frequentie (Larmor frequentie) die proportioneel is aan de sterkte van het magnetisch veld. De drie magnetische gradiënten veranderen de fase en frequentie van deze protonwentelingen en stellen ons in staat om de breinen van de proefpersonen in te delen in spatiëel gedefinieerde *voxels* (vergelijkbaar met pixels in een digitale afbeelding). Een radiofrequentie (RF) pulse kan vervolgens gebruikt worden om de protonen van lage naar hoge energietoestanden te brengen, hetgeen resulteert in een netto magnetisch moment in het spatiële vlak dat transversaal loopt aan het statische magnetische veld. Dit moment kan geregistreerd worden door middel van een RF ontvanger. Terwijl de protonen langzaam terugkeren naar de lage energietoestand verzwakt het magnetisch moment in het transversale vlak en verdwijnt het RF signaal. De snelheid waarmee de protonen terugkeren naar de lage energietoestand is afhankelijk van het soort weefsel waarin ze zich bevinden (sneller in water of cerebrospinale vloeistof; trager in grijze stof; nog trager in bot of kraakbeen) en van lokale afwijkingen in het magnetisch veld waaraan ze blootgesteld worden. Een belangrijke bron van deze lokale afwijkingen is de relatieve concentratie van zuurstofrijk en zuurstofarm bloed in de nabijheid van het proton. Terwijl zuurstofrijk bloed diamagnetisch is, is zuurstofarm bloed paramagnetisch. Hierdoor beïnvloeden beide typen bloed het lokale magnetische veld op een andere manier. Als een bepaald hersengebied actief wordt, verbruikt het zuurstof. Dit leidt aanvankelijk tot een toename in zuurstofarm bloed in de haarvaten dichtbij de bron van de activatie (waardoor de signaalsterkte in eerste instantie afneemt) gevolgd door een zogenaamde luxe-perfusie van zuurstofrijk bloed (waardoor de signaalsterkte drastisch toeneemt). Dit patroon van signaalverandering ten gevolge van breinactivatie heet het *Blood Oxygen Level Dependent* ofwel BOLD effect. Dit effect heeft een heel karakteristiek tijdsverloop, dus wanneer een voxel eenzelfde patroon van signaal af- en toename vertoont, kan dit worden aangeduid als indicator van activatie in die voxel. Op deze manier worden per proefpersooon over (nagenoeg) het hele breinvolume voxels met intensiteitswaarden (ofwel signaalsterktes) gemeten en getransformeerd aan een sjabloon van een standaard brein. De variaties in voxel intensiteitswaarden in de periode na blootstelling aan een experimentele stimulus (in ons geval gesproken woorden in een zinsverband) worden voor elke voxel in het genormaliseerde brein geanalyseerd. Hiervoor gebruiken we een lineaire regressieanalyse waarvan de regressoren overeenkomen met het tijdsverloop van de presentatie van experimentele stimuli (bijv. kritieke woorden), hetgeen geconvolueerd wordt met een standaardrepresentatie van de BOLD response, ofwel de *Haemodynamic Response Function* (HRF). De daaruit resulterende statische 'kaarten' van het brein worden getoetst aan de hand van een conservatieve statistische drempel om het risico op vals-positieve bevindingen (als gevolg van het groot aantal statistische toetsen) te minimaliseren.

7.2 Samenvatting van Resultaten

De resultaten uit Hoofdstuk 2 vormen een interessant uitgangspunt voor ons onderzoek naar crosslinguïstische lexicale interacties. In dit hoofdstuk maakten we gebruik van de sensitiviteit van één bepaalde Event-Related Potential (ERP) component uit het EEG, de N400 genaamd (Kutas & Hillyard, 1980). Deze component is gevoelig voor het moment waarop semantische incongruentie voor de luisteraar duidelijk wordt. De N400 heeft een negatieve polariteit en is in grotere mate negatief voor woorden die binnen de huidige context semantisch incongruent zijn dan voor woorden die semantisch congruent zijn. In ons onderzoek vonden we ten eerste een N400 effect tussen semantisch congruent en incongruente woorden (bijv. "When we moved house I had to put all my books in a *towel*" versus *bottle*). Ten tweede zagen wij een significante latentietijdverandering in de N400 wanneer het semantisch incongruente woord beginfonemen deelde met een (voor die zin) congruent woord. Deze latentietijdverandering beschouwden wij als bewijs dat L2 luisteraars gevoelig waren voor de semantische congruentie van beginfonemen van woorden. Dit betekent dat ze het semantisch integratieproces al gestart moeten hebben voordat het kritieke woord geïdentificeerd had kunnen worden op basis van de gesproken input. Hieruit kan worden afgeleid dat L2 luisteraars inderdaad intralinguale lexicale competitie ondervinden. Interessant genoeg vonden we geen latentijdverandering wanneer de semantisch incongruente woorden beginfonemen deelden met de vertaling van een (voor die zin) congruent woord (bijv. "When we moved house I had to put all my books in a *doughnut*" waarvan de beginfonemen lijken op die van *doos*). Deze data lieten het niet toe om crosslinguïstische lexicale activatie geheel uit te sluiten, maar suggereerden wel dat L1 lexicale items niet voor semantische integratie beschikbaar waren in L2 spraakverwerking. We vermoedden dat een mogelijke verklaring hiervoor te vinden zou zijn in de invloed van de zinscontext.

De mogelijke modulerende invloed van de zinscontext op crosslinguïstische activatie werd onderzocht in Hoofdstuk 3 van dit proefschrift door middel van twee oogbewegingsexperimenten. Aanvankelijk repliceerden we de bevinding van crosslinguïstische lexicale activatie (oftewel, dat men meer naar interlinguale kandidaten als *deksel* kijkt dan naar ongerelateerde kandidaten als *bloem*) in invariabele zinscontexten (bijv. "Click on the *desk*"). Daarnaast vonden we echter dat dit effect opvallend zwakker was wanneer de kritieke woorden waren ingebed in semantisch rijkere contexten (bijv. "My grandma has an ugly *desk*"). Opvallend genoeg vonden we ook een significante negatieve correlatie tussen het aantal keer dat gekeken werd naar de interlinguale kandidaat en een zelfinschatting van het niveau van L2 taalbeheersing van de proefpersonen. Kort gezegd vonden we hiermee bewijs dat twee belangrijke factoren de hoeveelheid crosslinguïstische lexicale activatie kunnen beïnvloeden, te weten: de rijkheid van de semantische context en het taalniveau in de tweede taal van de tweetalige. Dat wil zeggen, hoe rijker de zinscontext en hoe meer bedreven men is in de tweede taal, hoe minder waarschijnlijk het is dat men crosslinguïstische lexicale interactie ondervindt.

Hoofdstuk 4 laat ons zien dat een grote hoeveelheid crosslinguïstische overlap (zoals in het geval van interlinguale homofonie), ondanks de aanwezigheid van een zinscontext, nog steeds crosslinguïstische lexicale activatie kan bewerkstelligen. We zagen dat interlinguale homofonen in zinscontexten (bijv. "His cat was his favourite *pet*"; het woord *pet* klinkt hetzelfde als het Engelse woord voor huisdier) eerst de betekenis gerelateerd aan de contexttaal (in dit geval L2) en vervolgens de betekenis van de niet-contexttaal (in dit geval L1) activeerden. Dit gebeurde onafhankelijk van het feit of de niet-contextbetekenis het begrip van de de zin bevorderde of juist niet. De relatieve latenties van deze betekenisactivatie konden worden afgeleid uit N400 tijdsverschillen tussen de experimentele condities. Wanneer de homofoon congruent was met de niet-contexttaal, maar niet met de contexttaal, verdween de N400 eerder dan de N400 voor semantisch incongruente woorden. Dat woordbetekenissen uit de niet-contexttaal aanvankelijk niet beschikbaar zijn, werd ook duidelijk toen we keken naar *taalswitches*. Wanneer de *taalswitches* semantisch congruent waren met de context ontstond een kortdurende negativiteit die eerder verdween dan het N400 effect tussen semantisch congruent en incongruente woorden. *Taalswitches* (zowel semantisch congruent als incongruent) wekten eveneens een Late Positieve Component (LPC) op, die niet bij de homofonen aanwezig was. In navolging van Moreno, Federmeier, en Kutas (2002) denken we dat dit effect mogelijk te wijten is aan de onwaarschijnlijkheid van het horen van *taalswitches*. De opkomst van een kortdurende negativiteit voor zowel L2-incongruente/L1-congruente homofonen en semantisch congruente *taalswitches* kan gezien worden als bewijs voor een contexttaalprioriteit in L2 spraakverwerking. Verder laat de vroege offset van dit effect, tezamen met het ontstaan van een negatief effect voor L2-congruente/L1-incongruente homofonen, zien dat betekenissen uit de niet-contexttaal na een kleine vertraging alsnog actief worden. Deze resultaten impliceren noodzakelijkerwijze dat het taalverwerkingssyteem van de meertalige beschikt over een mechanisme om de context-taal prioriteit toe te kennen. Met andere woorden, informatie over taallidmaatschap moet nauw verweven zijn met woorden in het tweetalige lexicon.

Hoofdstuk 5 beschouwde twee mogelijke manieren waarop taallidmaatschap in het tweetalige brein opgeslagen kan zijn. Één manier om woorden aan een taal te koppelen is om gebruik te maken van vormverschillen (bijv. uitspraak of schrijfwijze) tussen de talen. Anderzijds zou taallidmaatschap opgeslagen kunnen zijn op een meer abstract niveau, gekoppeld aan lemmata of concepten. Om deze twee alternatieven te onderscheiden beschouwden we de neurale reacties van tweetaligen wanneer ze *taalswitches* hoorden die (a) vormverschillen bevatten (ofwel, vormeigenschappen die niet in de contexttaal aanwezig zijn), of (b) dezelfde klank hadden in beide talen (door middel van het gebruik van interlinguale homofonen en door semantische manipulatie van de zinscontext). Vergeleken met semantisch congruente controle woorden, induceerden semantisch incongruente woorden (onafhankelijk van het feit of het *taalswitches* betrof of niet) activiteit in met name een gebied in de linker hersenhelft (BA45). Deze bevinding komt overeen met eerdere resultaten en is hoogstwaarschijnlijk het gevolg van een groter beroep op semantisch integratie (zie bijv. Hagoort, Baggio & Willems, 2009) voor incongruente woorden vergeleken met controlewoorden. *Taalswitches* leidden tot activatie van met name de linker dorsolaterale prefrontaalcortex (DLPFC, BA46). De activatie van de DLPFC was ook te zien in het contrast tussen L2-incongruente/L1-congruente homofonen en controle woorden. Er waren geen significante verschillen tussen

L2-congruente/L1-incongruente homofonen en controle woorden. Onze resultaten laten dus zien dat de linker DLPFC actief was tijdens het verwerken van *taalswitches* in L2 spraakverwerking, onafhankelijk van het feit of deze *taalswitches* vormeigenschappen van de niet-contexttaal bezaten of niet. Deze resultaten suggereren dat taallidmaatschap op een abstract (lemma- of concept) niveau in het tweetalige lexicon wordt opgeslagen in plaats van op woordvormniveau.

7.3 Discussie

Als we de resultaten uit Hoofdstukken 4 en 5 van dit proefschrift onderling vergelijken valt een interessant verschil op. Hoofdstuk 4 liet zien dat L2-congruente/L1-incongruente homofonen een kortdurende negativiteit opwekten met een links-frontale distributie. Echter, hetzelfde contrast leverde geen significante verschillen op in ons fMRI onderzoek uit Hoofdstuk 5. Het is niet eenvoudig om fMRI data en EEG data met elkaar te vergelijken, aangezien beide methoden in grote mate van elkaar verschillen in termen van temporele resolutie. Bovendien geven ze verschillende aspecten van het neuronale activatie/communicatieproces weer. Terwijl BOLD activaties ontstaan door veranderingen in *Local Field Potentials* (LFPs) en (in mindere mate) *Multi-Unit spiking Activity* (MUA; bijv. Logothetis, 2001), komt het EEG signaal voort uit exitatoire en inhibitoire post-synaptische potentialen (voor een overzicht zie: Laufs, 2008). Voorts zijn er drie mogelijkheden om de discrepantie tussen de resultaten uit Hoofdstukken 4 en 5 te verklaren: (1) ze zouden verklaard kunnen worden door een tijdsverandering in het ERP effect hetgeen leidt tot minder goede overeenkomsten met de voorspelde BOLD-response in die conditie, (2) de omvang van de neuronale activiteit zou te zwak kunnen zijn om veranderingen in het locale zuurstofmetabolisme op de plaats van activatie teweeg te brengen, of (3) de ERP-response zou simpelweg andere neuronale processen kunnen weergeven die niet goed detecteerbaar zijn met BOLD metingen. Op basis van de huidige resultaten is het echter niet mogelijk te bepalen welke van deze verklaringen de juiste is. In ieder geval suggereert de aanwezigheid van een negatief ERP effect in het contrast tussen L2-congruente/L1-incongruente homofonen en controle woorden (Hoofdstuk 4) de activatie van de L1 betekenis van het homofoon, ondanks de afwezigheid van een significant effect in het overeenkomstige fMRI-contrast (Hoofdstuk 5).

Samengevat schetsen de resultaten uit dit proefschrift een veelomvattend beeld van het tweetalige spraakverwerkingsproces. We hebben gezien dat tweetaligen meerdere woordkandidaten activeren in L2 spraakverwerking (Hoofdstuk 2), maar dat de activatie van crosslinguïstische woordkandidaten beperkt wordt door de rijkheid van de zinscontext (Hoofdstukken 2 en 3), de taalvaardigheid van de tweetalige (Hoofdstuk 3), en de hoeveelheid crosslinguïstische overlap (Hoofdstuk 4). We hebben ook gezien dat de tweetalige in staat is om de context-taal prioriteit te geven tijdens L2-spraakverwerking (Hoofdstuk 4), waarschijnlijk door aanspraak te maken op abstracte taallidmaatschapsrepresentaties (Hoofdstuk 5). Deze bevindingen proponeren een model van spraakverwerking in de tweede taal, waarin aan taalcontext en taalvaardigheid belangrijke rollen worden toebedeeld.

