Parallel vs Sequential activation during spoken-word recognition tasks: An eye-tracking study

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Abstract

Through previous spoken word-recognition tasks, bilinguals have demonstrated an ability to access both languages in a simultaneous/parallel manner. Parallel activation contrasts with sequential activation (where only one language is active at any given time). Afrikaans-English bilingual speakers have never been tested for parallel activation and, additionally, both African languages and early bilinguals have been neglected when studying bilinguals' parallel activation. In this thesis, the extent to which the Afrikaans-English early bilingual mind accesses and makes use of both Afrikaans and English simultaneously is established through an eye-tracking, spoken-word recognition task. Furthermore, this parallel activation is recognised as correlated to the bilingual's proficiency in English, as well as the age of acquisition (AoA) of English. Thirty-one Afrikaans-English early bilinguals were tested, and were found to have activated Afrikaans through their proportion of looks (eye fixations) made to an Afrikaans phonetically-similar competitor object (e.g., *venster*, Afrikaans for "window") when asked to look to the English target (*fairy*). Participants' English AoAs were determined through the Language History Questionnaire, and their proficiency in English was tested by means of the standardised LexTALE test. Within these Afrikaans-English early bilinguals, a lower second-language English proficiency was found to increase parallel activation of the Afrikaans first language, as well as an older English age of acquisition (AoA), independently. It is proposed in this thesis that bilingual parallel activation exists rather as a continuum (from purely sequential activation to purely parallel activation of languages), dependent on a range of interacting, individual, structural, and context-specific variables.

Opsomming

Deur vorige gesproke woordherkenningstake, het tweetaliges die vermoë getoon om toegang tot albei tale gelyktydig / parallel te verkry. Parallelle aktivering staan in teenstelling met opeenvolgende aktivering (waar slegs een taal op enige gegewe tydperk aktief is). Afrikaans-Engelse tweetalige sprekers is nog nooit vantevore getoets vir parallelle aktivering nie, en ook, beide Afrika-tale en vroeë tweetaliges is nie regtig in ag geneem tydens die bestudering van parallelle aktivering in tweetalige sprekers nie. In hierdie tesis word die mate waartoe die Afrikaans-Engelse vroeë tweetalige spreker se brein toegang verkry tot, en gebruik maak van beide Afrikaans en Engels gelyktydig, bepaal deur middel van oognaspeuring tydens gesproke woordherkenning. Verder word hierdie parallelle aktivering erken as gekorreleerd met die tweetalige spreker se taalvaardigheid in Engels, sowel as die ouderdom van verwerwing van Engels. Een-en-dertig Afrikaans-Engelse vroeë tweetalige sprekers is getoets en daar is gevind dat hulle Afrikaans geaktiveer het deur hul verhouding van kyke (oogfiksasies) na 'n foneties-soortgelyke mededinger (bv. *venster*) wanneer hulle gevra is om te kyk na die Engelse teiken (*fairy*). Die deelnemers se ouderdom van verwerwing van Engels is gevind deur middel van die Language History Questionnaire en hul taalvaardigheid in Engels is getoets aan die hand van die gestandaardiseerde LexTALE-toets. Binne hierdie Afrikaans-Engelse tweetaliges, is gevind dat 'n laer tweede taal Engelse vaardigheid parallelle akitvering van die Afrikaans eerste taal verhoog het, sowel as 'n ouer ouderdom van verwerwing van Engels, onafhanklik van mekaar. In hierdie tesis word dit voorgestel dat tweetalige parallelle aktivering eerder as 'n kontinuum bestaan (van suiwer opeenvolgende aktivering tot suiwer parallelle aktivering van tale), afhankllik van 'n reeks interaktiewe, individuele, strukturele en konteks-spesifieke veranderlikes.

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Chapter 1: Introduction

1.1 Background to the research problem

"Man has no Body distinct from his Soul, for that called Body is a portion of the Soul …"

– William Blake (1790)

As Spivey, Richardson and Dale (2009: 2) explain Blake's statement in modern standings, the mind of an individual has been found to be inseparable from the body. For this reason, the study of bilingual language processing commonly resorts to examining eye movements in order to gain a window into the functioning of the mind. By inspecting the bilingual individual's focus, attention, and gaze of the eyes (Roberts and Siyanova-Chanturia 2013: 214), it is possible to evaluate the extent to which the languages they know are activated during different phases of language processing. A key advantage to the eye-tracking method is that it examines real-time comprehension processes (cognitive functioning) whilst input processing remains undisturbed (Roberts and Siyanova-Chanturia 2013: 213).

The method of eye-tracking has been applied in various bilingual cognitive functioning studies that investigate the interaction between individuals' first (L1) and second languages (L2) (Blumenfeld and Marian 2007; Ju and Luce 2004; Marian, Blumenfeld and Boukrina 2008; Marian and Spivey 2003a, 2003b; Marian, Spivey and Hirsh 2003; Shook and Marian 2017; Spivey and Marian 1999; Weber and Cutler 2004). This developing research, focused on bilingualism, has generated an incredible understanding of the bilingual mind in that the bilinguals' two languages are activated in parallel (Shook and Marian 2017: 2). In line with this research, "activation" is typically understood as the stimulation or operation of a language in cognition. Therefore, "parallel activation" is explained as the simultaneous activation or accessibility of both languages a bilingual speaks (Spivey and Marian 2003b: 98). In opposition, "sequential activation" in bilinguals is the consecutive or sequential and separated accessibility to each of the languages the bilingual speaks (Spivey and Marian 2003b: 98).

The interaction and interplay of language within the bilingual mind is commonly studied through spoken-word recognition which, in its narrowest definition, is the accessing of lexical representations from the speech signal (Dahan and Magnuson 2006). Ju and Luce (2004) explain spoken-word recognition as the multiple activations of phonological patterns that rely on the acoustic-phonetic input. Convincing evidence for language co-activation stems from eye-tracking studies that make use of phonological overlaps between cross-language word pairs (e.g., English *marker* and Russian *marka* ("stamp") from Spivey and Marian's 1999 study). A developing body of research on bilingualism engages with an interesting finding of bilinguals' parallel co-activation of two languages (Shook and Marian 2017: 229).

Present kinds of phonological research on bilinguals are in the Visual World Paradigm (VWP), as explained by Huettig, Rommers and Meyer (2011: 10), as studies that focus on the listeners' eye movements whilst being approached with an auditory input. In turn, a VWP experiment indicates that the individuals' visual attention relies on both the visual and auditory input (Huettig et al. 2011: 10). The VWP can also be explained as the sensitive, constant measure of ambiguity resolution in language processing, and includes competition effects in spoken-word recognition (Tanenhaus, Spivey-Knowlton, Eberhard and Sedivy 1995). Within these bilingual spoken-word recognition studies rooted in the VWP, competition between languages is strongly observed on an acoustic (phonetic) level. This is due to evidence from participants in which it was found that, upon hearing the spoken target word, other phonetically-similar words also competed for attention simultaneously, as these non-target words were consistent with the acoustic material of the speech cue (Huettig et al. 2011: 53). Previous bilingual studies using the VWP are illustrative of a highly interactive network of human language processing, explicated by the theory of the Bilingual Language Interaction Network for Comprehension of Speech (BLINCS) model (henceforth referred to as "BLINCS"; Shook and Marian 2013).

Shook and Marian (2013) explain BLINCS as a connectionist theory for the comprehension of bilinguals, as they (bilinguals) activate both of their languages in parallel. Not only does this theory provide an explanation for the phenomenon of parallel activation, it also explains how this parallel activation and interaction affects language processing in general (as interconnected, dynamic mappings), and audio-visual amalgamation throughout language processing (Shook and Marian 2013: 304). Essentially, BLINCS highlights the bilingual individual's language comprehension as an interconnected network of self-organised maps (SOMs; Shook and Marian 2013: 306). These SOMs make use of a learning algorithm which is constantly updated by means of new inputs (Kohonen 1995). BLINCS also explains how to separate the bilingual's two languages, and this model is not dependent on a universal language-identification arrangement or lexicon (Shook and Marian 2013: 304). Previously, the Input Switch theory explained that only one language could be active at a time (Macnamara and Kushnir 1971), and that each language of a late bilingual was said to be found in separate regions within Broca's area of the brain (Kim, Relkin, Lee and Hirsch 1997). However, with more bilingual language studies taking place since, these interpretations were disregarded, and theory began leaning more towards an interactive model, such as that of BLINCS.

1.2 Research problem statement

Recognising that most of the world's population speaks more than a single language (Aronin and Singleton 2012; Romaine 1995), studying bilingualism and multilingualism can provide valuable insight into human cognition through language capacity and how the brain encodes language (De Groot and Kroll 1997; Schreuder and Weltens 1993). Psycholinguistic research on VWP spoken-word recognition in bilinguals has debated the parallel activation of L1 and L2, the variables causing such parallel activations, and also the mechanisms used for language comprehension in the bilingual brain. This research has also focused on languages outside of Africa, and has mostly examined later bilinguals.

The first and general gap in bilingual studies is a lack of consensus as to whether the bilingual individual works with both languages in a parallel or a sequential manner. Although current research leans towards a more parallel stance (Huettig et al. 2011), there are studies with contrasting evidence. In Ju and Luce's (2004) study on late Spanish-English bilinguals, participants were tested in Spanish (the participants' L1). The authors found no parallel activation when specific acoustic-phonetic cues (voice onset times; VOTs) in Spanish were not tweaked to that of the English cues (Ju and Luce 2004). Weber and Cutler (2004) also did not observe any overt parallel activation in their Dutch-English bilinguals. Both studies will be later discussed in Chapter 2, but it is important to note that such examples provide insight into parallel activation currently under broader debate.

The secondary gap in bilingual studies is the neglect of language groups, such as those found in South Africa. Wolff's (2000) estimates that more than 50% of the African population is multilingual, however, there is limited research into patterns of L2 language activation, rather than any established knowledge. The Westernised, Educated, Industrialised, Rich, and Democratic (WEIRD) bias (Henrich, Heine and Norenzayan 2010) highlights how there are many human psychology claims based only on individuals from WEIRD backgrounds. This includes the field of psycholinguistics, as studies on bilinguals have also mainly focused on WEIRD societies, creating a bias through overgeneralised theories on how all bilinguals work with their languages (Bylund, in press). This leads the field to the novelty, necessity, and interest in the current research on the South African Afrikaans-English early bilingual. Bilinguals that speak both Afrikaans and English provide a unique language background to study, for South Africa, Africa at large, and the field of psycholinguistics.[1]

Lastly, early bilinguals have tended to be excluded from current research, with most studies utilising spoken-word recognition tasks to study late bilinguals (Ju and Luce 2004; Marian and Spivey 2003a, 2003b; Weber and Cutler 2004; Blumenfeld and Marian 2007). Alongside this, when early bilinguals are tested, they tend to present weaker signs of parallel activation in comparison to later bilinguals tested in their L1 (Canseco-Gonzalez, Brehm, Brick, Brown-Schmidt, Fischer and Wagner 2010: 70). Therefore, Afrikaans-English early bilinguals provide interesting language backgrounds to study, not only because African languages are understudied but because early bilinguals too are understudied.