Dit patroon van resultaten zou verklaard kunnen worden door aan te nemen dat woorden die tot één van de talen van de meertalige behoren, onderling verbonden zijn. Terwijl elk woord in de spraakstroom verwerkt wordt, accumuleert taallidmaatschapsinformatie. Hierbij stijgt de herkenningsdrempel van woorden uit de niet-context taal en/of daalt de herkenningsdrempel van woorden uit de contexttaal. Een mogelijke manier om een dergelijk mechanisme te instantiëren is om te veronderstellen dat, zodra een woord uit een bepaalde taal herkend wordt, het een kleine hoeveelheid activatie stuurt naar alle andere woorden binnen diezelfde taal. Daardoor zullen volgende woorden uit die taal makkelijker de herkenningsdrempel bereiken. In het licht van de resultaten uit dit proefschrift zou dit impliceren dat voor geïsoleerde woorden of eenvoudige zinnen een minimale hoeveelheid crosslinguïstische overlap genoeg is om crosslinguïstische lexicale activatie teweeg te brengen. Echter, in semantisch rijke contexten is een grotere hoeveelheid crosslinguïstische overlap (bijv. *taalswitches*, homofonen) noodzakelijk omt crosslinguïstische lexicale kandidaten de herkenningsdrempel te kunnen laten overschrijden.

7.4 Conclusies

Concluderend heeft dit proefschrift laten zien dat crosslinguïstische lexicale interacties geen onvermijdelijke consequenties zijn van crosslinguïstische overlap. Echter, ze treden alleen op wanneer de tweetalige voldoende cognitieve capaciteit beschikbaar heeft (bijv. als het alleenstaande woorden of invariabele zinnen betreft) of wanneer er sprake is van een grote mate van crosslinguïstische overlap. Verder is het waarschijnlijk dat deze interacties verdwijnen naarmate de tweetalige vaardiger wordt in zijn/haar tweede taal. Zelfs als we het meest extreme voorbeeld van crosslinguïstische overlap nemen, namelijk het verwerken van woorden die in grote mate gelijkend zijn tussen twee talen, hebben we laten zien dat het spraakverwerkingssyteem van de tweetalige prioriteit geeft aan de contexttaal en daarbij crosslinguïstische ambiguïteit vermijdt. Tenslotte hebben we laten zien dat woorden in het tweetalig lexicon verbonden zijn met abstracte taallidmaatschapsrepresentaties (bijv. *taalnodes*/*taaltags*), die de tweetalige in staat stellen om woorden uit verschillende talen uitelkaar te houden. Al met al kan de tweetalige erop gerust zijn dat zijn taalverwerkingssyteem goed uitgerust is om te kunnen omgaan met (onbedoelde) crosslinguïstische overlap. Echter, de resultaten uit dit proefschrift zijn allicht minder goed nieuws voor die tweetaligen die regelmatig hun talen afwisselen, aangezien het verwerken van *taalswitches* een grotere belasting betekent voor de cognitieve verwerkingscapaciteit van toehoorders.

7.5 Referenties

Allopenna, P., Magnuson, J. & Tanenhaus, M. (1998). Tracking the time course of spoken word recognition using eye movements: Evidence for continuous mapping models. *Journal of Memory and Language*, *38*(4), 419Ð439.

Costa, A., Colomé, A., Gómez, O., Sebastián-Gallés, N. (2003). Another look at cross-language competition in bilingual speech production: Lexical and phological factors. *Bilingualism: Language and Cognition*, *6*(3), 167-179.

Dijkstra, T. (2005). Bilingual Visual Word Recognition and Lexical Access. In J. F. Kroll & A. M. B. de Groot (Eds.), *Handbook of bilingualism: Psycholinguistic approaches* (pp. 179-201). New York: Oxford University Press.

Goldinger, S. D., Luce, P. A., & Pisoni, D. B. (1989). Priming lexical neighbors of spoken words: Effects of competition and inhibition. *Journal of Memory and Language*, *28*(5), 501-518.

Hagoort, P., Baggio, G., & Willems, R. M. (2009). Semantic Unification. In M. S. Gazzaniga (Ed.), *The Cognitive Neurosciences, 4th Edition* (pp. 819-836). Cambridge, MA: The MIT Press.

Indefrey, P. (2006). A meta-analysis of hemodynamic studies on first and second language processing: Which suggested differences can we trust and what do they mean? *Language Learning*, *56*(s1), 279-304.

Kutas, M., & Hillyard, S. A. (1980). Reading senseless sentences - Brain potentials reflect semantic incongruity. *Science*, *207*(4427), 203-205.

Laufs, H. (2008). Endogenous brain oscillations and related networks detected by surface EEG-combined fMRI. *Human Brain Mapping*, *29*(7), 762-769.

Logothetis, N. K., Pauls, J., Augath, M., Trinath, T. & Oeltermann, A. (2001). Neurophysiological investigation of the basis of the fMRI signal. *Nature*, *412*(6843), 150Ð157.

Marslen-Wilson, W. D., & Tyler, L. K. (1980). Temporal structure of spoken language understanding. *Cognition*, *8*(1), 1-71.

McClelland, J. L., & Elman, J. L. (1986). The TRACE model of speech perception. *Cognitive Psychology*, *18*(1), 1-86.

Moreno, E. M., Federmeier, K. D., & Kutas, M. (2002). Switching languages, switching palabras (words): An electrophysiological study of code switching. *Brain and Language*, *80*(2), 188-207.

Norris, D. (1994). Shortlist - A connectionist model of continuous speech recognition. *Cognition*, *52*(3), 189-234.

Tanenhaus, M.K., Spivey-Knowlton, M.J., Eberhard, K.M., & Sedivy, J.C. (1995). Integration of visual and linguistic information in spoken language comprehension. *Science*, *268*(5217), 1632-1634.

Zwitserlood, P. (1989). The locus of the effects of sentential-semantic context in spoken-word processing. *Cognition*, *32*(1), 25-64.

Appendices

Supplementary materials for Chapter 2

Table A.1 contains the stimulus materials used in the experiment described in Chapter 2 of this thesis.

Figure A.1 shows the unfiltered grand average ERP waveforms corresponding to Figure 2.2

Sentence frame	*FC*	*ICL2*	*Translation*	*ICL1*	*FI*
My password no longer works. I keep getting a message that I'm denied	access	accent	toegang	tomb	blanket
There's some really important data on that fileserver but only the administrators have	access	accent	toegang	tomb	blanket
If I want to work late at the office I need a key card to gain	access	accent	toegang	tomb	blanket
The journalist wanted to attend the royal wedding but was denied	access	accent	toegang	tomb	blanket
The man was paralysed from the waist down; he'd had a motorcycle	accident	actress	ongeluk	honesty	cupboard
I didn't mean to break that vase; it was a tragic	accident	actress	ongeluk	honesty	cupboard
The waitress dropped the tray on her customer by	accident	actress	ongeluk	honesty	cupboard
There was a huge traffic jam because of a terrible	accident	actress	ongeluk	honesty	cupboard
The comedian didn't know his wife was in the	audience	audacity	publiek	pool	effort
After the show the performer thanked the	audience	audacity	publiek	pool	effort
The Cosby Show was performed in front of a	audience	audacity	publiek	pool	effort
The actors received a standing ovation from the theatre	audience	audacity	publiek	pool	effort
My uncle's wife is my	aunt	answer	tante	touch	beggar

Table A.1 Stimulus materials used in Chapter 2 – continued on next page.

Sentence frame	*FC*	*ICL2*	*Translation*	*ICL1*	*FI*
I often spent my spring break with my uncle and	aunt	answer	tante	touch	beggar
Barney's uncle recently died, it was very sad for his cousin and his	aunt	answer	tante	touch	beggar
My father's youngest sister has a farm; she is my favourite	aunt	answer	tante	touch	beggar
I used to go to school carrying a very heavy	bag	bank	tas	tusk	pineapple
My girlfriend never has clothes with pockets so she always carries a small	bag	bank	tas	tusk	pineapple
He carried the shopping in a plastic	bag	bank	tas	tusk	pineapple
The man bought so many chocolate bars that he asked the cashier for a plastic	bag	bank	tas	tusk	pineapple
The Scottish national anthem is often accompanied by someone playing the	bagpipes	barrel	doedelzak	duvet	disguise
Aside from Scots there are also Irishmen who play the	bagpipes	barrel	doedelzak	duvet	disguise
We were greeted by a Scotsman in a kilt carrying a	bagpipes	barrel	doedelzak	duvet	disguise
At Scottish funerals there's always a man playing the	bagpipes	barrel	doedelzak	duvet	disguise
At the party there was punch in a large glass	bowl	boldness	kom	confidence	intention
Her mother poured the yoghurt into the	bowl	boldness	kom	confidence	intention
She ate the hot soup from the	bowl	boldness	kom	confidence	intention

Table A.1 Stimulus materials used in Chapter 2 – continued on next page.

Sentence frame	*FC*	*ICL2*	*Translation*	*ICL1*	*FI*
The little girl kept her goldfish in a glass	bowl	boldness	kom	confidence	intention
The swing, on the tree in the garden, hung from the thickest	branch	bra	tak	tub	daughter
The cat climbed into a tree and sat on a	branch	bra	tak	tub	daughter
You can climb that tree, but hold on to a thick	branch	bra	tak	tub	daughter
The apple hung just out of reach on a very high	branch	bra	tak	tub	daughter
On Sunday we have bacon and eggs for	breakfast	breast	ontbijt	onslaught	anger
The first meal of the day is	breakfast	breast	ontbijt	onslaught	anger
The meal before lunch is called	breakfast	breast	ontbijt	onslaught	anger
When I'm in a hurry I only have a bowl of cereals for my	breakfast	breast	ontbijt	onslaught	anger
If you don't brush your teeth, people will smell your	breath	bread	adem	udder	ear
The girl I dated was a fantastic kisser, but she had really bad	breath	bread	adem	udder	ear
Have a chewing gum! It really freshens your	breath	bread	adem	udder	ear
When it's very cold outside you can see your own	breath	bread	adem	udder	ear
To get water from a well, you need a	bucket	bubble	emmer	embassy	pie
The cleaning lady used soapy water from a large iron	bucket	bubble	emmer	embassy	pie

Table A.1 Stimulus materials used in Chapter 2 – continued on next page.

Sentence frame	*FC*	*ICL2*	*Translation*	*ICL1*	*FI*
The window cleaner carried a sponge, a ladder and an	bucket	bubble	emmer	embassy	pie
You need to put something under that leaky roof; do you have a	bucket	bubble	emmer	embassy	pie
The metal object that exits a gun when fired is called a	bullet	bulldozer	kogel	code	peach
You load a shotgun with a shell instead of with a	bullet	bulldozer	kogel	code	peach
In Dallas, President Kennedy was hit in the head by a	bullet	bulldozer	kogel	code	peach
They left the pirate a gun with only one	bullet	bulldozer	kogel	code	peach
At weddings, the bride and groom are the first to cut the	cake	cave	taart	target	bridge
For my birthday, my mother made me a huge chocolate	cake	cave	taart	target	bridge
When we arrived at the birthday party we were offered a piece of	cake	cave	taart	target	bridge
What's that nice smell? Are you baking a	cake	cave	taart	target	bridge
You can buy coke in a bottle or in a	can	cap	blik	bliss	department
Instead of buying fresh carrots and peas, I just bought them in an	can	cap	blik	bliss	department
Instead of fresh fish, I often have tuna from a	can	cap	blik	bliss	department
Very cheap beer always comes in a	can	cap	blik	bliss	department

Table A.1 Stimulus materials used in Chapter 2 – continued on next page.

Sentence frame	*FC*	*ICL2*	*Translation*	*ICL1*	*FI*
She wiped the table with a damp	cloth	clog	doekje	doom	editor
Harold cleaned the windows with a damp	cloth	clog	doekje	doom	editor
First apply the wax to the car, then rub it off using a	cloth	clog	doekje	doom	editor
The windscreen is all steamed up. Could you wipe it clean using that	cloth	clog	doekje	doom	editor
My friend and I often say the same thing at the same time, completely by	coincidence	coastline	toeval	tombstone	pride
I saw a long lost friend in the supermarket, completely by	coincidence	coastline	toeval	tombstone	pride
I never thought I'd meet YOU here! What a	coincidence	coastline	toeval	tombstone	pride
9/11 is also the number to phone the emergency services in America. It's a very weird	coincidence	coastline	toeval	tombstone	pride
When I'm working I sit at a	desk	devil	bureau	boot	cork
He stayed at work overnight and fell asleep at his	desk	devil	bureau	boot	cork
If I'm out of my office, just leave the package on my	desk	devil	bureau	boot	cork
The woman at the reception was sitting behind an enormous	desk	devil	bureau	boot	cork
The film wasn't as good as I hoped it would be; it felt like a bit of a	disappointment	disgrace	teleurstelling	tonight	brush

Table A.1 Stimulus materials used in Chapter 2 – continued on next page.

Sentence frame	*FC*	*ICL2*	*Translation*	*ICL1*	*FI*
Jenny's date never showed up; she couldn't hide her	disappointment	disgrace	teleurstelling	tonight	brush
Holland didn't qualify for the last World Cup, the whole country felt a huge sense of	disappointment	disgrace	teleurstelling	tonight	brush
Kasparov lost an exciting match; he couldn't hide his	disappointment	disgrace	teleurstelling	tonight	brush
For schizophrenics hallucinations and reality are very similar and they might find it impossible to make a	distinction	display	onderscheid	onset	commitment
Light and dark is a huge contrast which means it's very easy to make the	distinction	display	onderscheid	onset	commitment
One and two Euro coins are very similar in size so it's hard for old people to make an	distinction	display	onderscheid	onset	commitment
Murder and Manslaughter is not a clear-cut difference. Sometimes it's hard to make a	distinction	display	onderscheid	onset	commitment
The girl enjoyed making tiny clothes to dress up her	doll	donkey	pop	pocket	candle
Marie is a real tomboy; she would rather play with Lego than with her	doll	donkey	pop	pocket	candle
Barbie is a very famous type of	doll	donkey	pop	pocket	candle
The boy had a toy-car the girl had a	doll	donkey	pop	pocket	candle
The person behind the steering-wheel is the	driver	dryad	bestuurder	battalion	army
My mother isn't good at parking the car, but otherwise she's a good	driver	dryad	bestuurder	battalion	army

Table A.1 Stimulus materials used in Chapter 2 – continued on next page.