1.3 Research aims and focus

As described above, psycholinguistic research regarding the possible cross-linguistic (parallel) or sequential (separate) activation in South African, Afrikaans-English early bilinguals is currently lacking. The aim of the present thesis is to begin to address this gap by exploring spoken-word recognition in early L1-Afrikaans L2-English bilinguals using a VWP eye-tracking experiment. This research aims to add to the body of knowledge within the psycholinguistics field of early bilingual cognitive functioning. The bilinguals in this study with South African Afrikaans-English language backgrounds are referred to as “(the) bilinguals” in this thesis. Additionally, the South African English monolinguals in this study are referred to as “(the) monolinguals”.

1.4 Research questions

The research questions investigated in the present thesis are as follows:

1. Are Afrikaans-English early bilinguals found to activate their L1 Afrikaans in parallel with their L2 English?

[1] Although the argument that Afrikaans is an understudied, African language is a contested stance, this does not take away from the sheer lack of evidence on the Afrikaans language in the psycholinguistics field, at large.

2. What is the extent to which L1 Afrikaans activation in Afrikaans-English early bilinguals takes place, as modulated by:
    a. proficiency in English, and
    b. age of acquisition (AoA) of English?

1.5 Hypotheses

With reference to Research Question 1, it is hypothesised that parallel activation of Afrikaans and English will be captured in this eye-tracking study, as this would be consistent with previous bilingual studies (Blumenfeld and Marian 2007; Canseco-Gonzalez et al. 2010; Colomé 2001; Marian and Spivey 2003a, 2003b; Shook and Marian 2012, 2017; Spivey and Marian 1999). Parallel activation will be observed by means of more eye movements focusing on the phonetically-similar (competitive) Afrikaans object by bilinguals, in comparison to a lesser proportion of eye movements focusing on the same object by monolingual English speakers.

With regard to Research Sub-question 2a, differences in terms of English proficiency within the bilingual group are hypothesised to have a significant effect on the extent to which such fixations are made to the Afrikaans, phonetically-similar competitor object. This hypothesis relies on the fact that there are strong effects of proficiency on parallel activation in previous word-recognition studies (Blumenfeld and Marian 2007; Elston-Güttler, Paulmann and Kotz 2005; Van Hell and Dijkstra 2002; Perani et al. 1998). In comparison, however, it is hypothesised that the AoA will have an effect to a lesser extent than the English-proficiency effect. This is hypothesised as previous findings on word recognition are indicative of an effect of AoA, however, this effect is not as significant when it comes to early bilinguals (Blumenfeld and Marian 2007; Canseco-Gonzalez et al. 2010; Silverberg and Samuel 2004).

1.6 Research scope

The scope of the current research is formally within the grounds of VWP spoken-word recognition tasks, and considers the influence of sequential bilinguals' language background variables in the extent of parallel language activation. Therefore, the current research measures and compares the proportion of bilinguals' and monolinguals' eye fixations to objects on a display screen while these subjects are in the process of listening to auditory material. The auditory material is spoken in English but includes critical target words that sound similar to an Afrikaans-translated object in the same display. The VWP spoken-word recognition task makes use of controlled bilingual visual and auditory stimuli, whilst placing bilinguals in a monolingual English context. The main bilingual variables included in this study are the L2 proficiency and the age of L2 acquisition.

1.7 Core terminology

Sequential bilinguals have a **first language (L1)** learnt from birth, and a **second language (L2**) learnt after the onset of L1 acquisition. Consistent with common definitions, the terms "L1" and "L2" are, in other words, chronological terms relating to order of acquisition only. An **early sequential bilingual** will have learnt both their L1 and L2 roughly before the age of 12 years, often where the L1 is spoken in the home environment and the L2 outside of the home (though this need not always be the case; Aronin and Singleton 2012). A **simultaneous bilingual** will have learnt both languages from birth (Aronin and Singleton 2012)[2].

In order to study the bilingual mind, psycholinguists focus on the **activation** of the bilinguals' languages. In this thesis, "activation" refers to the stimulation or operation of language(s) in cognition. In turn, studying the activation of bilinguals' language(s) allows a better understanding of their cognitive comprehension, production and acquisition mechanisms (De Groot and Kroll 1997; Schreuder and Weltens 1993). As will be highlighted in more detail in Chapter 2, activating a bilingual's languages can be accomplished through stimulating similar phonemes of both languages.

In using the tool of eye-tracking (explained in more detail in Chapter 4), firstly, a set of important terminology is defined. Quick eye movements made from one fixation area to the next are referred to as "**saccades**" (Roberts and Siyanova-Chanturia 2013: 218). Saccades are jerky, almost twitchy eye movements which tend to be very fast (mean saccade duration for scene perception is 40–50ms; Conklin, Pellicer-Sánchez and Carrol 2018: 5). Between saccades, "**fixations**" occur when the eyes are stationary upon a region of interest (ROI) for a longer duration (Roberts and Siyanova-Chanturia 2013: 218). Both saccades and fixations are defined as involuntary, physiological responses, meaning that they are not of conscious control (Rayner, Slattery and Bélanger 2010). These terms were originally defined in relation to reading tasks (as will be explained in subsection 2.2.2), where the reader fixated on a word

[2] A **foreign language**, in comparison to an L2, is usually a language found in another country than the speaker has come from, and is generally learnt only in the classroom setting rather than in a more natural, home environment (Aronin and Singleton 2012).

for longer than 100ms and would quickly scan words through saccades (within 100ms). However, these terms are also utilised in visual perception and, more importantly, in the spoken-word recognition task of this study.

1.7.1 Summary list of terminology

- **Bilingual** – an individual who speaks and understands two languages
- **Early (sequential) bilingual** – an individual who learns to speak and understand two languages at an age younger than roughly 12 years
- **Simultaneous bilingual** – an individual who learns to speak and understand two languages from birth
- **First language (L1)** – the language an individual learns first
- **Second language (L2)** – the language an individual learns second (thus rendering the individual bilingual)
- **Foreign language** – a language learnt and utilised only in the classroom setting
- **Language activation** – the triggering or stimulation of a specific language (as spoken by an individual) in cognition
- **Parallel activation** – the simultaneous accessibility and activity of both the L1 and L2 of a bilingual
- **Sequential activation** – the successive and disconnected accessibility to the L1 and L2 of a bilingual
- **Saccades** – fast and jerky eye movements (roughly 40-50ms)
- **Fixations** – eye movements that focus on a region of interest (lasting longer than 50ms)

1.8 Thesis outline

This thesis begins by reviewing historical to present-day literature on eye-tracking methodology, its use in studying the eye-mind link and, particularly, bilingual parallel activation of languages in spoken-word recognition tasks. Following the establishment of the literature concerning parallel activation in bilinguals, theories from monolingual and bilingual interaction models are utilised to explain the phenomenon of parallel activation. Here, within the theory, there are also key assumptions expanded upon in the realm of bilingual parallel activation. Next, the methodology used for the experiment of the current research is expanded upon, with details of the participants, ethical considerations, materials, and apparatus used in its creation. The results of the eye-tracking experiment are then reported on, alongside the participant groups' language background information. Lastly, a discussion on how the current research fits into bilingual parallel activation literature is presented in terms of the variables studied and outcomes of the results. BLINCS is used to explain how the phenomena observed in this instance of parallel activation work in bilingual cognition, as well as both the inhibitory and excitatory factors that cause parallel activation. A Parallel Activation Continuum, as an original proposal, is a further explanation of the kind of individual, contextual, and structural variables that influence parallel activation in bilinguals. Finally, the thesis concludes with a discussion of the challenges of the study and suggestions for future research.

Chapter 2: Literature Review

2.1 Introduction

The current literature on VWP spoken-word recognition tasks is located within different areas of psycholinguistics, informing the interacting variables of parallel language activation. This literature review chapter begins with cognition as it is tied to eye movements within various studies, and thus forms the foundation to this eye-tracking study (section 2.2). The initial practice of studying this eye-mind link (Just and Carpenter 1980) was established in reading tasks, and then moved into spoken-word recognition tasks. Both these types of tasks are expanded upon in order to contextualise the current research. Subsection 2.2.3 then indicates the specific timing (down to the millisecond) at which mental activity is represented in eye-movement action, which is an essential aspect to this study's eye-tracking methodology.

Section 2.3 identifies and expands upon studies that have successfully documented parallel activation in bilinguals. Literature of this kind helps pinpoint the variables that either inhibit or unveil parallel activation in bilinguals. In studies of bilingual parallel activation, the extent of parallel activation has been found to be sensitive to various individual, structural (experimental aspects), and contextual variables of the study; this will also be discussed in section 2.3. Individual variables of language AoA and language proficiency have been shown to influence parallel activation in previous studies. Structural variables based on the experiment itself include: phonological overlap, the word frequency of each word tested, the standardisation of pictures seen, and the VOT. Contextual variables include the language immersion of the bilingual, and the language setting of the current interaction.

2.2 Attention allocation of individuals

Richardson, Dale and Spivey (2006: 2) highlight the collaboration and entanglement of cognition and the human senses. The authors explain that the mind is inextricable from sensory action when attempting to observe the former. Richardson et al. (2006) first note the vast evidence of the embodiment of cognition and its dependency on "perceptual simulations", showing that the senses are indivisible from motor processing such as eye movements (see subsections 2.2.1 and 2.2.2 for examples). If cognition is entangled with the senses, and the senses with motor processing, it is plausible to say that the mind is somewhat inseparable from action.

Essentially, motor actions are said to be indicators of, and tools to access, continuous cognitive processes (Richardson et al. 2006: 2). Eye movements (as the motor actions tied to sight) may therefore act as the indicator or tool to understand the cognitive processing of bilinguals. Eye location offers an index of attention, even more so during complex processing tasks like reading and scene perception (Rayner 2009). This means that our eyes indicate what we are paying attention to and how much cognitive effort is being exhausted to process the input at the fixation area (Conklin, Pellicer-Sánchez and Carrol 2018: 2).

In order to examine whether bilinguals exhibit parallel or sequential processing of their two languages, it is fundamental to study the attention allocation, fixations (or focus), and location of fixations of an individual's eyes. These fixations are the specific and subtle motor actions indicating attention and focus of the thoughts of the mind. This is termed the "eye-mind assumption" or the "eye-mind link" (Just and Carpenter 1980), and is expanded on in section 3.2.

2.2.1 Accessing cognition through the eyes

As already mentioned, there are several studies that show cognitive processes to be reliant on both perceptual and motor mechanisms, such as one's vision (Richardson et al. 2006: 2). Although auditory language processing became a popular technique following Cooper's (1974) introduction to the method of spoken-language comprehension, it is a technique still used to this day, and is used in this study. Essentially, this method follows participants' eye movements, when being spoken to, to sets of elements being referred to in the speech. Initially, Cooper (1974) noted that when a spoken word referred to a specific element in the display, the participants' eyes moved quickly to that referred-to element. Later, Just and Carpenter (1980: 330), having coined the "eye-mind link" or "-assumption", furthered this observation within reading tasks, yielding a timeframe in which eye movements take place relative to reading comprehension (see subsection 2.2.2).

In addition to these studies, vast evidence for the perceptual-motor embodiment of cognition comes from Stanfield and Zwaan (2001), and Zwaan, Stanfield and Yaxley (2002) in studying perceptual symbols during language comprehension. Richardson, Spivey, Barsolou and McRae (2003) further highlight this eye-mind assumption by testing how referring to verbs in spatial terms affects verb comprehension. In finishing off the concept of attention allocation and prominence of the eye-mind link as fundamental to this study, Altmann's (2011) work on the millisecond timing of eye movements is also looked at.