Sentence frame	*FC*	*ICL2*	*Translation*	*ICL1*	*FI*
When you take the car after a night out, the person who hasn't been drinking is the designated	driver	dryad	bestuurder	battalion	army
KITT is a famous car from the TV series Knightrider; Michael Knight was its	driver	dryad	bestuurder	battalion	army
The way in to a building is also called the main	entrance	entertainment	ingang	influence	pavement
The commandos arrived at the bunker to find two terrorists guarding the main	entrance	entertainment	ingang	influence	pavement
This door is the exit not the	entrance	entertainment	ingang	influence	pavement
See you tonight at the theatre; I'll meet you at the main	entrance	entertainment	ingang	influence	pavement
In the history of Alcatraz there's only one person who managed to make an	escape	escort	ontsnapping	honour	attention
The terrorists were completely surrounded; there was no	escape	escort	ontsnapping	honour	attention
Saddam Hussein was well guarded amid fears he might try to make an	escape	escort	ontsnapping	honour	attention
The prisoner was recaptured after failing in an attempt to make an	escape	escort	ontsnapping	honour	attention
Microsoft saw its sales decrease, but their competitors saw a significant sales	increase	incubation	toename	tool	blessing
As far as the unemployment rate is concerned, politicians fear a further	increase	incubation	toename	tool	blessing

Table A.1 Stimulus materials used in Chapter 2 – continued on next page.

Sentence frame	*FC*	*ICL2*	*Translation*	*ICL1*	*FI*
If I jog even faster my heart-rate will show a dramatic	increase	incubation	toename	tool	blessing
As the wind started to blow harder, the speed of the windmill showed a definite	increase	incubation	toename	tool	blessing
On the Fourth of July Americans celebrate their	independence	intimacy	onafhankelijkheid	onlooker	amount
Croatia is a country which only recently gained its	independence	intimacy	onafhankelijkheid	onlooker	amount
The American civil war started when the southern states declared their	independence	intimacy	onafhankelijkheid	onlooker	amount
When part of a country splits off to form a new country it declares its	independence	intimacy	onafhankelijkheid	onlooker	amount
When someone in your family dies, you often get money as your	inheritance	inhaler	erfenis	error	appearance
Richard and Susan weren't married so when he died, she didn't get an	inheritance	inhaler	erfenis	error	appearance
John has twelve brothers and sisters, so when his father died only little remained of his	inheritance	inhaler	erfenis	error	appearance
My grandpa left me his bicycle in his will. It was my only	inheritance	inhaler	erfenis	error	appearance
This chocolate bar is smooth on the outside and crunchy on the	inside	instance	binnenkant	building	angle

Table A.1 Stimulus materials used in Chapter 2 – continued on next page.

Sentence frame	*FC*	*ICL2*	*Translation*	*ICL1*	*FI*
There's a fly on the window. Is it on the outside or on the	inside	instance	binnenkant	building	angle
The thing is black on the outside but white on the	inside	instance	binnenkant	building	angle
People say that true beauty isn't on the outside but on the	inside	instance	binnenkant	building	angle
That guy is really stupid he must have a brain the size of a	pea	peacock	erwt	arrow	coat
This is smaller and rounder than bean, a It's a	pea	peacock	erwt	arrow	coat
The thing that kept the princess from sleeping was a	pea	peacock	erwt	arrow	coat
The princess looked under the mattress and found a	pea	peacock	erwt	arrow	coat
Tim wanted to go out, but his parents didn't give him	permission	perversion	toestemming	tuna	adult
If I want the day off work, I have to ask for	permission	perversion	toestemming	tuna	adult
I'd like to go to a conference, but I'll have to ask my boss for	permission	perversion	toestemming	tuna	adult
Before you board a naval vessel you have to ask the captain for	permission	perversion	toestemming	tuna	adult
At the barbecue we ate our food from a plastic	plate	place	bord	boredom	darkness

Table A.1 Stimulus materials used in Chapter 2 – continued on next page.

Sentence frame	*FC*	*ICL2*	*Translation*	*ICL1*	*FI*
The rich man ate his food from a beautiful ceramic	plate	place	bord	boredom	darkness
When the hungry boy finished eating there was nothing left on his	plate	place	bord	boredom	darkness
If you'd like some more potatoes, just pass me your	plate	place	bord	boredom	darkness
It's our parents' anniversary today; did you buy them a	present	pretzel	cadeau	cartoon	turtle
The boy was convinced that Father Christmas would bring him a	present	pretzel	cadeau	cartoon	turtle
The girl sneaked downstairs to take a look at her Christmas	present	pretzel	cadeau	cartoon	turtle
It's my girlfriend's birthday, so I need to buy her a	present	pretzel	cadeau	cartoon	turtle
When you're in France you should drink bottled water, not water from the	tap	talon	kraan	craft	beach
Africans have to go to a well to get water, we can just open the	tap	talon	kraan	craft	beach
The plumber had to repair the toilet, shower and the dripping	tap	talon	kraan	craft	beach
He drank water straight from the	tap	talon	kraan	craft	beach
The play had been sold out for months; many people couldn't get a	ticket	tissue	kaartje	casket	bone

Table A.1 Stimulus materials used in Chapter 2 – continued on next page.

Sentence frame	*FC*	*ICL2*	*Translation*	*ICL1*	*FI*
Robbie Williams is giving a concert in town; my sister saved up all her pocket money for a	ticket	tissue	kaartje	casket	bone
The concert is almost sold out so you'll have to rush to get a	ticket	tissue	kaartje	casket	bone
We wanted to go to the match but we didn't have a	ticket	tissue	kaartje	casket	bone
The playground had a swing made out of an old tractor	tyre	timer	band	button	cauliflower
The amount of grip you have on the road depends on the profile of your	tyre	timer	band	button	cauliflower
I'm sorry I'm late; my bike had a flat	tyre	timer	band	button	cauliflower
I cycled through some glass the other day; I'm glad it didn't puncture my	tyre	timer	band	button	cauliflower
The waitress was embarrassed when one glass of beer fell off her	tray	traitor	dienblad	decency	bench
I can't carry the soup, bread and coffee at once; I'll need an	tray	traitor	dienblad	decency	bench
When I take the dirty dishes to the kitchen, I pile everything on a	tray	traitor	dienblad	decency	bench
The waiter brought all the drinks on a wooden	tray	traitor	dienblad	decency	bench
A belt is an accessory to use with your	trousers	trout	broek	broom	drawing
You usually wear boxer-shorts under your	trousers	trout	broek	broom	drawing

Table A.1 Stimulus materials used in Chapter 2 – continued on next page.

Sentence frame	*FC*	*ICL2*	*Translation*	*ICL1*	*FI*
Many women don't like wearing skirts but prefer wearing	trousers	trout	broek	broom	drawing
Some Scots wear kilts in stead of	trousers	trout	broek	broom	drawing
I don't have a raincoat but I did bring an	umbrella	umpire	paraplu	parliament	consumption
It was raining but he had forgotten his	umbrella	umpire	paraplu	parliament	consumption
The thing you carry to stop you getting wet in the rain is called an	umbrella	umpire	paraplu	parliament	consumption
Because it frequently rains in London, James always carries an	umbrella	umpire	paraplu	parliament	consumption
I often spent my summer holiday with my aunt and	uncle	unctuousness	oom	owner	path
That's not my father! That's his twin brother, my	uncle	unctuousness	oom	owner	path
My cousin's father is my	uncle	unctuousness	oom	owner	path
My mother's elder brother lives in Birmingham; he's my favourite	uncle	unctuousness	oom	owner	path

Table A.1 Stimulus materials used in Chapter 2 including the sentence frame and corresponding target words in the Fully Congruent (FC), Initially Congruent with the L2 (ICL2), Initially Congruent with the L1 (ICL1), and Fully Incongruent (FI) conditions. The Dutch translation equivalent (Translation) of the FC item is given for comparison.

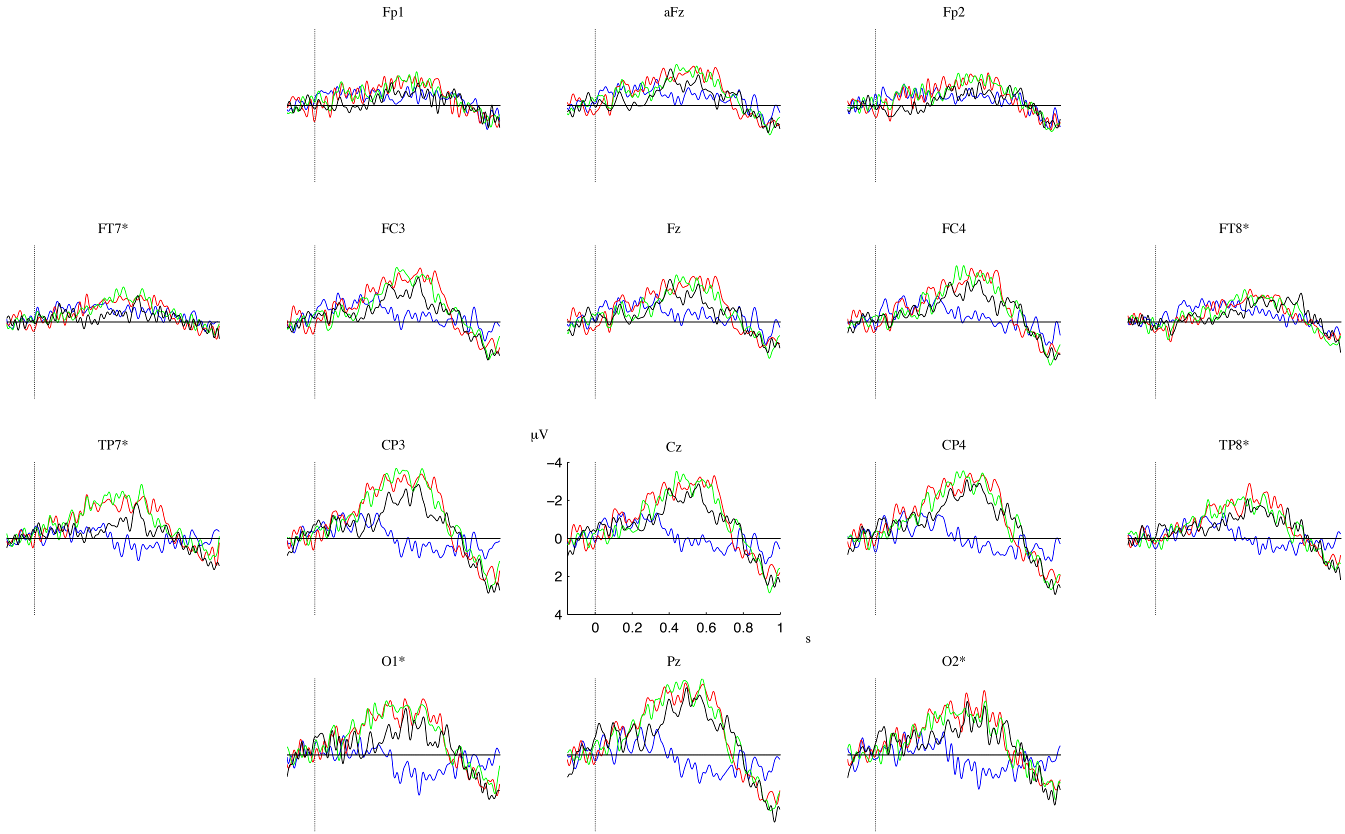


Figure A.1: Unfiltered grand average waveforms on 16 scalp electrodes and scalp topographies. (Blue) Fully congruent; (red) fully incongruent; (black) initially congruent with the L2; and (green) initially congruent with the L1. Asterisk denotes nonstandard electrode location. See Figure 2.2 for filtered waveforms.

Supplementary materials for Chapter 3

Table B.1 lists the stimulus materials used in Chapter 3 of this thesis.

Sentence frame	*Competitor*	*Distractors set 1*	*Distractors set 2*
A *carrot* is good for your eyesight.	*kerk* (church)	*fluitje* (whistle)	*schelp* (shell)
		spiegel (mirror)	*vogelhuis* (birdhouse)
The little boy pointed at the *carrot*.	*kerk* (church)	*schelp* (shell)	*fluitje* (whistle)
		vogelhuis (birdhouse)	*spiegel* (mirror)
A *bowl* of soup is good as a starter.	*boom* (tree)	*auto* (car)	*schaar* (scissors)
		snor (moustache)	*vliegtuig* (plane)
The couple was considering the *bowl*.	*boom* (tree)	*schaar* (scissors)	*auto* (car)
		vliegtuig (plane)	*snor* (moustache)
A *kitten* makes a nice pet.	*kist* (chest)	*moer* (nut)	*tomaat* (tomato)
		borstel (brush)	*been* (leg)
Each night he dreamt of the *kitten*.	*kist* (chest)	*tomaat* (tomato)	*moer* (nut)
		been (leg)	*borstel* (brush)
A *knife* is used to cut things.	*nijlpaard* (hippo)	*schelp* (shell)	*strik* (bow)
		vogelhuis (birdhouse)	*vogel* (bird)
I'm not afraid of the *knife*.	*nijlpaard* (hippo)	*strik* (bow)	*schelp* (shell)
		vogel (bird)	*vogelhuis* (birdhouse)
That *pie* contains cheese and vegetables.	*pijl* (arrow)	*deur* (door)	*bloem* (flower)
		kous (stocking)	*schommel* (swing)
He enthusiastically described the *pie*.	*pijl* (arrow)	*bloem* (flower)	*deur* (door)
		schommel (swing)	*kous* (stocking)
A *seatbelt* should be worn at all times in this vehicle.	*citroen* (lemon)	*kleed* (rug)	*ezel* (donkey)
		pot (pot)	*bril* (glasses)
That word rhymes with *seatbelt*.	*citroen* (lemon)	*ezel* (donkey)	*kleed* (rug)

Table B.1 Stimulus materials used in Chapter 3 – continued on next page.

Sentence frame	*Competitor*	*Distractors set 1*	*Distractors set 2*
That *meat* hasn't been cooked.	*mier* (ant)	*bril* (glasses) *tafel* (table)	*pot* (pot) *hoed* (hat)
The thing looked a lot like *meat*.	*mier* (ant)	*beker* (cup) *hoed* (hat)	*raam* (window) *tafel* (table)
A *shark* is a dangerous animal.	*sjaal* (scarf)	*raam* (window) *föhn* (hairdryer)	*beker* (cup) *paddestoel* (mushroom)
The magazine had a picture of a *shark*.	*sjaal* (scarf)	*berg* (mountain) *paddestoel* (mushroom)	*oog* (eye) *föhn* (hairdryer)
A *light bulb* is not very difficult to change.	*lijst* (frame)	*oog* (eye) *strik* (bow)	*berg* (mountain) *den* (pine)
He asked about the price of the *light bulb*.	*lijst* (frame)	*vogel* (bird) *den* (pine)	*aardbei* (strawberry) *strik* (bow)
A *stamp* is used on letters.	*stekker* (plug)	*aardbei* (strawber-ry) *ezel* (donkey)	*vogel* (bird) *tafel* (table)
He was very worried about the *stamp*.	*stekker* (plug)	*bril* (glasses) *tafel* (table)	*beker* (cup) *ezel* (donkey)
My *desk* is at the window.	*deksel* (lid)	*beker* (cup) *bloem* (flower)	*bril* (glasses) *meisje* (girl)
My grandma has a very ugly *desk*.	*deksel* (lid)	*schommel* (swing) *meisje* (girl)	*wolk* (cloud) *bloem* (flower)
Your *spine* is very vulnerable.	*spijker* (nail)	*wolk* (cloud) *hoed* (hat)	*schommel* (swing) *muts* (cap)
The child drew a picture of a *spine*.	*spijker* (nail)	*raam* (window) *muts* (cap)	*afvalemmer* (trashcan) *hoed* (hat)

Table B.1 Stimulus materials used in Chapter 3 – continued on next page.

Sentence frame	*Competitor*	*Distractors set 1*	*Distractors set 2*
		afvalemmer (trashcan)	*raam* (window)
A *flashlight* can be helpful in the dark.	*fles* (bottle)	*klerenhanger* (coat hanger)	*auto* (car)
		muis (mouse)	*snor* (moustache)
The man carefully moved the *flashlight*.	*fles* (bottle)	*auto* (car)	*klerenhanger* (coat hanger)
		snor (moustache)	*muis* (mouse)
The *money* was safe at the bank.	*mand* (basket)	*den* (pine)	*deur* (door)
		aardbei (strawberry)	*kous* (stocking)
We overheard a conversation about the *money*.	*mand* (basket)	*deur* (door)	*den* (pine)
		kous (stocking)	*aardbei* (strawberry)
That *closet* can be bought at Ikea.	*klomp* (wooden shoe)	*paddestoel* (mushroom)	*föhn* (hairdryer)
		oog (eye)	*berg* (mountain)
He changed the password to *closet*.	*klomp* (wooden shoe)	*föhn* (hairdryer)	*paddestoel* (mushroom)
		berg (mountain)	*oog* (eye)
The *bike* had a flat tyre.	*bijl* (axe)	*meisje* (girl)	*klerenhanger* (coat hanger)
		wolk (cloud)	*muis* (mouse)
He asked her what she thought of the *bike*.	*bijl* (axe)	*klerenhanger* (coat hanger)	*meisje* (girl)
		muis (mouse)	*wolk* (cloud)
The *lake* was unsuitable for swimming	*lepel* (spoon)	*muts* (cap)	*hand* (hand)
		afvalemmer (trashcan)	*knoop* (button)
He read a book about a *lake*.	*lepel* (spoon)	*hand* (hand)	*muts* (cap)
		knoop (button)	*afvalemmer* (trashcan)
The *spring* in the mattress was effective.	*sprinkhaan* (grasshopper)	*tomaat* (tomato)	*kleed* (rug)

Table B.1 Stimulus materials used in Chapter 3 – continued on next page.

Sentence frame	*Competitor*	*Distractors set 1*	*Distractors set 2*
		been (leg)	*pot* (pot)
He made a funny joke about a *spring*.	*sprinkhaan* (grasshopper)	*kleed* (rug)	*tomaat* (tomato)
		pot (pot)	*been* (leg)
The *duck* was swimming in the pond.	*dak* (roof)	*schaar* (scissors)	*moer* (nut)
		vliegtuig (plane)	*borstel* (brush)
In the end she chose the *duck*.	*dak* (roof)	*moer* (nut)	*schaar* (scissors)
		borstel (brush)	*vliegtuig* (plane)
The *leaf* had fallen from the tree.	*libel* (dragonfly)	*hand* (hand)	*fluitje* (whistle)
		knoop (button)	*spiegel* (mirror)
We managed to Google the word *leaf*.	*libel* (dragonfly)	*fluitje* (whistle)	*hand* (hand)
		spiegel (mirror)	*knoop* (button)

Table B.1 Stimulus materials used in Chapter 3, including the sentence frames and corresponding target items, competitors, and interlingual distractors for both experimental lists. English translations are given in parentheses.

Supplementary materials for Chapters 4 & 5

Table C.1 contains the stimulus materials used in Experiment 1 in Chapter 4 and Experiment 2 in Chapter 5.

Table C.2 contains the stimulus materials used in Experiment 2 in Chapter 4 and Experiment 1 in Chapter 5.

Figure C.1 shows the unfiltered grand average ERP waveforms corresponding to Figure 4.2

Figure C.2 shows the unfiltered grand average ERP waveforms corresponding to Figure 4.3

Sentence frame	*NL spelling*	*Condition*
The Red Cross is an organisation that provides *aid* to impoverished people.	eed	L2-congruent/L1-incongruent
He set the mouse trap using some cheese as *bait* for the mice.	beet	L2-congruent/L1-incongruent
When they asked the waiter for the *bill* he brought the wrong one.	bil	L2-congruent/L1-incongruent
The dog was happy when his owner gave him a *bone* to chew on.	boon	L2-congruent/L1-incongruent
The employee had not reached his sales target and had to go to his *boss* to explain himself.	bos	L2-congruent/L1-incongruent
In Wales people used to make their living mining for *coal* for minimal pay.	kool	L2-congruent/L1-incongruent
My mother makes nice food. She's a very good *cook* though we seldom admit it.	koek	L2-congruent/L1-incongruent
It was the car thief's worst fear. He was being pursued by a *cop* on a motorcycle.	kop	L2-congruent/L1-incongruent
The earth has magma in its *core* which is usually rather hot.	koor	L2-congruent/L1-incongruent
The farmer was going to get milk from his favourite *cow* when he tripped over the pail.	kou	L2-congruent/L1-incongruent
Some people believe the Holy Grail is the *cup* that caught the blood of Jesus.	kap	L2-congruent/L1-incongruent
The doctor had prescribed the correct medicine but in the incorrect *dose* for this patient.	doos	L2-congruent/L1-incongruent
Sales of British beef suffered a huge *drop* after the BSE scare.	drop	L2-congruent/L1-incongruent
You must go with the *flow* if you want to be successful.	vlo	L2-congruent/L1-incongruent
The God Pan famously played the *flute* to the annoyance of his fellow deities.	vloed	L2-congruent/L1-incongruent
The Pentagon's computer network was breached in a skilful *hack* by the foreign terrorist.	hek	L2-congruent/L1-incongruent
A pig-like animal that lives in the forest is called a *hog* or a boar.	hok	L2-congruent/L1-incongruent
The pirate no longer had a hand, but he had a *hook* instead.	hoek	L2-congruent/L1-incongruent

Table C.1 Stimulus materials used in Chapter 4, Experiment 1 & Chapter 5, Experiment 2 – continued on next page.

Sentence frame	*NL spelling*	*Condition*
When the mother and daughter were reunited they rushed to give each other a *hug* and a kiss.	hak	L2-congruent/L1-incongruent
The dead soldier's companion had to write a letter to his next of *kin* to inform them of his death.	kin	L2-congruent/L1-incongruent
Ontario is near a large body of water called *lake* Ontario.	leek	L2-congruent/L1-incongruent
When the alpha male departs the other just follow his *lead* rather than risking his wrath.	lied	L2-congruent/L1-incongruent
On the lowest branch of the tree was a single *leaf* that hadn't fallen off.	lief	L2-congruent/L1-incongruent
To remember what I need to buy I make a *list* with all my shopping.	list	L2-congruent/L1-incongruent
When you borrow money from a bank it's called getting a *loan* of money.	loon	L2-congruent/L1-incongruent
The stunt pilot took his plane into a 360 degree *loop* followed by a downward spiral.	loep	L2-congruent/L1-incongruent
The gambler had a streak of bad *luck* at the poker table.	lak	L2-congruent/L1-incongruent
These days, people hardly ever send normal letters but prefer to use electronic *mail* for their correspondence.	meel	L2-congruent/L1-incongruent
These days people use their Satellite Navigation instead of using a *map*, the old fashioned way	mep	L2-congruent/L1-incongruent
The untidy teenager had left his room in a bit of a *mess* to his mother's annoyance.	mes	L2-congruent/L1-incongruent
Uncle Robert was very kind to his nephew and his *niece* during the summer.	nies	L2-congruent/L1-incongruent
I need to find a pen so I can make a quick *note* of that.	noot	L2-congruent/L1-incongruent
The rowing boat went around in circles because we had only brought one *oar* for rowing.	oor	L2-congruent/L1-incongruent

Table C.1 Stimulus materials used in Chapter 4, Experiment 1 & Chapter 5, Experiment 2 – continued on next page.

Sentence frame	*NL spelling*	*Condition*
While they were walking in the woods, they moved along at a steady *pace* that was too fast for grandma.	pees	L2-congruent/L1-incongruent
His cat Felix was his favourite *pet* in the world.	pet	L2-congruent/L1-incongruent
The theatre crew moved a table onto the stage as a *prop* for the play.	prop	L2-congruent/L1-incongruent
Tiger woods carefully prepared his *putt* on the 18th hole.	pad	L2-congruent/L1-incongruent
Through the clouds there shone a single *ray* of sunlight.	ree	L2-congruent/L1-incongruent
A meteorite is basically a large *rock* from space.	rok	L2-congruent/L1-incongruent
Do not disturb the hen on its *roost* while it's laying an egg.	roest	L2-congruent/L1-incongruent
The tree absorbs water through its *root* in the soil.	roet	L2-congruent/L1-incongruent
The hill wasn't very steep, there was just a gradual *slope* upwards.	sloop	L2-congruent/L1-incongruent
You put coins in a vending machine via a *slot* on the front.	slot	L2-congruent/L1-incongruent
Her room was scrupulously clean without a single *speck* of dust in sight.	spek	L2-congruent/L1-incongruent
The prince and princess were under a *spell* by their fairy Godmother.	spel	L2-congruent/L1-incongruent
The proud owner took his new car for a *spin* on a race track.	spin	L2-congruent/L1-incongruent
The lama hit the bemused tourist in the eye with a bit of *spit* from his mouth.	spit	L2-congruent/L1-incongruent
The rear-wheel of his bicycle had one bent *spoke* that was causing all the trouble.	spook	L2-congruent/L1-incongruent
In extremely hot weather, it's advisable to find a cool *spot* in the shade.	spot	L2-congruent/L1-incongruent
When preparing shitake mushrooms you first remove the *stem* then chop up the rest.	stem	L2-congruent/L1-incongruent
Neil Armstrong took one small *step* on the moon.	step	L2-congruent/L1-incongruent
The Wall Street trader was ecstatic when his *stock* rose sharply.	stok	L2-congruent/L1-incongruent
At its source this river was just a small *stream* from the mountains.	striem	L2-congruent/L1-incongruent
When a blood vessel bursts in your brain it's called having a *stroke* or a CVA.	strook	L2-congruent/L1-incongruent

Table C.1 Stimulus materials used in Chapter 4, Experiment 1 & Chapter 5, Experiment 2 – continued on next page.

Sentence frame	*NL spelling*	*Condition*
He took the sick animal to a *vet* to have it examined.	wet	L2-congruent/L1-incongruent
After the accident, the car was a complete *wreck* and had to be written off.	rek	L2-congruent/L1-incongruent
Medical Doctors have to swear an *aid* to do no harm.	eed	L2-incongruent/L1-congruent
When the rabid dog attacked him he suffered a nasty *bait* on his leg.	beet	L2-incongruent/L1-congruent
The zoo keeper shot the rhino in his left *bill*, and it fell asleep.	bil	L2-incongruent/L1-congruent
The beanstalk had grown after Jack had planted the magic *bone* in the garden.	boon	L2-incongruent/L1-congruent
Little red riding hood was going to visit her grandma in the *boss* but she was too late.	bos	L2-incongruent/L1-congruent
Sauerkraut is a type of *coal* that is often eaten in Germany.	kool	L2-incongruent/L1-congruent
At four o'clock I had a cup of tea and a piece of *cook* in my break time.	koek	L2-incongruent/L1-congruent
You must bend down near those low beams or you might bang your *cop* on them.	kop	L2-incongruent/L1-congruent
For the Christmas mass the altar boy was supposed to sing in the *core* but he got laryngitis.	koor	L2-incongruent/L1-congruent
It's nice and warm indoors. I'd hate to go out into the *cow* to go shopping.	kou	L2-incongruent/L1-congruent
The monk had a brown robe with a *cup* over his head.	kap	L2-incongruent/L1-congruent
When you move house you have to put all your books in a *dose* for transportation.	doos	L2-incongruent/L1-congruent
The girl went to the sweet shop and bought a bag of salty *drop* for her father.	drop	L2-incongruent/L1-congruent
The dog was bitten by a large *flow* in his fur.	vlo	L2-incongruent/L1-congruent
Regular rising of the sea level because of the orbit of the moon it's called *flute* which is inevitably followed by low tide.	vloed	L2-incongruent/L1-congruent
To keep them from escaping, the animals were kept behind a barbed wire *hack* that had been electrified.	hek	L2-incongruent/L1-congruent

Table C.1 Stimulus materials used in Chapter 4, Experiment 1 & Chapter 5, Experiment 2 – continued on next page.