2.2.2 The eye-mind link in reading tasks

Just and Carpenter (1980) highlight the relationship between the fixation of one's eyes and the cognitive processing of what is being focused upon when an individual is reading. The main finding from their study was that, on account of being able to pace the information intake (by reading slower), reading pace was identified as corresponding to the reader's internal comprehension rate, with fixations lasting longer when processing loads were greater (Just and Carpenter 1980: 329). Just and Carpenter (1980) found their 14 participants to average at 239ms (SD = 168ms) when fixating on a word. The authors focused on the points at which fixations were longer or shorter in duration, and thus where the variations in fixations occurred.

Just and Carpenter (1980: 330) indicate that content words are always fixated on while reading, yet shorter function words (such as *the*, *of*, and *a*) are often not fixated on in ordinary reading. Furthermore, an average reading pace of 1.2 words per fixation takes place when readers are given an age-appropriate text (Just and Carpenter 1980: 330). However, this number drops when the text is more difficult (such as one that uses scientific terminology) or if the reader being tested has a lower level of education (Just and Carpenter 1980: 330). For example, the word *flywheels* had a considerably longer fixation duration than the words *are* or *smooth*, which can be attributed to a longer duration of cognitive processing caused by the word's irregularity and its thematic importance in the text (Just and Carpenter 1980: 330). Therefore, Just and Carpenter (1980: 330) explain that the region or word that is longer fixated on can be assumed to be the region or word that is causing an increase in comprehension difficulty. The common misunderstanding at the time was that all individual fixations were roughly 250ms, however, as Just and Carpenter (1980: 330) show, there are variations of fixations due to the processing difficulty of words. In turn, as much as Just and Carpenter (1980) coined the "eye-mind link" as an assumption, their evidence is only limited to how an individual's eyes are linked to his/her cognition whilst reading.

2.2.3 Expanding evidence for the perceptual-motor (eye-mind) link

Barsalou (1999) argues that, theoretically, cognition is intrinsically perceptual, and shares systems with perception at both a cognitive and neural level. On a more empirical basis, Stanfield and Zwaan (2001), Zwaan et al. (2002), and Richardson et al. (2003) present support for this argument. Furthermore, these authors' respective studies act as evidence for the argument of cognitive processes being reliant on both perceptual and motor mechanisms, thereby strengthening the eye-mind assumption as it pertains to this study.

Stanfield and Zwaan (2001, cited in Zwaan et al. 2002) found support for Barsalou's (1999) idea that cognition is intrinsically perceptual in the sphere of language comprehension. Participants were presented with sentences such as *He hammered the nail into the wall* or *He hammered the nail into the floor* (reported by Zwaan et al. 2002: 168). In the first sentence, *nail* was presented verbally so as to enable the visualisation of this term as horizontal (i.e. *nail* being hammered perpendicularly *into the* (vertical) *wall*). The second instance of *nail* was presented verbally so as to enable the visualisation of this term as vertical (i.e. *nail* being hammered perpendicularly *into the* (horizontal) floor). In short, the nail's visualised orientation is implied by the position of the nail in each sentence (Stanfield and Zwaan 2001, cited in Zwaan et al. 2002). Every sentence was followed by a line drawing of the object referred to, either congruent or incongruent to the previous sentence's implied orientation (Stanfield and Zwaan 2001, cited in Zwaan et al. 2002). Subjects then made timed responses as to whether the object seen in the picture at that point in time was previously mentioned in the sentence (Stanfield and Zwaan 2001, cited in Zwaan et al. 2002). The participants' responses were significantly faster when there was a congruency between the implied sentence orientation of the object and the visual image of the object, in comparison to slower responses when there was a discrepancy (Stanfield and Zwaan 2001, cited in Zwaan et al. 2002). These findings support perceptual symbol theories in which it is assumed that subjects activate and operate perceptual symbols whilst comprehending language, such as that of an object's implied orientation in a given sentence, as this is part of the mental depiction of that sentence contextualising the object (Stanfield and Zwaan 2001, cited in Zwaan et al. 2002). takes place. Essentially, the activation of a visual representation in the subject's mind occurs with the comprehension of language, or, the comprehension of language stimulates a visual, mental representation of the object. Additionally, these findings strengthen perceptual-motor links and the eye-mind assumption in that visual stimuli are better comprehended by an individual when in line with their thoughts about the orientation of the object (as triggered by the sentence).

Zwaan et al. (2002) conducted another study on the activation of perceptual symbols in language comprehension. Their results further confirm the perceptual-motor link to cognition. In this study, participants read sentences that described an animal or object in a specific location, but the shape of the animal/object would change on account of its location (Zwaan et al. 2002: 168). For example, the sentence could explain that an *eagle* was either *in the sky* or *in a nest* (Zwaan et al. 2002: 168). The *eagle in the sky* would take the form of a spread-winged eagle flying in the air but, for an *eagle in a nest*, one could imagine the eagle's wings to be at rest, folded inwards alongside its body, and the bird of prey to be in a seated or nesting position. Again, the participants would then see a visual image, and would have to either recognise if it had been mentioned in the previous sentence (Experiment 1) or merely name the object seen (Experiment 2).

In both Experiments 1 and 2, the participants' response times were quicker when the pictured object's shape implied by the sentence was matched to the shape of the visual image, in comparison to an average slower response time when there was an incongruency (Zwaan et al. 2002: 168). Again, these results argue for the idea that perceptual symbols are activated during language comprehension (Zwaan et al. 2002: 168). In a second experiment, much like in Stanfield and Zwaan's (2001) study, a naming task was used to provide a strengthened test of the perceptual symbols (Zwaan et al. 2002: 168). This experiment was different to Experiment 1 (a recognition task) as it did not necessarily require an explicit comparison between the sentence and the picture (Zwaan et al. 2002: 168). In turn, Zwaan et al.'s (2002) findings, alongside those of Stanfield and Zwaan's (2001), support the idea that perceptual symbols of referents are activated alongside language comprehension, even in times where the perceptual features are only implied and not explicitly stated (Zwaan et al. 2002: 170). This, again, indicates and strengthens the argument for the perceptual-motor cognition link, favouring the eye-mind assumption.

Richardson et al. (2003) argue that spatial effects of verb comprehension present evidence for the perceptual-motor characteristic of linguistic depictions. Firstly, Richardson et al. (2003) mention that language regularly makes use of metaphorical and spatial terms and phrases, thereby creating a concrete representation of abstract thoughts. An example such as *looking up to someone* is a concrete, vertical representation of the abstract understanding of 'respect' (Richardson et al. 2003: 786). In previous research by Richardson, Spivey, Edelman, and Naples (2001), participants were found to assign a horizontal image diagram to the word *push*, and a vertical image diagram to the word *respect*. Richardson et al. (2003) explain this offline consistency in verb-diagram assignment as evidence that language creates spatial forms of presentation.

Richardson et al. (2003) tested participants in both a visual-discrimination- and a picture-memory task while these participants listened to short sentences. The results indicated that participants had faster reaction times in labelling the verb as either horizontal or vertical, when the common horizontal/vertical characteristic of the verb's image representation (as is referred to in language) was congruent to the horizontal/vertical positioning of the visual stimuli (Richardson et al. 2003: 776). For example, participants' reaction times were quicker when the verb *respect* in the sentence *The man respects his father* was paired with a vertical visual scheme than with a horizontal scheme (Richardson et al. 2003).

These spatial and perceptual aspects of language could be considered as metaphorical comprehensions foundational to our language, and are even seen as rooted in one's embodied experiences (Gibbs 1996; Lakoff 1987). Richardson et al. (2003) explain delayed response times as a result of incongruency between linguistic representations (in the form of spatial language) and perceptual mechanisms (in the form of visual representations of horizontal or vertical). Furthermore, these incongruencies were influential in both online performance (i.e. the performance on the processing tasks that is monitored as these tasks take place) as well as delayed memory tasks. Richardson et al.'s (2003) findings serve as evidence for the perceptual-motor link to cognition. The studies referred to above show support for the eye-mind assumption as well, as they are all forms of the perceptual-motor cognition relationship.

2.2.4 The eye-mind link in VWP spoken-word recognition tasks

The eye-mind link was then examined in VWP spoken-word recognition tasks, much like the methodology of the present study. Studies such as those by Tanenhaus et al. (1995) and Allopenna, Magnuson and Tanenhaus (1998) focus on the phonological domain as it is tied to the VWP, but in the monolingual setting. These studies became the foundation to the present study's focus on bilinguals' language activation, as they focused on the activation of phonologically similar words within American English monolinguals.

The attention-allocation findings of American English monolinguals in Tanenhaus et al.'s (1995) study moved eye-mind studies into the VWP spoken-word recognition domain. Tanenhaus et al. (1995) found that monolingual American English individuals, when told to *Pick up the large red rectangle*, regularly make anticipatory eye movements to the selection of red objects in the display before even hearing the noun *rectangle* to completion. Tanenhaus et al. (1995) presented their participants with a set of objects on a table. These objects would sometimes include two with initially similar-sounding names (such as *candy* and *candle*). The participants were then told to move the objects around on the table.

Tanenhaus et al.'s (1995) results were that the average time to execute an eye movement to the target object mentioned (e.g., *candy*) tended to be longer when an object with a phonologically similar name (e.g., *candle*) was present in the object set, than when no such phonologically-competitive object was present. The average time to execute an eye movement to the target object mentioned (such as *candle*) was 145ms from the end of the word, when there were no other phonologically similar objects to compete with (Tanenhaus et al. 1995: 1633). However, when the phonologically similar term (*candle*) was also placed in the object set, the average eye movement execution became 230ms – 85ms longer than the average time to execute an eye movement to the target object mentioned (Tanenhaus et al. 1995: 1633).

Allopenna et al. (1998) found similar results from their VWP spoken-word recognition tasks. These authors tested participants' eye movements to pictures of four objects on a screen while being verbally instructed to move a single object (e.g., *Pick up the beaker; now put it below the diamond*; Allopenna et al. 1998). If the word used was *beaker*, the objects on the screen included two possible distractor objects, one being a cohort competitor with a name that began with the same onset and vowel as the name of the target object (*beetle*), another being a rhyme competitor (*speaker*), and an unrelated competitor (*carriage*; Allopenna et al. 1998: 419). The authors found that the probability of fixations on both the pictures of the beaker and the beetle increased as the word *beaker* was heard. As initial acoustic material from *beaker* became phonologically incongruent with *beetle*, the probability of eye movements to the picture of the beetle declined while the probability of eye movements to the picture of the beaker started to increase (Allopenna et al. 1998). Subsequently, in the rhyming domain, eye movements to the picture of the speaker started to increase as the end of the word *beaker* was heard. Although the results found no evidence for rhyme effects, they do give strong evidence, particularly for activation of cohort competitors (Allopenna et al. 1998: 437). The results showed that the participants were equally likely to focus on the referent and its cohort competitor initially but, over time, began to focus on and between the referent and its rhyme competitor (Allopenna et al. 1998: 434).

These studies became the basis for the parallel activation studies detailed in section 2.3, and were fundamental in bringing the eye-mind assumption into VWP spoken-word recognition tasks. However, Cooper (1974), Rayner (1998), and Altmann's (2011) studies put attention allocation into a timeframe of observation for language activation, as the abovementioned monolingual studies were not as descriptive with timing as bilingual studies became while testing language activation.