Sentence frame	*NL spelling*	*Condition*
Snoopy didn't sleep in the house, but he had his own *hog* outdoors.	hok	L2-incongruent/L1-congruent
Launching a projectile at a 45 degree *hook* will get it the farthest.	hoek	L2-incongruent/L1-congruent
Some women wear shoes with a high *hug* so they might look taller.	hak	L2-incongruent/L1-congruent
A goatee is a long beard that is predominantly on the *kin* of the person in question.	kin	L2-incongruent/L1-congruent
He didn't know much about the subject. He was a bit of a *lake* though he'd never admit it.	leek	L2-incongruent/L1-congruent
At his birthday party, his friends sang a nice *lead* for him.	lied	L2-incongruent/L1-congruent
He bought a box of chocolates for his *leaf* at the station.	lief	L2-incongruent/L1-congruent
The cunning fox made up a *list* to catch the rabbit.	list	L2-incongruent/L1-congruent
His employer gave him a cheque worth twice his monthly *loan* for his services.	loon	L2-incongruent/L1-congruent
The little boy liked burning ants with his *loop* and the afternoon sun.	loep	L2-incongruent/L1-congruent
For her fingernails the fashion model chose red nail *luck* with glitter.	lak	L2-incongruent/L1-congruent
Windmills were often used to grind grain into a fine white powder called *mail* which is used to make bread.	meel	L2-incongruent/L1-congruent
When his little brother stole his sweet the angry boy gave him a *map* on the cheek.	mep	L2-incongruent/L1-congruent
Chinese people eat with chopsticks instead of using a fork and a *mess* or even a spoon.	mes	L2-incongruent/L1-congruent
Tissues are useful when you feel a *niece* coming on.	nies	L2-incongruent/L1-congruent
An almond is a type of *note* that is often very salty.	noot	L2-incongruent/L1-congruent
My grandpa is deaf in one *oar*, so I always approach him from the right.	oor	L2-incongruent/L1-congruent
The muscle is attached to the bone by a *pace* which is susceptible to infections.	pees	L2-incongruent/L1-congruent
On his head, the policeman wore a *pet* to hide his baldness.	pet	L2-incongruent/L1-congruent

Table C.1 Stimulus materials used in Chapter 4, Experiment 1 & Chapter 5, Experiment 2 – continued on next page.

Sentence frame	*NL spelling*	*Condition*
The bored student crumpled his paper into a *prop* and threw it at the teacher.	prop	L2-incongruent/L1-congruent
That's not a frog! It's a slimy brown *putt* in that pond.	pad	L2-incongruent/L1-congruent
In the forest we saw the hoof prints of a *ray* in the sand.	ree	L2-incongruent/L1-congruent
Her farther wouldn't let her leave the house wearing her short *rock* and strapless top.	rok	L2-incongruent/L1-congruent
The exposed metal had been out in the rain and was now covered in *roost* and fungus.	roest	L2-incongruent/L1-congruent
The chimney sweep's face had become black from all the *root* in the chimney.	roet	L2-incongruent/L1-congruent
The car had been so badly damaged in had to be taken to the *slope* for demolition.	sloop	L2-incongruent/L1-congruent
His bike was stolen despite him having a very secure *slot* on it.	slot	L2-incongruent/L1-congruent
On Sundays we have eggs and *speck* for breakfast.	spek	L2-incongruent/L1-congruent
The boy wanted to play a *spell* with his friends.	spel	L2-incongruent/L1-congruent
To his horror, the arachnophobe saw a *spin* on the wall and screamed.	spin	L2-incongruent/L1-congruent
The wild boar was roasting on the *spit* when the hunters returned home.	spit	L2-incongruent/L1-congruent
In the cartoons Casper was a friendly *spoke* that never harmed a soul.	spook	L2-incongruent/L1-congruent
The disgraced politician didn't want to hold a press conference for fear of being the object of *spot* by the media.	spot	L2-incongruent/L1-congruent
To be heard above the noise he had to raise his *stem* and shout.	stem	L2-incongruent/L1-congruent
The little girl didn't get a bike, but a small pink *step* for her birthday.	step	L2-incongruent/L1-congruent
His dog, Fido, loves it when you throw a *stock* for him to chase.	stok	L2-incongruent/L1-congruent
The boy who was whipped had a large red *stream* on his back.	striem	L2-incongruent/L1-congruent
Israel and Palestine fought many battles over the Gaza *stroke* and the West Bank.	strook	L2-incongruent/L1-congruent

Table C.1 Stimulus materials used in Chapter 4, Experiment 1 & Chapter 5, Experiment 2 – continued on next page.

Sentence frame	*NL spelling*	*Condition*
Driving under the influence is against the *vet* in most countries.	wet	L2-incongruent/L1-congruent
He took his favourite bottle of wine off the *wreck* and dusted it off.	rek	L2-incongruent/L1-congruent
John went for a walk in the *aid* after breakfast.	eed	L2 incongruent/ L1 incongruent
My mother isn't good at reversing the *bait* which isn't very handy when parking.	beet	L2 incongruent/ L1 incongruent
When you make tea you have to boil the *bill* or it'll be cold	bil	L2 incongruent/ L1 incongruent
The addict wanted to smoke the *bone* but the policeman caught him in time.	boon	L2 incongruent/ L1 incongruent
In the morning, he liked to read the *boss* while drinking coffee.	bos	L2 incongruent/ L1 incongruent
When the washing machine had finished he started to hang the *coal* on the balcony.	kool	L2 incongruent/ L1 incongruent
To his wife's disgust he decided to grow his *cook* to see how it looked.	koek	L2 incongruent/ L1 incongruent
A grocers' store is the right place to buy a *cop* and some lettuce for dinner.	kop	L2 incongruent/ L1 incongruent
She needed to be well trained to run the *core* in under 3 hours.	koor	L2 incongruent/ L1 incongruent
Jim tried desparately to erase the *cow* but windows wouldn't let him.	kou	L2 incongruent/ L1 incongruent
The children went to greet the *cup* when he came to town.	kap	L2 incongruent/ L1 incongruent
The striker wanted him to pass the *dose* so he could score.	doos	L2 incongruent/ L1 incongruent
The mother decided to bathe her *drop* before bringing her to bed.	drop	L2 incongruent/ L1 incongruent
The business man had to rent a *flow* on his trip to America.	vlo	L2 incongruent/ L1 incongruent
The cannibal decided to eat the *flute* without cooking it.	vloed	L2 incongruent/ L1 incongruent
The players persisent fouling really started to annoy the *hack* so he sent him off.	hek	L2 incongruent/ L1 incongruent
To stick the pieces together you must apply the *hog* in a thick coating.	hok	L2 incongruent/ L1 incongruent
To make an omelette you must fry the *hook* on both sides.	hoek	L2 incongruent/ L1 incongruent
Sometimes it's necessary to shoot a *hug* to end its suffering.	hak	L2 incongruent/ L1 incongruent
Barry needed some more inspiration to write the *kin* but it just didn't come.	kin	L2 incongruent/ L1 incongruent

Table C.1 Stimulus materials used in Chapter 4, Experiment 1 & Chapter 5, Experiment 2 – continued on next page.

Sentence frame	*NL spelling*	*Condition*
From the free kick Beckham scored a fantastic *lake* to put his team in front.	leek	L2 incongruent/ L1 incongruent
The man didn't want to harm the *lead* just scare it a little.	lied	L2 incongruent/ L1 incongruent
The girl had to return the *leaf* because it didn't fit after all.	lief	L2 incongruent/ L1 incongruent
It took quite a while to warm the *list* in winter.	list	L2 incongruent/ L1 incongruent
Gordon Ramsey paused to taste the *loan* before rushing it to the waiting guests.	loon	L2 incongruent/ L1 incongruent
Father wanted to help his *loop* with her homework, but he didn't understand it himself.	loep	L2 incongruent/ L1 incongruent
Fred was going to sail his new *luck* across the English channel.	lak	L2 incongruent/ L1 incongruent
The boxer tried to hit his *mail* but he dodged the blow.	meel	L2 incongruent/ L1 incongruent
The mother wanted to embrace her *map* but she didn't seem interested.	mep	L2 incongruent/ L1 incongruent
We use liquid helium to cool the *mess* and make it superconducting.	mes	L2 incongruent/ L1 incongruent
Delia was baking a *niece* when her phone rang.	nies	L2 incongruent/ L1 incongruent
The chicken crossed the *note* to get to the other side.	noot	L2 incongruent/ L1 incongruent
I tend not to butter my *oar* to limit my calorie intake.	oor	L2 incongruent/ L1 incongruent
They managed to hide the *pace* before the police came.	pees	L2 incongruent/ L1 incongruent
Jeremy took grate pleasure in driving the *pet* on the racetrack.	pet	L2 incongruent/ L1 incongruent
Hammond nearly died when he crashed the *prop* on the runway.	prop	L2 incongruent/ L1 incongruent
Ray used matches to burn the *putt* until it smoked.	pad	L2 incongruent/ L1 incongruent
The pilot had been trained to fly the *ray* in adverse weather conditions.	ree	L2 incongruent/ L1 incongruent
The murderer was going to kill his latest *rock* with a spoon.	rok	L2 incongruent/ L1 incongruent
To relax I often surf the *roost* on my laptop.	roest	L2 incongruent/ L1 incongruent
I hate having to iron my *root* before I wear it.	roet	L2 incongruent/ L1 incongruent
George stood under the misletoe hoping to kiss the *slope* with the green necklace.	sloop	L2 incongruent/ L1 incongruent

Table C.1 Stimulus materials used in Chapter 4, Experiment 1 & Chapter 5, Experiment 2 – continued on next page.

Sentence frame	*NL spelling*	*Condition*
The film council decided to ban the *slot* because it contained excessive violence.	slot	L2 incongruent/ L1 incongruent
It takes two psychologists to change a *speck* it seems.	spek	L2 incongruent/ L1 incongruent
The new appliance can effictively wash the *spell* and dry it too.	spel	L2 incongruent/ L1 incongruent
Dettol is something you use to clean your *spin* when it's dirty.	spin	L2 incongruent/ L1 incongruent
Ainsley used a clean knife to cut the *spit* in half.	spit	L2 incongruent/ L1 incongruent
Many adventurers wish to climb the *spoke* some day.	spook	L2 incongruent/ L1 incongruent
In developing countries it often isn't safe to drink the *spot* without boiling it first.	spot	L2 incongruent/ L1 incongruent
I've always wanted to visit my *stem* in New Zealand.	stem	L2 incongruent/ L1 incongruent
The actor had to play the *step* in the new musical.	step	L2 incongruent/ L1 incongruent
The salesman even offered to polish the *stock* while he waited.	stok	L2 incongruent/ L1 incongruent
Her sister always borrowed her *stream* without asking her first.	striem	L2 incongruent/ L1 incongruent
He really needed to dust his *stroke* before his girlfriend arrived.	strook	L2 incongruent/ L1 incongruent
The customer was idly browsing the *vet* when the salesman approached him.	wet	L2 incongruent/ L1 incongruent
He intened to swim the *wreck* that year.	rek	L2 incongruent/ L1 incongruent
I often spent my spring break with my uncle and *aunt* in London.	n/a	Congruent control
The man bought so many chocolate bars that he asked the cashier for a plastic *bag* to carry them with.	n/a	Congruent control
Honey is made by a particular type of insect called a *bee* which is sometimes confused with a wasp.	n/a	Congruent control
The boy was late for school because he had a flat tyre on his *bike* and had to walk the whole way.	n/a	Congruent control
If you don't brush your teeth, people will smell your *breath* and avoid you like the plague.	n/a	Congruent control

Table C.1 Stimulus materials used in Chapter 4, Experiment 1 & Chapter 5, Experiment 2 – continued on next page.

Sentence frame	*NL spelling*	*Condition*
When we arrived at the birthday party we were offered a piece of *cake* and a glass of wine.	n/a	Congruent control
The lion is related to our common household *cat*, but is substantially more dangerous.	n/a	Congruent control
I don't want to pay with cash. Can I write you a *cheque* for that amount?	n/a	Congruent control
Harold cleaned the windows with a damp *cloth* but the grime didn't come off.	n/a	Congruent control
Cancer is a terrible disease for which there is still no *cure* which is effective.	n/a	Congruent control
Barbie is a very famous type of *doll* which is made of plastic.	n/a	Congruent control
A nightmare is basically a bad *dream* which often leaves you frightened.	n/a	Congruent control
The chicken was about to lay an *egg* when it was startled by the fox.	n/a	Congruent control
Wendy wanted to go on the merry-go-round at the country *fair* but her mother wouldn't let her.	n/a	Congruent control
A boxing match is basically an organised *fight* between combatants wearing gloves.	n/a	Congruent control
Chuck Norris punched the man in the face with his bare *fist* and nearly broke his own hand.	n/a	Congruent control
The moth was drawn to the *flame* of the candle.	n/a	Congruent control
For the picnic I brought a wine in a bottle and coffee in a thermos *flask* made of aluminium.	n/a	Congruent control
The careless child dropped his glass on the *floor* and it broke.	n/a	Congruent control
Pizza is my favourite *food*, and beer is my favourite drink.	n/a	Congruent control
Saint Peter stands before the *gate* to Heaven.	n/a	Congruent control
To minimize the risk of infection the surgeon wore a latex *glove* on his hand.	n/a	Congruent control

Table C.1 Stimulus materials used in Chapter 4, Experiment 1 & Chapter 5, Experiment 2 – continued on next page.

Sentence frame	*NL spelling*	*Condition*
When you're obsessed with making lots of money your primary sin is *greed* which seems to be awfully common these days.	n/a	Congruent control
The widow was overcome by *grief* at her husbands funeral.	n/a	Congruent control
The man escaped a prison sentence because the jury wasn't convinced of his *guilt* and he was promptly released.	n/a	Congruent control
There were two recent wars in the Persian *gulf* which were remarkably similar.	n/a	Congruent control
Bees live in an organised structure called a *hive* which is ruled over by a queen.	n/a	Congruent control
On formal occasions Scottish men wear a *kilt* instead of trousers.	n/a	Congruent control
One sunny day the boy wanted to fly his *kite* in the park.	n/a	Congruent control
The space shuttle crew did their final checks before the *launch* which was due to commence within the hour.	n/a	Congruent control
His last film was too short, but this one had just the right *length* to be enjoyable.	n/a	Congruent control
The truck could hardly move because of its heave *load* of concrete blocks.	n/a	Congruent control
The rock band's hotel room was a mess, to the dismay of the *maid* who had to clean it up.	n/a	Congruent control
Muslims pray in a *mosque* and Christians go to church.	n/a	Congruent control
Midday is also called *noon* in colloquial speech.	n/a	Congruent control
I extended my hand to the dog and it gave me its *paw* to shake.	n/a	Congruent control
We went to the Vatican to see the *Pope* give an address to his followers.	n/a	Congruent control
When the baby took its first steps its parents felt enormous *pride* in him.	n/a	Congruent control
You'll catch a cold in you stand outside in the pouring *rain* like that!	n/a	Congruent control
Could you put the book back on the *shelf* when you're done with it?	n/a	Congruent control
Some caterpillars make a thin fibre called *silk* which can be used to make clothing.	n/a	Congruent control

Table C.1 Stimulus materials used in Chapter 4, Experiment 1 & Chapter 5, Experiment 2 – continued on next page.

Sentence frame	*NL spelling*	*Condition*
On Fred's birthday, all his colleagues sang him a *song* while wearing colourful party hats.	n/a	Congruent control
The child made a sandcastle using his bucket and *spade* and a whole load of sand.	n/a	Congruent control
The meat-lover ordered a T-bone *steak* for his dinner.	n/a	Congruent control
The first locomotives used to run on *steam* before the introduction of the combustion engine.	n/a	Congruent control
The Ten Commandments were carved on tablets made of *stone* and were given to Moses on Mount Sinai.	n/a	Congruent control
The knight drew his *sword* and charged.	n/a	Congruent control
When you buy duty-free goods you don't have to pay *tax* on them.	n/a	Congruent control
The commando sneaked up behind the terrorist and slit his *throat* so he wouldn't cry out.	n/a	Congruent control
When you want to chop a block of wood in half, an axe can be a useful *tool* to have around.	n/a	Congruent control
When I take the dirty dishes to the kitchen, I pile everything on a *tray* and hope it doesn't fall off.	n/a	Congruent control
The huge ocean liner was set to go on a *cruise* to the Mediterranean.	n/a	Congruent control
His wife felt his adultery was a violation of her *trust* and promptly divorced him.	n/a	Congruent control
I'm sorry I'm late; my bike had a flat *tyre* and I was forced to walk.	n/a	Congruent control
James Bond used to wear a Rolex *watch* but now he wears an Amigo.	n/a	Congruent control
Blinking with one eye is called giving someone a *wink* which may easily be misinterpreted.	n/a	Congruent control

Table C.1 Stimulus materials used in Chapter 4, Experiment 1 & Chapter 5, Experiment 2, including the sentence frame, target word (italics), Dutch spelling of the homophone (where applicable), and experimental condition.

Sentence frame
The murderer chopped up his victims using an *axe/bijl/frog/schelp* that he had bought in a local hardware store.
To fell the tree the lumberjack took a swing with his *axe/bijl/frog/schelp* and struck it at its base.
To free potential car crash victims, firemen often carry an *axe/bijl/frog/schelp* and various cutting equipment.
When you chop wood you should probably use an *axe/bijl/frog/schelp* rather than a chainsaw.
Elastic trousers don't need a *belt/riem/crew/paus* to secure them.
In times of hunger people often needed to tighten their *belt/riem/crew/paus* metaphorically speaking.
The prisoner didn't have a rope to hang himself so he used his trouser /emphbelt/riem/crew/paus which the guards had forgotten to take off him.
To stop his trousers from falling down the man bought a leather *belt/riem/crew/paus* in the store.
When a child fails in school the parents usually get the *blame/schuld/fuse/lus* though they aren't necessarily at fault.
When the company stock fell, the sales division got the *blame/schuld/fuse/lus*, but the directors were equally at fault.
When the German economy failed in the late twenties the Jews got the *blame/schuld/fuse/lus* which turned out to be a prelude for the holocaust.
When the marriage failed the wife was quick to give her adulterous husband the *blame/schuld/fuse/lus* though he still denied everything.
In the popular fairytale, the miller's son gave his cat one *boot/laars/pool/eer* and then the other.
On his right feet the jockey wore a special type of *boot/laars/pool/eer* with lowered wind resistance.
The duke of Wellington gave his name to a type of *boot/laars/pool/eer* made out of rubber.
The soldier was reprimanded because of a spot of mud on his newly polished *boot/laars/pool/eer* and his previously clean trousers.
Between the accelerator and clutch is a pedal called the *brake/rem/thorn/beul* which should slow the car.
The runaway train could no longer stop because someone had sabotaged the *brake/rem/thorn/beul* before it left.
When skidding through corners, rally drivers sometimes use the hand *brake/rem/thorn/beul* in the car.
When you stop the car you have to apply the *brake/rem/thorn/beul* until the vehicle is at a standstill.

Table C.2 Stimulus materials used in Chapter 4, Experiment 2 & Chapter 5, Experiment 1 – continued on next page.

Sentence frame
Among dog owners the Labrador is very popular *breed/ras/chick/room* to own.
Farmers who have race-horses often limit themselves to a single *breed/ras/chick/room* of horse.
That's not a hound or a bulldog but some type of intermingled *breed/ras/chick/room* of dog.
The winner of the dog show was of a very rare *breed/ras/chick/room* of dog.
A rhondondendron is a type of *bush/struik/birth/broek* that has very characteristic flowers.
The child had scratches all over him when he emerged from the thorny *bush/struik/birth/broek* in the garden.
The hunter was on alert when he heard something rustling in a nearby *bush/struik/birth/broek* but his prey had long since eluded him.
The rose grew on a thorny *bush/struik/birth/broek* in the garden.
Batman has a secret hideout in a *cave/grot/dark/haat* below Wayne Manor.
Early Humans used to make paintings in the walls of their *cave/grot/dark/haat* usually depicting animals.
In the side of the mountain there is a cold, dark *cave/grot/dark/haat* that I'd rather not enter.
The stalactites in this particular *cave/grot/dark/haat* were less impressive than the stalagmites.
A throne is basically a fancy *chair/stoel/fear/aard* that the monarch sits on.
In Texas criminals are still executed with an electric *chair/stoel/fear/aard* or a lethal injection.
My uncle laughed so loud he fell off his *chair/stoel/fear/aard* and rolled on the floor.
The dentist owns a reclining *chair/stoel/fear/aard* that he makes you sit in.
After some inappropriate behaviour the woman slapped him on the *cheek/wang/row/vlak* and stormed off.
Jesus told his followers they should turn the other *cheek/wang/row/vlak* when struck.
She gave him a depressingly platonic kiss on the *cheek/wang/row/vlak* and went inside.
The girl had a dimple in her *cheek/wang/row/vlak* which was rather alluring.
Citizen Kane liked playing with his sledge when he was a *child/kind/part/oog* but never got around to it afterward.
In a stable in Bethlehem is where the *child/kind/part/oog* was born.
The bad parents were incapable of raising their *child/kind/part/oog* so it had to be placed in foster care.

Table C.2 Stimulus materials used in Chapter 4, Experiment 2 & Chapter 5, Experiment 1 – continued on next page.

Sentence frame
The woman was pregnant with her first *child/kind/part/oog* and would soon be going into labour.
According to the Ancient Greek burial rite under the tongue of the deceased a *coin/munt/nerve/kuil* was placed with which to pay the boatman.
Before the football match the referee flips a *coin/munt/nerve/kuil* to decide who kicks off.
For ten pounds you have a note, but for one pound there is only a *coin/munt/nerve/kuil* as there is for lesser amounts.
The trolley at the supermarket requires me to insert a *coin/munt/nerve/kuil* or I won't be able to use it.
Freud had his patients lie on a sofa which is a kind of *couch/bank/guess/beurs* made for reclining comfortably.
Her lazy husband spent his whole day lying on the *couch/bank/guess/beurs* watching sports.
I'm not going out tonight, but I'll rather have a lazy evening on the *couch/bank/guess/nerve* with a good book.
The most comfortable place to sit in my apartment is my five person *couch/bank/guess/beurs* from Ikea.
For corrupting Adam and Eve, God placed a *curse/vloek/dough/taart* upon the serpent.
In the middle ages, when land was infertile, people sometimes thought an evil sorcerer had placed a *curse/vloek/dough/taart* on it.
The prince had been turned into a frog when the witch placed a *curse/vloek/dough/taart* on him.
Using black magic, the voodoo witch doctor placed a *curse/vloek/dough/taart* on his rival.
The blood on his finger suggested he may have suffered a *cut/snee/salt/zweet* while sorting his papers.
The boy had been playing with a knife and now had a deep *cut/snee/salt/zweet* in his finger.
The broken glass had given him a nasty *cut/snee/salt/zweet* on his heel.
When shaving with a manual razor you might get a *cut/snee/salt/zweet* on your face.
A pit-bull terrier is a particularly aggressive type of *dog/hond/hill/tuin* that should be handled with caution.
In cartoons the cat is often afraid of the *dog/hond/hill/tuin* but should really be more afraid of the mouse.
The man was out walking his *dog/hond/hill/tuin* which was a less than perfect alibi.
The sign on the gate said beware of the *dog/hond/hill/tuin* but we chose to ignore it.
Don't get distracted by the woman in the red *dress/jurk/key/plek* or you might not do your work properly.

Table C.2 Stimulus materials used in Chapter 4, Experiment 2 & Chapter 5, Experiment 1 – continued on next page.

Sentence frame
For the cocktail party, her husband had bought her a nice *dress/jurk/key/plek* and matching shoes.
It was her dream to get married wearing a white wedding *dress/jurk/key/plek* and white laced shoes.
On the red carpet, Sharon Stone wore a stunning black *dress/jurk/key/plek* with silk embroidery.
A famous delicacy from Peking is *duck/eend/knot/huur* that has been roasted in the oven.
I saw an animal swimming in our pond; it turned out to be a *duck/eend/knot/huur* and not a swan as we initially thought.
In his infancy, the swan was mistaken for a very ugly *duck/eend/knot/huur* and was cast out.
The boy in the park threw bread to the big, fat *duck/eend/knot/huur* that was swimming in the pond.
The children where playing around so wildly in the pool that water had splashed over the *edge/rand/speed/traan* and needed to be mopped up.
The glass on that table is too near the *edge/rand/speed/traan* and it might fall.
The parachutist stood on top of the cliff and peered over the *edge/rand/speed/traan* at the jagged rocks below.
When on top of a tall tower some people prefer not to stand too close to the *edge/rand/speed/traan* for fear of falling off.
Maternal milk is produced by a type of *gland/klier/plough/tred* in the breast.
Saliva is produced by a type of *gland/klier/plough/tred* in your mouth.
Some hormones are produced in a *gland/klier/plough/tred* in your brain.
Sweat is produced by a type of *gland/klier/plough/tred* under your skin.
The boy was told off by his teacher for sniffing the *glue/lijm/plume/loods* from the blue bottle.
The wooden toy was broken, but father managed to repair it with a tube of *glue/lijm/plume/loods* and a few nails.
When the old horse died it was sent to the factory to be made into *glue/lijm/plume/loods* as had many of its brethren.
You make paper-maché with strips of newspaper and *glue/lijm/plume/loods* to keep it all together.
During puberty children experience a period of accelerated *growth/groei/turn/krant* that can sometimes be quite inconvenient.
Grandma is always the first to notice your *growth/groei/turn/krant* remarkably.
The samples were put in a Petri dish with lots of nutrients to facilitate the *growth/groei/turn/krant* of bacteria.
The tumour was treated with radiation in an attempt to slow its *growth/groei/turn/krant* or destroy it altogether.

Table C.2 Stimulus materials used in Chapter 4, Experiment 2 & Chapter 5, Experiment 1 – continued on next page.

Sentence frame
This needle makes a tiny *hole/gat/sky/kring* in the artery.
When he removed the screw from the wall it left a large *hole/gat/sky/kring* that would have to be filled in.
When he took his shoes of he noticed his sock had *hole/gat/sky/kring* at the toe end.
Where the iceberg had hit the ship there was now a large gaping *hole/gat/sky/kring* in the hull.
In Sherwood Forest lived a famous outlaw who wore a *hood/kap/thirst/smoes* and carried a bow.
Over his head, the monk wore a brown *hood/kap/thirst/smoes* to conceal his face.
Some youths prefer to wear a sweater with a *hood/kap/thirst/smoes* than a normal one.
The executioner put on a black *hood/kap/thirst/smoes* so as not to be recognized.
A non-alcoholic drink made with apples is called apple *juice/sap/nail/zicht* which can be made into cider if fermented.
A particularly bitter drink is grapefruit *juice/sap/nail/zicht* which only few people regularly drink.
I don't want a soft drink. I'd prefer to have some fruit *juice/sap/nail/zicht* or a glass of water.
You can squeeze oranges to make *juice/sap/nail/zicht* and add a bit of honey for the taste.
Santa lifted the boy onto his *lap/schoot/stamp/voogd* before asking him if he'd been a good boy.
That cat has rather sharp claws so I'd rather he didn't sit on my *lap/schoot/stamp/voogd* if you don't mind.
The boy had been crying so he was allowed to sit on the teacher's *lap/schoot/stamp/schoot* for the rest of the day.
The child sat in his mother's *lap/schoot/stamp/schoot* to keep him quiet.
A butcher is a shop where you can buy *meat/vlees/noise/schoen* for dinner.
A carnivore is another word for an animal that eats *meat/vlees/noise/schoen* rather than plants.
Pork is a kind of *meat/vlees/noise/schoen* that comes from pigs.
Vegetarians don't eat *meat/vlees/noise/schoen* out of principle.
It's amazing what an artist can do with a canvas and some *paint/verf/chap/nut* be it watercolours, oils or acrylics.
That wall is boringly white. It needs a dash of *paint/verf/chap/nut* and perhaps a poster or two.
The decorator used a bucket of white *paint/verf/chap/nut* for the ceiling.
You shouldn't touch that wooden fence because of the wet *paint/verf/chap/nut* that could stick to your hands.