2.2.5 Attention allocation in real time

With reference to English reading tasks, Rayner (1998) specified eye fixations to average at about 200–250ms. Although this timeframe of attention allocation is limited to the reading domain, it was the same timeframe seen in earlier studies of the VWP, such as those from Cooper (1974) and Tanenhaus et al. (1995).

Altmann (2011: 190) re-analysed two previous VWP spoken-word recognition studies by Cooper (1974) and Tanenhaus et al. (1995). In both studies, participants' eye movements were observed when they were presented with either a real-life set of objects or objects displayed on a screen, while these participants heard spoken instructions. These instructions either influenced the movement of the objects presented within their visual environment or were narratives that described events possibly affecting items depicted in a current or previously-seen scene (Altmann 2011: 190). Altmann (2011: 190) re-analysed these studies essentially to test the time it would take for the oculomotor system (a part of the central nervous system directing eye movements) to respond to the spoken words being heard. However, Altmann (2011: 190) reiterates that this timeframe is, additively, distinguishing between the "signal" (eye movements as a result of the comprehension of language heard) or "noise" (eye movements due to other external and irrelevant factors).

Altmann (2011: 190) aimed to determine a critical time-course in which "signal" eye movements took place, observing when eye movements moved to a visual target in relation to when the unfolding spoken-word referring to that target was heard. The results from this experiment indicated that language-mediation of oculomotor control took place within 200ms of the onset of the target word, determining an appropriate fixation target (Altmann 2011: 192).

What Cooper (1974) initially identified was that listeners' eye movements related to the text read at almost an immediate rate. More than 90% of the listeners in his study made eye movements to the target objects, showing an activation of the target words and their comprehension of these words, either while the target word was spoken or at least within 200ms afterwards. Therefore, the timeframe for VWP spoken-word recognition task comprehension should be observed at roughly 200ms post the target-word onset (this is expanded on in section 4.5).

In concluding the importance of attention allocation of individuals, the entanglement of the human cognition to the senses is implemented to contextualise this study, as the methodology makes use of the eyes as a 'window' to subjects' thinking or cognition. Richardson et al. (2006) first showed the vast evidence of the embodiment and dependency of cognition on "perceptual simulations", making the senses inseparable from motor processing. Cognition was further shown by the above studies as deeply entangled with the senses, and the senses with motor processing. Consequently, such studies highlighted how the human mind/ cognition is somewhat indivisible from human actions or reactions. Eye movements (as the motor actions tied to sight) are, therefore, used in this study to indicate the moment-to-moment cognitive processing of bilinguals, as eye location offers a guide to attention (Rayner 2009).

2.3 Parallel activation in bilinguals

Attention allocation, as studied with VWP spoken-word recognition tasks, has been utilised in a developing body of research to examine the extent to which bilinguals activate their two languages in parallel (Shook and Marian 2017: 229). As Grosjean (2001: 7) proposed with the Language Mode hypothesis, even when only one of the bilingual's languages are in use at a given moment, it is likely that the other is never completely deactivated nor completely activated at the same level. As such, the extent to which each language is active is considered on a continuum, from a completely monolingual language mode (monolingual situation) on one end, through an intermediate (partial) language mode, to a bilingual language mode on the other end. Language mode is described as the state of activation of the bilingual's language and language processing mechanisms at a given point (Grosjean 2001: 3).

With Grosjean's (2001) hypothesis in mind, as there are still varying results when assessing parallel activation in bilinguals, the next subsection inspects when parallel activation takes place and when it does not. Successfully recorded parallel activation studies will be discussed first, highlighting their fundamental variables in the creation of parallel activation. Secondly, unsuccessful parallel activation studies are examined for variables that prohibit the co-activation of languages in bilinguals.

2.3.1 Parallel activation studies

The following set of studies has observed parallel activation in bilinguals, but many studies differ on control variables. In testing bilinguals in their L2, there are individual, contextual, and structural variables that are tied to the activation of an L1, creating a parallel activation of bilinguals' languages. Individual variables, such as a later age of L2 acquisition and lower L2 proficiency, are linked to increased parallel activation of the L1 in L2 tests. In addition, contextual variables, such as bilingual language immersion and bilingual language settings, can influence increased parallel activation. Lastly, structural variables – such as more phonological overlap, similar word frequencies and similar VOTs across languages, as well as cognates present – can influence increased parallel activation as well.

2.3.1.1 Language setting and immersion

Originally, the interest in parallel activation in bilinguals was a result of Preston and Lambert's (1969) bilingual version of the Stroop task. This study was one of the first to produce fundamental supporting evidence in favour of parallel activation. However, with reference to current research on bilinguals, this bilingual Stroop task is critiqued, as this task creates a bilingual setting which enables the natural and simultaneous activation of both languages.

In the original Stroop task (Stroop 1935), participants were asked to name the colour of the ink in which a word was printed while the written text of that word denoted a colour. Participants were found to be more inaccurate, and took longer to name the ink colour of the word when the colour denoted by the text of that word was inconsistent (e.g., naming the green colour of the word *blue*) in comparison to when the word was printed in black ink (Stroop 1935).

In Preston and Lambert's (1969) bilingual version of the Stroop task, bilinguals were asked to name the ink colours of words in one language, when the spelling of the colour could either be consistent with that language or be their other language. Preston and Lambert (1969) were testing whether bilinguals had delayed responses if the written words and the naming of the colours were inconsistent in the participants' languages. Results from multiple studies much like Preston and Lambert's (1969) showed that participants took the longest when the act of colour-naming was performed in one language but the printed words were presented in a different language (Altarriba and Mathis 1997; Chen and Ho 1986; Dyer 1971; Preston and Lambert 1969). Results were considered as language interference, meaning that because there were two languages active in the bilingual mind at that moment during the task, there was a delayed effect in the processing of the task.

Although parallel activation is somewhat acknowledged in this case, this is not a fair indication of the extent to which there is parallel activation in bilinguals. Here, it is expected that participants would experience parallel activation, as both languages are explicitly and blatantly existent in the stimuli of the experiment. A more inconspicuous stimuli set would be needed in order to test the extent to which bilinguals activate the language not being used at that given moment.

Bilingual parallel activation studies have since moved more into the domain of spoken-word recognition tasks using eye-tracking methods (Marian and Spivey 2003a, 2003b; Spivey and Marian 1999). Spivey and Marian's (1999) participants were late Russian–English bilinguals that had immigrated to the US in their teenage years and were, from that point onwards, immersed in an English context (whilst studying at a US university). In this eye-tracking study, bilinguals heard Russian sentences while watching a screen that displayed one picture each in each quadrant (Spivey and Marian 1999). The four pictures consisted of one target object; one competitor object, where the English label for this object was phonetically similar to the target object; and two unrelated distractors. To provide an explanation of Figure 1 below (adapted from Spivey and Marian 1999: Fig. 1.), an example of a Russian sentence used was *Poloji marku nije krestika* ("Put the stamp below the cross"). This was heard by the participants while the target object of a stamp was displayed in the bottom-right quadrant alongside the phonologically-similar English *marker* in the top-left quadrant and two distractor objects (see Figure 1). The target object was *marku* ("stamp"), while the phonologically-similar and competing object of the English *marker* is seen as it is being fixated upon (the cross indicating this fixation). There were two conditions in this study, one where the competitor object was present, and another where this was replaced by a control distractor object (Spivey and Marian 1999: 282). The whole experiment was also replicated in English to further test any bi-directional influence of L2 to L1 (Spivey and Marian 1999: 282).

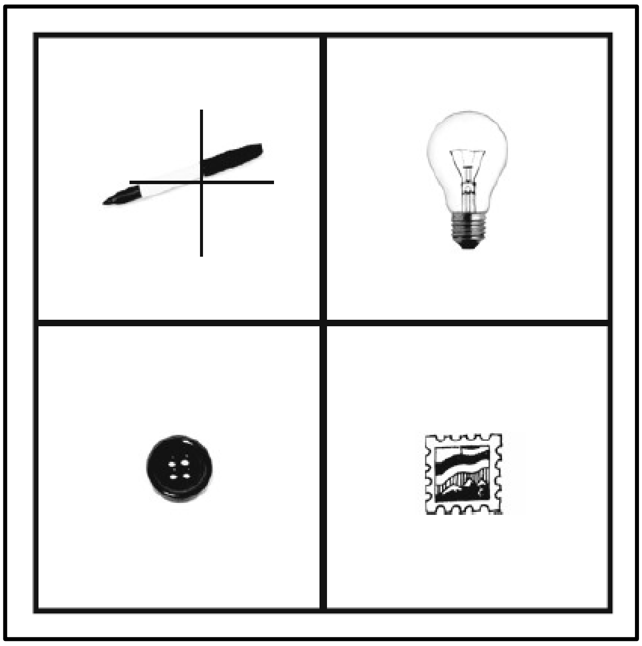


Figure 1. An example of the Russian–English screen display in (Spivey and Marian 1999)

Spivey and Marian (1999) investigated whether lexical access in bilinguals is language-specific (limited to the intentional language and thus only activating the language in use) or language-general (where both languages can be activated), depending on whether the bilingual looked to the unused language's phonetically-similar object. The findings of Spivey and Marian's (1999) study emphasised that bilingual speakers are unable to turn off their other spoken languages when in a monolingual context, as these bilinguals often looked to the unused language's competing object (this was later also confirmed by Marian and Spivey's (2003a) and (2003b) studies). Participants across the English and Russian versions were shown to produce significantly more eye movements to the between-language distractor or competitor object (31%) than to the control distractor (13%).

Furthermore, results showed that competition was stronger from the L2 into the L1, creating an asymmetry of results (Spivey and Marian 1999). Significantly more eye movements in the Russian test (the participants' L1) were made to the competitor object (32%) than the control object (7%), but the difference was not as significant in the English test (competitor object = 29%, control object = 18%). This asymmetry is hypothesised to be a result of the participants' immersion, or living, socialising and working in their L2-English context, (ie. being deeply engaged in, on a daily basis, the English language spoken in the context, even if this is not one's L1), as mentioned above (Spivey and Marian 1999: 282).

Although parallel activation is recognised in Spivey and Marian's (1999) study, several factors may have resulted in a bilingual test setting rather than the planned monolingual context (Marian and Spivey 2003b: 100). Therefore, the methodological flaws of this study include the participants being aware that the experiment was on bilingualism, the use of bilingual experimenters fluent in both Russian and English, and back-to-back Russian–English experimental version sessions (Marian and Spivey 2003b: 100). The extent to which parallel activation took place is therefore questioned, as the setting itself stimulated a bilingual language activation.

2.3.1.2 Monolingual language setting

Marian and Spivey (2003b) again worked at proving parallel activation within the late Russian–English bilingual when placed in a monolingual setting. This study attempted to control for the language setting more so than in the earlier works on parallel language activation (Marian and Spivey 2003b: 100). This was done by means of participants being tested only in one language, without code-switching, without mention of the other language, and without any mention of the necessity of bilingualism (Marian and Spivey 2003b: 100).

The first experiment tested the between-language competition from the L1 to the L2, and thus was conducted in English. The participants were L1-Russian speakers who moved to the US around the age of 13 years and were, at the time of testing, university students who received high marks on the college SAT entry exam (Marian and Spivey 2003b: 100). In the second and separate experiment, participants had a similar background but were tested in Russian to identify the between-language competition from the L2 to the L1. Participants were highly proficient, and were immersed in their L2 of English as a result (Marian and Spivey 2003b: 100).

The results still yielded parallel activation of both Russian and English, as parallel activation of lexical items between languages was noted, and a significant number of eye movements were made to the competitor object, in comparison to the distractor object, across both experiments (Marian and Spivey 2003b: 97). However, Marian and Spivey (2003b) were now recognising the possibly vast and influential sets of variables that affect parallel activation. They subsequently suggested that the strength of the between-language competition effect could possibly vary across L1 and L2 as well as possibly being facilitated by several factors, such as language immersion and language setting (Marian and Spivey 2003b: 97).

2.3.1.3 Phoneme overlap and word frequencies

Another parallel activation case was in phoneme monitoring by Colomé (2001). Colomé (2001) used an adapted speech-production task to test the prediction that even the language that a bilingual individual is not currently speaking is nonetheless activated. The participant group of this study comprised fluent and early Catalan-Spanish bilinguals, as Catalan and Spanish are the two official languages in Catalonia, and both languages are used equally at all levels in society (Colomé 2001: 733).

Participants were asked to determine if a certain phoneme was a part of a Catalan word. However, the phoneme could have been a part of the Catalan word spoken, its Spanish translation, or absent from both nouns (Colomé 2001: 726). Participants took more time to process and reject phonemes found in the translation language (Spanish) whilst being tested in Catalan, than the phonemes that were absent from both the Catalan and Spanish nouns (Colomé 2001: 726). Thus, Colomé (2001: 721) interpreted the results of delayed responses as parallel activation of both the target language (Catalan) and the language not in use (Spanish).

Marian and Spivey (2003a: 173) tested the performance of late bilingual Russian–English speakers and monolingual English speakers during a spoken-word recognition task of competing lexical items using eye-tracking. This was a similar study to their 1999 version. Participants were Russian–English bilinguals who immigrated to the US at around 15.62 years, and were highly proficient in English, receiving high scores on the SAT college entrance exams (Marian and Spivey 2003a: 173). This study controlled for variables such as the physical similarity of the objects, the word frequencies in the two languages, and the amount of phonetic overlap, so as to avoid any potential confounds (Marian and Spivey 2003a: 177). Such variables were considered in order to create a balanced and similar (as possible) experiment across languages tested, so as to determine the extent to which parallel activation can take place across the L1 and L2 (Marian and Spivey 2003a: 177).

The bilingual speakers were found to have made more eye movements to the between-language competitor word *marker* (which was phonologically similar to "marku", the Russian translation of the target word *stamp*) in comparison to the monolingual English speakers (Marian and Spivey 2003a: 173). Thus, the Russian–English bilinguals indicated an activation of both languages, even though they were only tested in English (Marian and Spivey 2003a). Again, however, this study received criticism regarding its methodology in that the monolingual English setting was not as monolingual as it was intended to be.

One of the most convincing studies was that by Shook and Marian (2012) who tested two different-modality languages (which have no intersection in input structure but rather have distinct phonological systems) for parallel activation. The languages tested were American Sign Language (ASL) and English. In this study, participants were instructed in English to select objects from a display whilst their eye movements were recorded (Shook and Marian 2012: 314). The participants were hearing ASL-English bimodal[3] bilinguals (proficient in both languages, as tested by the Language Experience and Proficiency Questionnaire), and a set of English monolinguals forming the control group. The bilingual group contained both early and late bimodal bilinguals (Shook and Marian 2012)[4]. Shook and Marian's (2012: 315) aim was to investigate whether, during spoken comprehension, language co-activation (i.e. parallel activation) takes place between languages that do not share a modality.

In looking at parallel processing by means of bimodal bilinguals' eye fixations, Shook and Marian (2012) found parallel activation of ASL during English comprehension. During critical testing, the target item appeared with a competing item that overlapped with the target in ASL phonology (Shook and Marian 2012: 314). The target-competitor pairs were comprised of pairs of signs that corresponded with three of four phonological distinctions in ASL (handshape, hand movement, space location of the sign, and positioning of the palm/hand; Shook and Marian 2012: 317). The bimodal bilingual's eyes focused more on the competing items than the items that were phonologically unrelated, in addition to these individuals looking more often at these competing items in comparison to monolinguals (Shook and Marian 2012: 314). Thus, the authors were able to conclude that ASL was co-activated alongside English during spoken English comprehension (Shook and Marian 2012: 314). These findings also propose that language co-activation is not modality-dependent (Shook and Marian 2012: 314).

[3] A bimodal bilingual is an individual who speaks two languages, and these languages are of different modalities, such as a signed language and a spoken language (Shook and Marian 2012: 315). In opposition, a unimodal bilingual would be someone who speaks two languages that are of the same modality.

[4] Shook and Marian (2012: 321) report that, with the comparison of the fixation proportions between early and late bilinguals, similar fixations to the competitor (54.1% vs. 51.4%) and distractor items (34.5% vs. 35.8%) were made.

2.3.1.4 Proficiency

A number of studies have looked at the influence of proficiency on parallel activation in bilinguals, finding that a lower L2 proficiency increases a parallel activation of the L1 when these bilinguals are tested in their L2 (Blumenfeld and Marian 2007; Elston-Güttler et al 2005; Van Hell and Dijkstra 2002; Perani et al. 1998). Overall, it is highlighted that the lower a bilingual's L2 proficiency, the more likely parallel activation of the L1 is to be observed when s/he tested in his/her L2.

Blumenfeld and Marian's (2007) eye-tracking study focused more intensively on variables of proficiency and phonological overlap, and identifying their influence on parallel activation. This was done by testing proficiency and manipulating lexical frequencies in German-L1 English-L2 late bilinguals, and English-L1 German-L2 late bilinguals (Blumenfeld and Marian 2007: 633). Both groups were late bilinguals (Blumenfeld and Marian 2007: 638). Proficiency was manipulated in terms of the native language of the speakers, and lexical frequency was stimulated through target words that either overlapped across translation equivalents (cognate words, or words that are identical in two languages orthographically and semantically) or did not overlap at all (Blumenfeld and Marian 2007: 633). Bilinguals tested were only chosen to participate if they self-rated their L2 proficiency as a score of 3 or more on a scale from 0 (no proficiency) to 5 (excellent proficiency) – in addition to having been immersed in the L2 setting for six months or longer (Blumenfeld and Marian 2007: 639).

The participants in Blumenfeld and Marian's (2007) study were presented with spoken words with phonological overlap (between target words and competitor words) on one of three types: low-, medium-, and high overlap. The participants were tested in English, and eye movements to German competitors were utilised as indicators of German parallel activation (Blumenfeld and Marian 2007: 633). The results indicated that both bilingual groups co-activated German while comprehending the cognate targets, but the L1-German bilinguals were the only ones to co-activate German when comprehending English-specific targets (Blumenfeld and Marian 2007: 633). Blumenfeld and Marian's findings (2007: 634) show that high language proficiency and cognate status both triggered parallel language activation in bilinguals.

Perani et al. (1998) reason that proficiency is found to be more influential than AoA in determining brain representations of languages while processing auditory narratives in one's L1 and L2 (brain representations were monitored in the cortical area which is the outer layer of the cerebrum, a part of the brain utilised in higher functions like vision, hearing, and speech). The authors (1998) used the positron emission tomography (PET) method to compare the brain area activity of one group of early and late bilinguals (both groups being highly proficient in their L2s) to another group with low proficiency in the L2. Perani et al. (1998) found that the activation areas of both the early and late highly proficient learners of L2 were comparable across both L1 and L2. However, in the low proficiency group, there were differential regions of activation found as produced by the L1 and L2 (Perani et al. 1998).

In another parallel activation study, this time on trilinguals, Van Hell and Dijkstra (2002) found that during the L1 (Dutch) task, the L2 (English) but not L3 (French) cognate words were activated. However, the trilinguals had higher proficiencies in their L2 (English) when compared with their lower proficiency levels in their L3 (French). In comparison, the other trilingual group (that had equal and minimal L2 and L3 proficiency levels) activated both their L2 and L3 during the same language task.

Elston-Güttler et al. (2005) tested the reaction times and event-related brain potentials (ERP) of bilinguals with differing L2 proficiencies in a semantic-priming word-recognition task. ERPs measure electrophysiological brain responses that are triggered by a sensory, cognitive, or motor event. Elston-Güttler et al. (2005) found that the bilinguals with low L2 proficiencies activated their L1 at the word level when tested in their L2 language. However, the highly proficient L2 group did not activate their L1 in parallel as much as the low proficiency group did, as seen in their ERPs (Elston-Güttler et al. 2005). Rather, the highly proficient L2 group was found to react similarly to the group of monolingual speakers of the L2 (Elston-Güttler et al. 2005). Elston-Güttler et al. (2005) explained that bilingual word recognition can be considered as non-selective, yet, the L2 proficiency has a significant effect on the access to this recognition.

In testing parallel activation of Dutch and English in the orthographic context, Van Heuven, Dijkstra and Grainger (1998) also made use of orthographically-similar between-language words. Participants were grouped into either the high-proficiency group (students of English/ students who had stayed in an English-speaking country for a brief duration, i.e. 6–12 months) or the low-proficiency group (students of Dutch or other academic fields; van Heuven et al. 1998: 465). Van Heuven et al. (1998) tested whether the recognition of target words (exclusively from one language) was affected by the presence of orthographically-similar neighbours (either from the same language as the target word, or from the bilinguals' other language).

With the increased number of Dutch orthographically-similar neighbours present, a slowed response time occurred for English target words (Van Heuven et al. 1998). Alongside this, an increase in English orthographically-similar neighbours caused facilitating effects for English target words and a hindering effect for Dutch (Van Heuven et al. 1998). A control group of monolingual English speakers was shown to have the same facilitating effect as English orthographically-similar neighbours, but no effect from their Dutch neighbours. In turn, Van Heuven et al. (1998) explained this to be indicative of the parallel activation of English and Dutch words in the English-Dutch bilingual. However, the results additionally indicated that the high proficiency participants were able to control or ignore the effect of the non-target language neighbours better than the lower proficiency bilinguals (Van Heuven et al. 1998). Therefore, the lower proficiency bilinguals experienced an influence of their L1 on the L2 in the parallel activation of their L1 during L2 processing, yet the higher proficiency bilinguals did not experience this parallel activation to the same extent.

2.3.1.5 Age of acquisition

Many studies investigating language activation and processing in bilinguals have recognised the necessity in either controlling or considering the AoA of the L2s (Blumenfeld and Marian 2007, Canseco-Gonzalez et al. 2010; Jared and Kroll 2001). In Silverberg and Samuel's (2004) study on Spanish–English bilinguals, a lexical-decision task was conducted in which Spanish (L1) targets preceded English (L1) primes. In this study, there were three types of primes: the Semantic primes, such as *nail* with the target *tornillo* ("screw"); Mediated Form primes, such as *bull*/*toro* with the target *tornillo*; and Form primes, such as *torture* with the target *tornillo* (Silverberg and Samuel 2004). Both the English primes of *nail* (a semantic prime) and *bull* ("toro" in Spanish as a facilitated prime) caused a parallel activation of the Spanish word *tornillo* in the early bilingual group (Silverberg and Samuel 2004). Yet, no effect was observed in either of the late-bilingual groups (Silverberg and Samuel 2004).