Table C.2 Stimulus materials used in Chapter 4, Experiment 2 & Chapter 5, Experiment 1 – continued on next page.

Sentence frame
That guy is really stupid he must have a brain the size of a *pea/erwt/dwarf/worst* or at least something very small.
The princess looked under the mattress and found a *pea/erwt/dwarf/worst* that was keeping her awake.
The thing that kept the princess from sleeping was a small, green *pea/erwt/dwarf/worst* under her mattress.
This is smaller and rounder than a bean. It's a *pea/erwt/dwarf/worst* that comes from a pod.
Before you boil the potato please remove the *peel/schil/leech/friet* and rinse off any remaining dirt.
Don't eat the orange like that! You first need to remove the *peel/schil/leech/friet* or it'll taste horrible!
In this lime sorbet we added the outer part of the lime's *peel/schil/leech/friet* also known as the zest.
Marmalade is a sort of Jam made with orange *peel/schil/leech/friet* and lots of sugar.
After the Berlin wall fell many people bought a *piece/stuk/art/punt* to remind themselves of that historic occasion.
Beethoven's 5th symphony is a very famous *piece/stuk/art/punt* of classical music.
The boy was happy with his cake, but his father wanted a bigger *piece/stuk/art/punt* as was obvious from the look on his face.
The chocolate cake was so good that everyone wanted a *piece/stuk/art/punt* for himself.
At the barbecue we ate our food from a plastic *plate/bord/chain/stijl* and with plastic cutlery.
If you'd like some more potatoes, just pass me your *plate/bord/chain/stijl* and I'll give you some.
The rich man ate his food from a beautiful ceramic *plate/bord/chain/stijl* using his expensive silver cutlery.
When the hungry boy finished eating there was nothing left on his *plate/bord/chain/stijl* at all.
At the checkout I always manage to choose the slowest *queue/rij/herd/zuil* even though it looked the shortest. For popular rides in amusement parks you often have to stand in a *queue/rij/herd/zuil* for ages.
Tickets for the concert go on sale tomorrow. If you get there early enough you'll avoid the *queue/rij/herd/zuil* and you'll have the best chance of getting one.
When the new Playstation was launched people stood for hours in a long *queue/rij/herd/zuil* to buy one.
Climbers attach themselves to a *rope/touw/fool/sprong* to keep from falling.
Sumo wrestlers have to stay inside a ring which is laid out by a *rope/touw/fool/sprong* as each person tries to push the other out.
The man committed suicide by hanging himself using a *rope/touw/fool/sprong* attached to the ceiling.

Table C.2 Stimulus materials used in Chapter 4, Experiment 2 & Chapter 5, Experiment 1 – continued on next page.

Sentence frame
The sailing boat was still fastened to the shore by a *rope/touw/fool/sprong* from its stern.
A circle is a very basic *shape/vorm/crowd/baan* that occurs often in nature.
Abstract sculptures often have an odd *shape/vorm/crowd/baan* that doesn't resemble anything.
An octahedron is a very remarkable *shape/vorm/crowd/baan* that you might not have seen before.
Some people go running to stay in *shape/vormcrowd/baan* and others go to the gym.
Jaws was a famous film about a *shark/haai/lid/heks* that ate lots of people.
One of the most dangerous animals in the sea is the great white *shark/haai/lid/heks* that has been known to attack people.
The marine biologist sat in a cage under water to protect him from the *shark/haai/lid/heks* that he was observing.
The tourist was swimming in the ocean when he was eaten by a *shark/haai/lid/heks* that had been lurking nearby.
If you stay out in the sun too long you risk burning your *skin/huid/cause/neus* instead of bronzing it.
Many anti-aging commercials try to sell you products for your *skin/huid/cause/neus* that will keep it smooth.
The burn victim needed a transplant of *skin/huid/cause/neus* from his abdomen.
A pimple is a reddish spot on your *skin/huid/cause/neus* that can be very annoying.
Instead of getting his shirt wet, George rolled up his *sleeve/mouw/slice/vlieg* before doing the washing up.
The child didn't have a tissue so he wiped his nose on his *sleeve/mouw/slice/vlieg* to the exasperation of his mother.
The man who cheated at poker had an ace up his *sleeve/mouw/slice/vlieg* with which he was sure to win.
We all think the magician had the card up his *sleeve/mouw/slice/vlieg* otherwise it would be impossible.
Ammonia is very good for cleaning but I can't stand the *smell/geur/rent/moed* of it.
Freshly baked bread has a very pleasant *smell/geur/rent/moed* and it is equally pleasant to eat.
Rotten Eggs have a very distinctive *smell/geur/rent/moed* that one would recognise anywhere.
Someone's having a barbecue! I can tell by the *smell/geur/rent/moed* in the air.
A cobra is a dangerous *snake/slang/joint/slok* that is indigenous to warm climates.
Lurking in the grass in the garden was a venomous *snake/slang/joint/slok* that was ready to bite.
The animal on the symbol for pharmacies is a *snake/slang/joint/slok* that is green.

Table C.2 Stimulus materials used in Chapter 4, Experiment 2 & Chapter 5, Experiment 1 – continued on next page.

Sentence frame
The animal that caused Adam and Eve to be expelled from paradise was a *snake/slang/joint/slok* that had told them to eat the forbidden fruit.
A bungalow has the advantage that you don't have to go up the *stairs/trap/fault/moord* for anything.
In case of fire, don't use the lift but go down the *stairs/trap/fault/moord* to escape.
To keep in shape I don't use the lift but take the *stairs/trap/fault/moord* to reach my office.
To reach the cellar you have to go down the *stairs/trap/fault/moord* at the end of the hall.
A violin produces sound through a vibration on a *string/snaar/trout/graad* that is amplified by the sound box.
Bass players that play Jazz music tend to pluck on a *string/snaar/trout/graad* rather than use the bow.
Don't strum the guitar too hard or you might break *string/snaar/trout/graad* or two.
To play a note on a guitar an octave higher you put your finger halfway along the *string/snaar/trout/graad* on the neck of the guitar.
A scorpion is an animal with a sting in its *tail/staart/guide/vlam* which you should probably avoid.
For added balance the cat has a *tail/staart/guide/vlam* which seems to be fun for it to chase after.
To keep flies away, a horse tends to swing its *tail/staart/guide/vlam* around.
You should never grab a snake by its *tail/staart/guide/vlam* or it might turn round and bite you.
A walkman is a device that can play a *tape/band/twin/teen* but not a cd.
Before the advent of digital media, I used to have a memo recorder with a *tape/band/twin/teen* to catalogue my thoughts.
The criminal made the confession to the undercover officer and the FBI caught it all on *tape/band/twin/teen* which proved to be important in the subsequent trial.
When you brought a video back to the rental store you had to rewind the *tape/band/twin/teen* or pay a small fine.
Grapefruit has a very bitter *taste/smaak/cloud/reeks* that some people find appealing.
I forgot to add salt, so the meal was rather lacking in *taste/smaak/cloud/reeks* but my guests were to polite to complain.
Some cheeses are very mild but others have a rather strong *taste/smaak/cloud/reeks* that some people might not like.
What colours you wear is a question of *taste/smaak/cloud/reeks* but some combinations are more suited than others.

Table C.2 Stimulus materials used in Chapter 4, Experiment 2 & Chapter 5, Experiment 1 – continued on next page.

Sentence frame
The gambler had bet heavily on the dice and was now hoping for a lucky *throw/worp/bin/gaas* to win him the money.
The Judo champion managed to floor his opponent with a stunning hip *throw/worp/bin/gaas* that took the wind right out of him.
To win the javelin event, the athlete needed a 100 meter *throw/worp/bin/gaas* or would be condemned to second place.
When a basketball player tries to get the ball in the basket he needs an accurate *throw/worp/bin/gaas* or he might miss.
Cannibalism occurs occasionally in a certain *tribe/stam/dust/pers* in the Amazon Jungle.
Chief Running-Bear was the head of a *tribe/stam/dust/pers* of Native Americans.
The Apache are a Native American *tribe/stam/dust/pers* that live mainly in Oklahoma.
The Zulu are a *tribe/stam/dust/pers* that live mainly in the south of Africa.
I'd rather take a plane than a boat when I go on a business *trip/reis/crime/markt* abroad.
I'm going away for the weekend, but it's only a short *trip/reis/crime/markt* and I'll be back at work on Monday.
The man had to go on a business *trip/reis/crime/markt* to visit a customer.
The travel reporter had to go on a long *trip/reis/crime/markt* to the far East.
One of the most distinctive characteristics of an elephant is its long *trunk/slurf/lawn/schaap* but its tusks and huge ears are also a dead giveaway.
The boy refused to give the elephant the sweet and promptly received a slap in the face from its *trunk/slurf/lawn/schaap* which left him with a nasty bruise.
The elephant drank water through its *trunk/slurf/lawn/schaap* as if it were a giant straw.
The elephant picked up the peanut with its *trunk/slurf/lawn/schaap* and ate it.
A tsunami is a very large *wave/golf/strike/buik* which is often the result of an earthquake at sea.
The boat was rocked when a particularly large *wave/golf/strike/buik* hit it.
The surfer was waiting for a large *wave/golf/strike/buik* so he could get on his board.
The unsuspecting sunbather was washed over by a *wave/golf/strike/buik* of salty water.
Before the advent of plumbing, people would have to get their water from a *well/put/bribe/kers* in the town square.

Table C.2 Stimulus materials used in Chapter 4, Experiment 2 & Chapter 5, Experiment 1 – continued on next page.

Sentence frame
The calf nearly drowned after it had stumbled into a *well/put/bribe/kers* but the villagers rescued it on time.
The fireman had to save the boy who had fallen into a *well/put/bribe/kers* before he died from hypothermia.
To get water, the farmer lowered the bucket into the *well/put/bribe/kers* and raised it again once it had been filled.
Charles is the future King and Camilla is his *wife/vrouw/age/kant* but she will never be Queen.
Counselling is often the last resort for a husband and *wife/vrouw/age/kant* with marital difficulties.
The man had remarried after he lost his first *wife/vrouw/age/kant* in a car crash.
When the vicar pronounced them man and *wife/vrouw/age/kant* a loud cheer erupted from the crowd.
Cinderella asked her fairy godmother to grant her a *wish/wens/gear/hof* so that she might go to the ball.
Some people believe that when you see a falling star you're supposed to make a *wish/wens/gear/hof* and keep it secret.
The birthday girl blew out the candles on her cake and made a *wish/wens/gear/hof* that she kept to herself.
When Aladdin rubbed the magic lamp he was allowed to make a *wish/wens/gear/hof* by the genie.
The assailant was holding a knife, but the martial arts specialist managed to break his *wrist/pols/dish/draad* and disarm him.
The tennis player had a sweatband on his head and two on each *wrist/pols/dish/draad* for this important match.
Working with a computer mouse all day might lead to pains in your *wrist/pols/dish/draad* know as Repetitive Strain Injuries.
You usually wear your watch on your *wrist/pols/dish/draad* unless you're washing up.
A popular myth concerns the fountain of eternal *youth/jeugd/run/vis* but unfortunately it's not likely to exist.
He grew up in a small village where he had a very pleasant *youth/jeugd/run/vis* by modern standards.
Many Dutch novelists seem to have had a traumatic *youth/jeugd/run/vis* which fuels their writing.
The old man thought about all the things he used to do in his *youth/jeugd/run/vis*, but never got around to anymore.
He closed his fleece jacket with the *zip/rits/blend/zaag* on the front.
Some trousers have buttons instead of a *zip/rits/blend/zaag* on the front.
To close the sleeping-bag you use the *zip/rits/blend/zaag* on the side.
You can open the tent using that *zip/rits/blend/zaag* on the flap.

Table C.2 Stimulus materials used in Chapter 4, Experiment 2 & Chapter 5, Experiment 1. Italics denote target words in the Congruent/no-switch, Congruent/language switch,Incongruent/no switch, & Incongruent/language switch, conditions respectively.

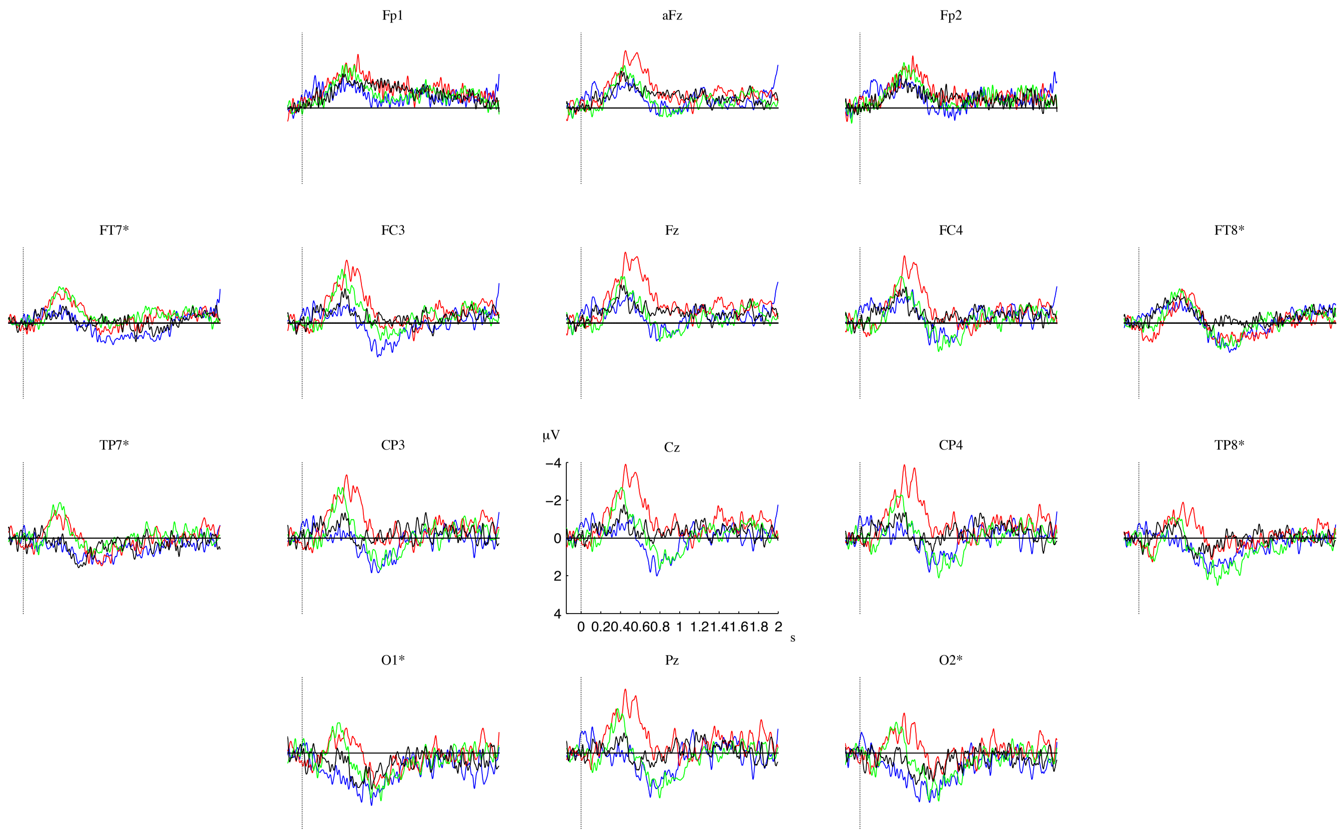


Figure C.1: Unfiltered grand average waveforms on 16 scalp electrodes. (Blue) Correct control; (red) L2-incongruent/L1-incongruent; (green) L2-incongruent/L1-congruent; and (black) L2-congruent/L1-incongruent. Asterisk denotes nonstandard electrode location. See Figure 4.2 for filtered waveforms

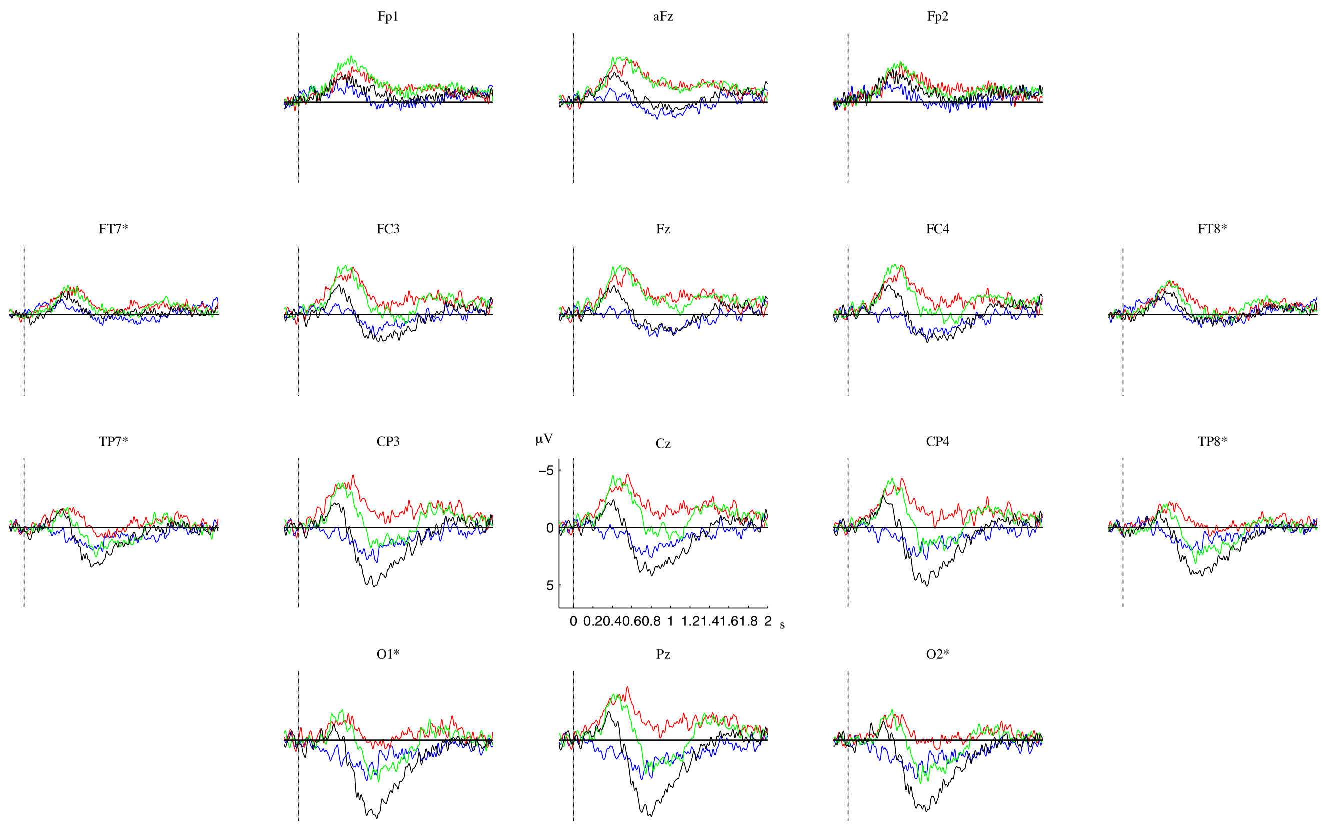


Figure C.2: Unfiltered grand average waveforms on 16 scalp electrodes. (Blue) Correct control; (red) incongruent (green) incongruent, language switch; and (black) congruent, language switch. See Figure 4.3 for filtered waveforms

Curriculum Vitae

Ian FitzPatrick was born in Halmstad, Sweden on July 16th 1981. After moving to the Netherlands at age 5, FitzPatrick attended Openbare Basisschool De Drieschaar and obtained his Voortgezet Wetenschappelijk Onderwijs (VWO) diploma from Regional Scholengemeenschap Het Rhedens in 1999. FitzPatrick received his Bachelor's degree in Psychology from the University of Leiden (Netherlands) specialising in Neuropsychology before reading Cognitive Neuroscience at the Radboud University in Nijmegen (Netherlands), during which time he co-founded the student journal Nijmegen CNS. He did his Master's research project on bilingual speech recognition at the Donders Institute for Brain, Cognition, and Behaviour under the supervision of Prof. Dr. Dr. Peter Indefrey, graduating in September 2006. From November 2007 to November 2008 FitzPatrick was the Ph.D. representative for the Humanities section of the Max Planck Gesellschaft and member of the PhDnet steering group. As of January 2010 FitzPatrick is working as a Post Doctoral researcher at the Department of Techology and Information of the University Pompeu Fabra in Barcelona, Spain.

List of Publications

FitzPatrick, I. & Indefrey, P. (2010). Lexical competition in non-native speech comprehension. *Journal of Cognitive Neuroscience*, *22*(6), 1165-1178.

FitzPatrick, I. & Indefrey, P. (2009). Native language semantic activation in non- native speech comprehension: Evidence from Event-Related Potentials. [abstract] *Journal of Cognitive Neuroscience, Supplement* (ISSN: 1096-8857), pp. 119-120.

Duhaime, M.B., Alsheimer, S., Angelova, R. & FitzPatrick, I. (2008). In Defense of Max Planck. [Letter to the Editor] *Science*, *320* (5878) pp. 872b

FitzPatrick, I. & Weber, K. (2008). "Il piccolo principe est allé": Processing of language switches in auditory sentence comprehension. *The Journal of Neuroscience*, *28*(18), pp. 4581-4582.

FitzPatrick, I. & Indefrey, P. (2007). Effects of sentence context in non-native natural speech comprehension. [abstract]. *Journal of Cognitive Neuroscience, Supplement* (ISSN 1096-8857), pp. 84.

MPI Series in Psycholinguistics

1. The electrophysiology of speaking: Investigations on the time course of semantic, syntactic, and phonological processing. *Miranda van Turennout*
2. The role of the syllable in speech production: Evidence from lexical statistics, metalinguistics, masked priming, and electromagnetic midsagittal articulography. *Niels O. Schiller*
3. Lexical access in the production of ellipsis and pronouns. *Bernadette M. Schmitt*
4. The open-/closed-class distinction in spoken-word recognition. *Alette Haveman*
5. The acquisition of phonetic categories in young infants: A self-organising artificial neural network approach. *Kay Behnke*
6. Gesture and speech production. *Jan-Peter de Ruiter*
7. Comparative intonational phonology: English and German. *Esther Grabe*
8. Finiteness in adult and child German. *Ingeborg Lasser*
9. Language input for word discovery. *Joost van de Weijer*
10. Inherent complement verbs revisited: Towards an understanding of argument structure in Ewe. *James Essegbey*
11. Producing past and plural inflections. *Dirk Janssen*
12. Valence and transitivity in Saliba: An Oceanic language of Papua New Guinea. *Anna Margetts*
13. From speech to words. *Arie van der Lugt*
14. Simple and complex verbs in Jaminjung: A study of event categorisation in an Australian language. *Eva Schultze-Berndt*

15. Interpreting indefinites: An experimental study of children's language comprehension. *Irene Krämer*

16. Language-specific listening: The case of phonetic sequences. *Andrea Weber*

17. Moving eyes and naming objects. *Femke van der Meulen*

18. Analogy in morphology: The selection of linking elements in Dutch compounds. *Andrea Krott*

19. Morphology in speech comprehension. *Kerstin Mauth*

20. Morphological families in the mental lexicon. *Nivja H. de Jong*

21. Fixed expressions and the production of idioms. *Simone A. Sprenger*

22. The grammatical coding of postural semantics in Goemai (a West Chadic language of Nigeria). *Birgit Hellwig*

23. Paradigmatic structures in morphological processing: Computational and cross-linguistic experimental studies. *Fermín Moscoso del Prado Martín*

24. Contextual influences on spoken-word processing: An electrophysiological approach. *Daniëlle van den Brink*

25. Perceptual relevance of prevoicing in Dutch. *Petra M. van Alphen*

26. Syllables in speech production: Effects of syllable preparation and syllable frequency. *Joana Cholin*

27. Producing complex spoken numerals for time and space. *Marjolein Meeuwissen*

28. Morphology in auditory lexical processing: Sensitivity to fine phonetic detail and insensitivity to suffix reduction. *Rachèl J. J. K. Kemps*

29. At the same time...: The expression of simultaneity in learner varieties. *Barbara Schmiedtová*

30. A grammar of Jalonke argument structure. *Friederike Lüpke*

31. Agrammatic comprehension: An electrophysiological approach. *Marlies Wassenaar*

32. The structure and use of shape-based noun classes in Miraña (North West Amazon). *Frank Seifart*

33. Prosodically-conditioned detail in the recognition of spoken words. *Anne Pier Salverda*

34. Phonetic and lexical processing in a second language. *Mirjam Broersma*

35. Retrieving semantic and syntactic word properties. *Oliver Müller*

36. Lexically-guided perceptual learning in speech processing. *Frank Eisner*

37. Sensitivity to detailed acoustic information in word recognition. *Keren B. Shatzman*

38. The relationship between spoken word production and comprehension. *Rebecca Özdemir*

39. Disfluency: Interrupting speech and gesture. *Mandana Seyfeddinipur*

40. The acquisition of phonological structure: Distinguishing contrastive from non-contrastive variation. *Christiane Dietrich*

41. Cognitive cladistics and the relativity of spatial cognition. *Daniel B.M. Haun*

42. The acquisition of auditory categories. *Martijn Goudbeek*

43. Affix reduction in spoken Dutch. *Mark Pluymaekers*

44. Continuous-speech segmentation at the beginning of language acquisition: Electrophysiological evidence. *Valesca Kooijman*

45. Space and iconicity in German Sign Language (DGS). *Pamela Perniss*

46. On the production of morphologically complex words with special attention to effects of frequency. *Heidrun Bien*

47. Crosslinguistic influence in first and second languages: Convergence in speech and gesture. *Amanda Brown*

48. The acquisition of verb compounding in Mandarin Chinese. *Jidong Chen*

49. Phoneme inventories and patterns of speech sound perception. *Anita Wagner*

50. Lexical processing of morphologically complex words: An information- theoretical perspective. *Victor Kuperman*

51. A grammar of Savosavo, a Papuan language of the Solomon Islands. *Claudia Wegener*

52. Prososdic structure in speech production and perception. *Claudia Kuzla*

53. The acquisition of finiteness by Turkish learners of German and Turkish learners of French: Investigating knowledge of forms and functions in production and comprehension. *Sarah Schimke*

54. Studies on intonation and information structure in child and adult German. *Laura de Ruiter*

55. Processing the fine temporal structure of spoken words. *Eva Reinisch*

56. Semantics and (ir)regular inflection in morphological processing. *Wieke Tabak*

57. Processing strongly reduced forms in casual speech. *Susanne Brouwer*

58. Ambiguous pronoun resolution in L1 and L2 German and Dutch. *Miriam Ellert*

59. Lexical interactions in non-native speech comprehension: Evidence from electro-encephalography, eye-tracking, and functional magnetic resonance imaging. *Ian FitzPatrick*

ISBN 978-90-76203-38-6