These two parallel activation effects were, therefore, limited to the early bilinguals with high L2-proficiency levels. Comparatively, the group comprising late L2-learners, also with high L2-proficiency levels, only exhibited effects of parallel activations of phonological similarity (e.g., English *torture* – Spanish *tornillo*) and thus of form-related primes. Silverberg and Samuel (2004) discussed these findings as evidence of a collective semantic level of the L1 and L2 found in early bilinguals, and a collective lexical level of the L1 and L2 in the late bilinguals. However, in the proficient, later-L2 bilinguals (learning their L2 after 7 years of age), there was evidence of L2 words being merged into their L1 lexical representations (Silverberg and Samuel 2004: 391). As a results, Silverberg and Samuel (2004) explained that both the type and the extent of interaction between a bilingual's two languages depend mostly on the age of L2 acquisition (found independently from proficiency).

2.3.1.6 Other examples of parallel activation

A variety of parallel activation evidence was also observed within differing visual word-recognition tasks, such as orthographic priming (Bijeljac-Babic, Biardeau and Grainger 1997) and phonological overlap (Brysbaert, Van Dyck and Van de Poel 1999; DeGroot, Delmaar and Lupker 2000; Dijkstra, Grainger and Van Heuven 1999).

In two written-word recognition tasks, Bijeljac-Babic et al. (1997) tested bilinguals' lexical-decision response times when briefly presented with either orthographically-similar or -dissimilar related primes in reference to a target word. The primes used were words either from the same language or across the bilinguals' languages, and were all words of high frequency (Bijeljac-Babic et al. 1997: 447). Bijeljac-Babic et al. (1997) found that target recognition was delayed, both within and across languages, when there was an orthographically-similar prime to the target word, in comparison to orthographically-dissimilar primes. Furthermore, the delayed target recognition across languages increased on account of the subjects' language proficiency in the language of the prime words (Bijeljac-Babic et al. 1997). In turn, orthographically-similar strings of letters were shown to activate lexical representations simultaneously across bilinguals' languages, even when these subjects were placed in a monolingual context (Bijeljac-Babic et al. 1997).

Dijkstra et al. (1999) then tested Dutch-English bilinguals. These bilinguals were L1-Dutch speakers who had learnt (and were continuing to learn) English as a foreign language at school for six years by the time the study took place. They also used English regularly in their studies. These participants were tested with English words that varied in their degrees of orthographic, phonological, and semantic overlap with Dutch words. English target words could therefore either be spelled identically to the Dutch words and/or could be a homophone of the Dutch words alongside being similar in semantic identity to the Dutch word (Dijkstra et al. 1999). The authors used both a continuously demasking task as well as a visual lexical-decision task, finding similar results throughout (Dijkstra et al. 1999). By means of measuring response times, the results indicated facilitating effects of cross-linguistic orthographic and semantic similarity, and inhibitory effects of phonological overlap (Dijkstra et al. 1999).

The above studies that test bilinguals in their L2, and find L1 activation, differ on the controlled individual, contextual, and structural variables that influence such L1 activation (and in turn, parallel activation). Individual variables include: a later age of L2 acquisition and lower L2 proficiency. Contextual variables are, namely, a bilingual's language immersion and the current bilingual language settings. The structural variables are just as influential on parallel activation, including: more phonological overlap, similar word frequencies and similar VOTs across languages, as well as cognates present. These are important variables to note, as in order to claim parallel activation in bilinguals, one would need to control for these variables.

2.3.2 Sequential activation studies

The following set of studies has no observations of parallel activation in bilinguals but, again, differ on control variables. Individual variables such as an earlier age of L2 acquisition and a higher L2 proficiency lead to decreased parallel activation of L1 in an L2 setting. Additionally, contextual variables such as a monolingual language immersion and monolingual language setting can influence decreased parallel activation. Lastly, structural variables such as fewer phoneme overlaps, dissimilar word frequencies and VOTs across languages, and the absence of cognates also have an influence in the decrease of parallel activation (thus an increase of sequential activation).

2.3.2.1 Language immersion

In a similar VWP spoken-word recognition study by Weber and Cutler (2004), there were no indications of parallel activation in Dutch-English bilinguals. Weber and Cutler's (2004) results indicated no significant eye movements to the English phonological competitors despite using the same methodology as Spivey and Marian (1999). The Dutch participants did not seem to be distracted by the English phonological competitors (Weber and Cutler 2004) as the Russian-L1 speakers from Marian and Spivey's (1999) and Spivey and Marian's (2003a, 2003b) studies had been. For example, when hearing the Dutch target word *deksel* ("lid"), the participants did not seem to look at the image of the competing, phonologically-similar *desk* any more than the unrelated distractor pictures (Weber and Cutler 2004: 19).

Weber and Cutler's (2004) participants were Dutch-English bilinguals who lived in the Netherlands, learnt English more as a foreign language than an L2, and were more regularly immersed in their L1 of Dutch (Weber and Culter 2004: 4). The participants of this study were almost in complete opposition to Marian and Spivey's (1999) and Spivey and Marian's (2003a, 2003b) participants, thus providing an explanation for this lack of parallel activation.

2.3.2.2 Monolingual language setting and age of acquisition

As Spivey and Marian (1999) and Marian and Spivey (2003a, 2003b) already indicated, their experiments may have yielded slightly more parallel activation of languages in their bilinguals on account of creating a marginally more intermediate language-mode setting than monolingual-mode setting (Marian and Spivey 2003b: 100). Marian and Spivey (2003b: 100) note that a few features may have directed the participants in those studies away from the monolingual to the intermediate language mode. To reiterate, features included participants' awareness of participating in an experiment on bilingualism, participants being tested by bilingual experimenters fluent in both languages, and both languages being tested in adjacent experimental sessions (Marian and Spivey 2003b: 100).

Language setting can influence the strength to which languages are activated in parallel (Marian and Spivey 2003b: 100). However, Canseco-Gonzalez et al. (2010) suggest that the language mode is not quite as influential as AoA in the parallel activation of languages in a bilingual. Canseco-Gonzalez et al. (2010: 689) tested Spanish-English bilinguals in Grosjean's (2001) language modes under conditions designated as "monolingual mode", "mixed mode", and "bilingual mode".

In the monolingual mode, participants were not aware that the experiment involved bilingualism in any way – all forms, stimuli, signs around the room, and instructions were in English, and the experimenter was a monolingual English speaker thus incapable to stimulate a bilingual mode (Canseco-Gonzalez et al. 2010: 689). Entering the mixed mode, the participants were uninformed that their bilingualism was a requirement to participate in the study, and again, all stimuli were in English, and the experiment was conducted completely in English (Canseco-Gonzalez et al. 2010: 689). The difference in this mode was that the experimenter was bilingual and, pretending to have discovered participants' bilingualism, gave a few instructions (e.g., *Please take a seat*) and spoke infrequently with the participant in Spanish (Canseco-Gonzalez et al. 2010: 689). Lastly, in the bilingual mode, participants were informed that the experiment was about bilingualism, and the door sign addressed participants in numerous languages (Canseco-Gonzalez et al. 2010: 689). Once again, the experiment was carried out entirely in English, but the bilingual experimenter spoke infrequently to the participant in Spanish (Canseco-Gonzalez et al. 2010: 689).

Bilinguals were separated into groups of L1 Spanish (English learnt after the age of six years), L1 English (Spanish learnt after the age of six years), and early bilinguals (who learnt both languages before the age of six years (Canseco-Gonzalez et al. 2010: 684). The bilinguals who had learnt Spanish at an earlier age (i.e. the L1-Spanish group and the English-Spanish early bilinguals) showed an effect of parallel activation of Spanish, even when in the English monolingual setting.

However, Canseco-Gonzalez et al. (2010) concluded that this language mode manipulation only had a major influence on the L1-Spanish bilingual group (who learnt English after six years of age) and not as significantly on the L1-English bilingual group (who learnt Spanish after six years of age) or the early English-Spanish bilingual group. Only the L1-Spanish bilinguals demonstrated activated lexical candidates in Spanish, even when they were completely immersed in their L2 English-speaking environment (monolingual mode) (Canseco-Gonzalez et al. 2010: 703). Canseco-Gonzalez et al. (2010) hypothesised that the English-Spanish early bilingual group was more skilled in working between two languages and avoiding the Spanish interference or activation because it was irrelevant in the English setting. In turn, the authors hypothesise that an early bilingual can suppress his/her L1 when being tested in his/her L2 as a result of being skilled in moving between two languages (Canseco-Gonzalez et al. 2010).

Overall, Canseco-Gonzalez et al. (2010) explain that these results related to the findings of other parallel activation studies, such as Blumenfeld and Marian (2007), and Marian and Spivey (2003a, 2003b). However, the authors find that the effect of parallel activation is limited to those who acquire the irrelevant language (i.e. the language the participant was not being test in at that point) after six years of age (Canseco-Gonzalez et al. 2010). Therefore, Canseco-Gonzalez et al. (2010) believe that their results show how bilinguals are able to access both of their languages in a monolingual setting, but that this is only if the irrelevant language is acquired at a later age (i.e. after the age of six years). In turn, the AoA seems to have more of an influence on parallel activation than language mode.

2.3.2.3 Voice onset time

Ju and Luce (2004) further helped determine the influence that acoustic-phonological cues have on bilingual speakers, as their study failed to replicate Spivey and Marian's (1999) conclusions.

Ju and Luce's (2004: 315) participant group comprised late Spanish-English bilinguals (mean AoA for English was 16 years) who were tested in a spoken-word recognition task. Participants were highly fluent in English (Ju and Luce 2004: 315), and were tested in Spanish.

The VOT differed between Spanish and English in that Spanish, in terms of voiceless stops, has shorter VOTs than English. There were 12 critical trials, half of which had adapted targets with English-appropriate VOTs, and the other half had regular targets with Spanish-appropriate VOTs (Ju and Luce 2004: 315). In order to produce these English VOT adapted targets, two recordings were made: one with regular Spanish words and the other with the identical Spanish words articulated in an English-like manner (Ju and Luce 2004: 315). Therefore, the two sets of stimuli (unaltered vs. altered) only varied by the initial part spoken (about 88ms; Ju and Luce 2004: 315).

The results highlighted that at only one point were participants distracted by the competing object, i.e. when the Spanish words contained English suitable VOTs (Ju and Luce 2004: 318). Ju and Luce (2004) concluded that without a strong acoustic cue (such as VOT), there may be an inhibited level of parallel activation of languages. The authors even go as far as mentioning that Spivey and Marian's (1999) stimuli could have encouraged greater parallel activation had there been more consideration for strong acoustic cues such as voicing (Ju and Luce 2004: 318).

The above studies observed no evidence of parallel activation in bilinguals yet, are shown to differ on control variables. Individual variables such as an earlier age of L2 acquisition and a higher L2 proficiency indicated a decrease of L1 activation in an L2 setting. Contextual variables such as a monolingual language immersion and monolingual language setting indicated the same lack of L1 activation. Furthermore, structural variables such as fewer phoneme overlaps, dissimilar word frequencies and VOTs across languages, as well as the absence of cognates were shown to have an influence in decreasing parallel activation (indicating sequential activation).

2.4 Bidirectional activation

Having now established the factors that are fundamental to seeing parallel activation in bilinguals, a further question that arises is whether bilinguals experience bidirectional activation of languages. As noted in previous studies, there is often only a single direction of influence in triggering the activation of the other language (Canseco-Gonzalez et al. 2010;

Spivey and Marian 1999 and 2003b). However, it has been noted that this triggering occurs both by means of the L1 triggering the L2 (Canseco-Gonzalez et al. 2010; Marian and Spivey 2003b) and the reverse operation of the L2 triggering the L1 (Spivey and Marian 1999). However, if parallel activation in bilinguals is said to help determine the mechanisms of multilingual cognition in general, one would need proof of a consistent co-activation of languages regardless of which language the individual is being tested in.

One such example of bidirectional triggering of parallel activation in bilinguals is that from Marian and Spivey (2003a). Marian and Spivey (2003a) tested Russian–English bilinguals alongside English monolinguals in the processing of competing lexical items (spoken-word recognition). Their study aimed to increase the activation of Russian whilst controlling the amount of phonological overlap and word frequencies in both languages (Marian and Spivey 2003a: 175). This manipulation of a previous study (Spivey and Marian 1999), with the aim of observing competition from, and into, both languages, created evidence for bidirectional parallel activation (Marian and Spivey 2003a: 175). Marian and Spivey's (2003a: 187) results demonstrated a more equally distributed direction of competition between languages, as it was observed that there was competition from, and into, both languages. Furthermore, it is important to note the differences in results from Marian and Spivey's (1999) vs. Spivey and Marian's (2003a) factors of the respective studies, such as language setting.

2.5 Literature Review Conclusion

The current literature focuses on VWP spoken-word recognition tasks as located within different areas of psycholinguistics, informing the interacting variables of parallel language activation. Firstly, cognition was shown as inseparable from perceptual reactions, such as eye movements, reasoning the use of an eye-tracker in this study (section 2.2). Just and Carpenter (1980) were first to study this eye-mind link establishing such in reading tasks, and later, this expanded into testing spoken-word recognition tasks. These two types of tasks were used in contextualising the current research. Subsection 2.2.3 lead the testing of this study to a specific timing (within milliseconds) at which mental activity is observed in eye-movement action, a fundamental feature to this study's eye-tracking methodology.

Section 2.3 spoke to the several parallel and sequential activation studies of bilinguals, indicating the variables that either inhibit or unveil this parallel activation. Additionally, these studies of bilingual parallel activation highlighted that the extent of parallel activation is sensitive to various individual, structural (experimental aspects), and contextual variables of the study. Individual variables of language AoA and language proficiency, structural experiment variables, such as: phonological overlap, the word frequency of each word tested, the standardisation of pictures seen and the VOT, alongside contextual variables of language immersion and language setting of the current interaction, are all variables that were identified and expanded on in this review.

Chapter 3: Theoretical Framework

3.1 Introduction

Considering the studies and evidence in favour of parallel activation of spoken-word recognition in bilinguals, the next necessary step would be to interpret, explain, and predict this phenomenon. The phenomenon of parallel activation firstly rests on assumptions such as the eye-mind assumption and the Language Mode hypothesis, which will be explained and expanded upon in sections 3.2 and 3.4, respectively. With these fundamental phenomena of parallel activation explained, a more in-depth look into parallel activation theories and models will be offered. In turn, the processing mechanisms in the bilingual's language comprehension and interactions are further detailed.

3.2 The eye-mind assumption

As already explained in detail in Chapter 2, Just and Carpenter (1980: 330) adopted the "eye-mind assumption/link" in reading tasks, as the individual's eyes remain fixated on a word for the duration in which this word is being processed (indicated by what is called the "gaze direction"). It is widely agreed that, throughout complex information processing tasks (e.g., reading), attention and one's eye movements are interconnected (Rayner 1998). Although this assumption was developed for reading experiments, the concept of the eyes being indicative of what the individual is processing was passed on and into various other bilingual studies (Allopenna et al. 1998; Rayner 1998; Tanenhaus et al. 1995). Just and Carpenter's (1980) assumption was utilised in other gaze direction attention studies, such as those of Huettig et al.'s (2011) VWP.

3.3 The Visual World Paradigm

The VWP, as already briefly introduced, is a method that focuses on participants' eye movements whilst they listen to auditory input (Huettig et al. 2011: 10). Huettig et al. (2011: 1) explain that the paradigm allows the researcher access to the way language users integrate linguistic information with information found in the visual environment. The paradigm is said to be suited to cognitive psychology, such as studying the processing of bilinguals' language comprehension and activation in spoken-word recognition tasks, where participants are presented with visual and auditory information (Huettig et al. 2011: 1).

Experiments in the VWP examine individuals' visual attention and spoken-word recognition, and thus are reliant on both visual and auditory input (Huettig et al. 2011: 10). Furthermore, the VWP is recognised as a real-time measure of an individual's ambiguity resolution while processing language, and assesses competition effects in spoken-word recognition (Tanenhaus et al. 1995). The VWP allows for the testing of the incredibly rapid phenomenon of eye movements for comprehension, with Rayner's (1998) and Altmann's (2011) research showing that within 200ms of a participant hearing a word (i.e. the auditory input), the individual's eyes move to an image that represents the word as it is displayed on the screen.

Importantly for studies looking at parallel activation in bilinguals, as shown in Roberts and Siyanova-Chanturia (2013), the VWP can be used to chart the comprehension procedures of individuals presented with uninterrupted and undisturbed input (such as L2 grammatical knowledge and whether learners are able to retrieve and make use of their L2 knowledge within real-time input processing). In turn, the VWP is a more natural measurement of an individual's processing than other online techniques (Roberts and Siyanova-Chanturia 2013: 214). This aspect of the VWP is therefore useful in testing the spoken-word recognition of bilingual speakers, as natural data can be retrieved from participants in such studies.

3.4 The Language Mode hypothesis

As already touched on in Chapter 2, Grosjean's (2001) Language Mode hypothesis proposes as a state of activation of a bilingual's languages and language processing mechanisms at a given point. The continuum of language mode, moving from a completely monolingual situation on the one end, through to an intermediate (partial activation) language mode, and ending on a bilingual language mode on the other end, is dependent upon the activation levels of a bilingual's two languages at any given moment (Spivey and Marian 2003b: 100). Grosjean (2001: 7) proposes that the other language of a bilingual is possibly never completely deactivated (at the monolingual end of the continuum), and that it will also rarely reach the same level of activation as the language in use at any given moment (at the opposite, completely bilingual end of the continuum).

Grosjean and Ping Li (2013: 15) explain that, in their everyday lives, bilinguals will find themselves at differing points along the continuum, and the changes to different points can occur very quickly. However, the authors highlight distinct context-related features in order to recognise when a bilingual is being placed in anything other than a monolingual situation (Grosjean and Ping Li 2013: 17). Everyday and regular features include speaking, reading, and overhearing conversations in either or both of the bilingual's languages. These everyday features are essentially tied to the use of cross-language homophones, or even a high concentration of between-language homographs and/or cognates (Grosjean and Ping Li 2013: 17). Additionally, more structural and subtle features include participant knowledge that the study relates to bilingualism, a laboratory that works on bilingual research, a bilingual university context, a task that makes use of bilingual instructions, and the presence of elements of the other language in the stimuli (such as code-switches; Grosjean and Ping Li 2013: 17).

Figure 2 (taken from Grosjean and Ping Li (2013)) presents a diagram illustrating the subconscious processes involved in a bilingual's activation of his/her L1 and/or L2. First, the bilingual individual queries whether the first language [language A (La)] or the second language [language B (Lb)] is needed in the current context. Both languages are inactive at that point, as represented by the squares with light diagonal lines (Grosjean and Ping Li 2013: 14). In this example, the first question, "Which language should be used?", is answered with La, so the square becomes black to represent full activation of the language (Grosjean and Ping Li 2013: 14). This first subconscious process is named the "language choice", and the language chosen is labelled as the "base language" (Grosjean and Ping Li 2013: 14). The bilingual then works through the next question, "Should the other language be brought in?" / "Is the other language needed?". If the answer to these questions is "no", the Lb remains inactive, and only La is active and used (Grosjean and Ping Li 2013: 14). When only one language is active, this is called the "monolingual mode" (represented in the bottom-left area of Figure 2; Grosjean and Ping Li 2013: 14). Examples of this mode include reading a book written only in one language and, in this mode, the bilingual will only use the activated language (in this case, La, and not the deactivated language, Lb; Grosjean and Ping Li 2013: 14).

However, if the answer to the second question is "yes", and Lb is needed (for example, when the bilingual is conversing with his/her family members who speak the same two languages), then Lb is also activated, as seen on the right-hand side of Figure 2. In this example, the bilingual subject pre-empts the possible need for Lb when conversing with his/her bilingual family members through the secondary but partial activation of language (Lb). This then places the bilingual in a bilingual mode during which elements of both languages can be used (Grosjean and Ping Li 2013: 14–15). An example of a bilingual mode would be listening to music in one language but talking over the music to a monolingual speaker of the other language. Another example would be intense code-switching between both languages in a conversation with another bilingual.

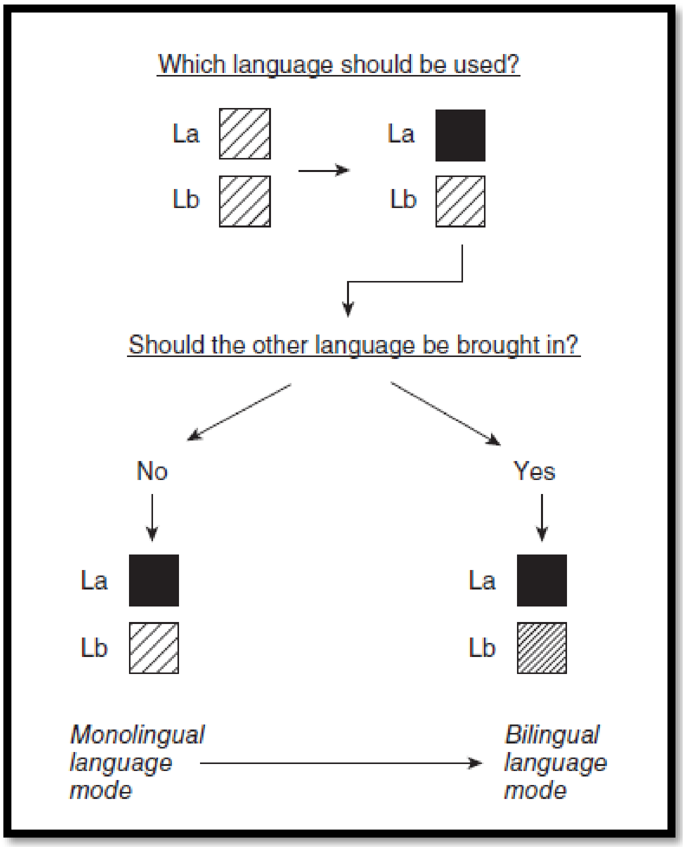


Figure 2. The subconscious processes involved in a bilingual's activation of his/her L1 and/or L2 (taken from Grosjean and Ping Li (2013))

3.5 The Input Switch theory

Originally, the theory behind bilingual language processing was Macnamara and Kushnir's (1971) Input Switch theory. The bilingual brain was said to have an "input switch" that could activate one language and deactivate the other (Macnamara and Kushnir 1971). Spivey and Marian (1999: 281) explain the Input Switch theory as one that is intuitively attractive, as it is a simple description for how a bilingual places the input of one language onto the suitable mental lexicon, and can ignore any irrelevant vocabulary from their other language knowledge. The Input Switch theory was supported by various studies on the lack of long-term activation of words from different languages which shared the same meaning (Gerard and Scarborough 1989; Kirsner, Brown, Abrol, Chadha and Sharma 1980; Scarborough, Gerard and Cortese 1984; Watkins and Peynircioglu 1983).

Early studies using functional magnetic resonance imaging (fMRI) of Broca's area in late bilinguals, showed the activation of two separate, distinct regions during sub-vocal production of the two different languages (Kim et al. 1997), thus providing further support for the theory.

Additionally, studies after that of Kim et al. (1997) showed that the degree of neuroanatomical overlap depended on the AoA, and L1–L2 proficiency and typology. In essence, the closer the L1 and L2 are in these terms, the more likely one will find an overlap in their parallel activation (Basnight-Brown 2014). As such, there was much support for the Input Switch theory until Spivey and Marian's (1999) study indicating a parallel activation of the bilingual's languages. However, there were first models – such as the monolingual Interactive Activation, and TRACE models – which addressed aspects of monolingual language cognition before moving into the bilingual sphere of comprehension.

3.6 The Interactive Activation model

McClelland and Rumelhart (1981) developed the Interactive Activation (IA) model which was first utilised in the analysis of monolinguals' written-word recognition. The IA assumes four layers of processing, namely visual features, letters, words, and language (see Figure 3). The simultaneous visual perception processing works within these layers in an interactive manner (McClelland and Rumelhart 1981: 377). Both top-down features (conceptually operated) and bottom-up (data-induced) processing simultaneously inform one another (McClelland and Rumelhart 1981: 377).

According to the IA, once a word is presented in written form, features of the individual letters are first recognised or activated, triggering letters that match those specific features, and thus triggering words that share the same orthography (Basnight-Brown 2014: 13). For example, an individual reads the word *table*, and the features of this word activate a range of words with similar features, such as other five-letter words (e.g., *taboo*) or words beginning with the same letters (e.g., *tablet* or *tabloid*). These features are the data-specific, bottom-up processes accessed by visual input. However, because this is an interactive model, the conceptually-operated systems are working simultaneously with this received input. Such top-down features include the semantic setting, triggering words that would be salient in such a context, and frequency of word use, such as *table* being a more commonly-used noun than *tablet*.

Perceptual processing is assumed to be interactive on various levels, where each level communicates with another neighbouring level, as depicted in Figure 3 (McClelland and Rumelhart 1981: 378). Such communication across levels can either be in the form of increasing activation of recipients (excitatory messages) or in decreasing/cancelling activation in recipients (inhibitory messages; McClelland and Rumelhart 1981: 378). The arrows in the diagram represent excitatory communications, and the circular ends of connections are the inhibitory communications (McClelland and Rumelhart 1981: 378).

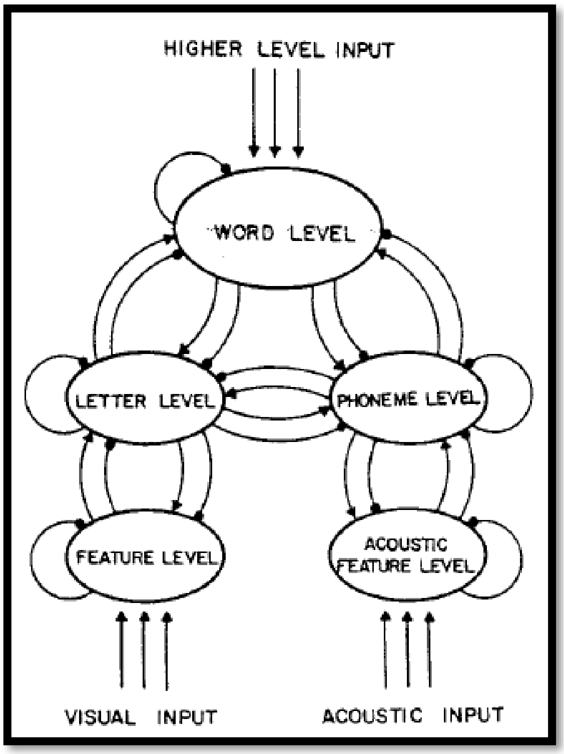


Figure 3. The monolingual Interactive Activation model (McClelland and Rumelhart 1981)

3.7 The TRACE model of monolingual speech perception

McClelland and Elman (1986) developed the TRACE monolingual model, named as such because “the network of units forms a dynamic processing structure called ‘the Trace’ which serves at once as the perceptual processing mechanism and as the system’s working memory” McClelland and Elman (1986: 1). The primary purpose of this model was to account for the incorporation or omission of information from multiple sources while processing information during speech perception. Information processing in this model is much like that in the IA, as it includes both excitatory and inhibitory interactions of many smaller processing units which are endlessly updated and interactive due to the activations of other units to which it is connected (McClelland and Elman 1986: 2).

The model is divided into two parts, where the first part – TRACE I – deals with short segments of real speech, and proposes a mechanism for working with the cues to identify phonemes that differ as a function of context (McClelland and Elman 1986: 1). TRACE II, on the other hand, accounts primarily for lexical influences on phoneme perception, including any online processing (McClelland and Elman 1986: 14). The TRACE model consists principally of many units which are organised into three levels: the auditory feature, the phoneme level, and the word level (McClelland and Elman 1986: 8). Each unit represents a hypothesis about the perceptual object defined relative to the beginning of the utterance or the first phoneme heard (McClelland and Elman 1986: 8).

The model was constructed within a framework that allows the exploitation of simultaneous and often mutual restrictions of speech perception (McClelland and Elman 1986: 2). For example, in the sentence *I put my wallet in my bag*, when considering the word *bag*, the first acoustic cue is the phoneme /b/. This phoneme /b/, coupled with the other phonemes making up the word *bag*, is an excitatory measure for the comprehension of the word, yet also restricts phonemes unrelated to both the /b/ and subsequent phonemes. The finishing cues when identifying the word are then the semantic and syntactic context in which the word *bag* is found, simultaneously restricting other possible words that would not be found in this context, such as *bark*. Therefore, within speech perception, there are simultaneous excitatory and inhibitory interactions of auditory features, phonemes, and word levels (McClelland and Elman 1986: 2).

Essentially, the human mind is said to be constantly hypothesising on all three of these levels about which word has just been spoken in order to establish the word heard. Therefore, upon hearing a word, the mind works with the acoustic features, phonemic information as well as the current semantic information to map what has been heard onto a word in one's mental lexicon (stored in the memory; McClelland and Elman 1986: 33). TRACE is therefore also considered to be an "interactive model", allowing for the higher, more abstract levels of knowledge (and memory) to interact with lower levels of processing such as working with auditory features, phonemes, and word levels (McClelland and Elman 1986: 1).

Although interactive, TRACE assumes that lexical access takes place in stages, with possible words being constantly assessed alongside the unfolding speech stream (Canseco-Gonzalez et al. 2010: 677). This model is also dependent on the initial phonemes of a word to trigger a set of words as options relative to the phonetic pattern. An example would be, upon hearing the sound /b/ in the word *bag*, the individual creates a mental set of possible words activated by this sound, such as *bat* and *ball* (Canseco-Gonzalez et al. 2010: 677). The set is constantly updated upon receiving new incoming spoken material (Canseco-Gonzalez et al. 2010: 677). Canseco-

Gonzalez et al. (2010: 677) explain that as one hears more of a word spoken, the set of options narrows until there is only one contender left as the recognised word.

3.8 The Bilingual Interactive Activation model

Dijkstra and Van Heuven's (1998) Bilingual Interactive Activation model (BIA), which used the basic framework from the IA, moved the theory of spoken-word recognition into the bilingual sphere. Previously, as recognised in the Input Switch theory, languages were said to be "switched off". However, neuro-imaging methods and cognitive psychology paradigms led to the conception that both of a bilingual's languages are automatically active (in parallel) when initially interacting with words (Basnight-Brown 2014: 12).

The BIA focuses on orthographic representations of given words, and is therefore only suitable for participants' recognition of written words in the activation of languages (Dijkstra and Van Heuven 2002: 175). In simple terms, when a word is presented, features of the individual letters are activated, followed by the activation of letters that are congruent with those particular features (Basnight-Brown 2014: 14). The activated letters will, successively, activate words that share orthography (and those precise letters) in order to recognise and comprehend the word (Basnight-Brown 2014: 14).

The BIA rests on three key assumptions: (i) there are connections between nodes found at different levels and across nodes at each level, (ii) the lexicon is integrated, and this leads to competition between words in both languages, and (iii) language nodes take into account the degree of activation and act as a language filter (see Figure 3; Basnight-Brown 2014: 13).

In terms of the bilingual word-recognition process, it can be asked if lexical contenders from both languages or from a single language only are activated during the process (Dijkstra and Van Heuven 2002: 176). In the empirical literature, these two viewpoints of bilingual processing have been termed respectively as the "language non-selective access hypothesis" (both languages are activated simultaneously) vs. the "language selective access hypothesis" (only one language activated at a time; Dijkstra and Van Heuven 2002: 176). These mechanisms of the BIA are said to work in a non-selective process (by means of the bottom-up input received) as well as a language-specific process (top-down language selection). Both processes influence word recognition, with both languages active simultaneously (Basnight-Brown 2014: 14).

A second query in bilingual word recognition would be if the lexical representations of the two languages are found together in a single, combined lexicon (irrespective of which language the words belong to) or in separate, different lexicons for each language (Dijkstra and Van Heuven 2002: 176). There are two contrasting theoretical perspectives on this, namely the language-selective access of independent lexicons and the language non-selective access of an integrated lexicon (Dijkstra and Van Heuven 2002: 176). Having two separate lexical systems results in competition effects that are restricted to contenders of one language only (language-selective access of independent lexicons; Dijkstra and Van Heuven 2002: 176). In contrast, in an integrated lexical system, competition or selection effects can occur between lexical contenders of both languages (non-selective integrated lexicon), which has been seen in multiple parallel activation studies (Dijkstra and Van Heuven 2002: 176).

Focusing on the word level of the BIA, all words inhibit each other whilst being activated, regardless of the language to which they belong (Dijkstra and Van Heuven 2002: 177). Dijkstra and Van Heuven (2002: 177) explain that activated word nodes from the same language send activation on to the matching language node, but also send inhibitory feedback to all word nodes in the other language. Therefore, the language nodes collect activation from words in the language they represent, and inhibit active words of the other language. One could then measure the activation of the lexicon by means of the activity in the language nodes (Dijkstra and Van Heuven 2002: 177).

Grainger and Dijkstra (1996) explain monolingual visual word recognition as a retrieval of orthographic representations stored in the mental lexicon matching the input letter string. Within monolingual word recognition, word contenders become activated that are similar to the input string seen in letters (Andrews 1989; Coltheart, Davelaar, Jonasson and Besner 1977; Grainger and Segui 1990). However, in adaption of the monolingual stance, the BIA defends the position that lexical access is generally and naturally non-selective, and the bilingual mental lexicon is essentially combined across languages (Dijkstra and Van Heuven 2002: 176).

Much like the monolingual version initially, as a string of letters is presented to the individual, the BIA explains the visual input as particular features at each letter position that contain these features while simultaneously inhibiting letters for which the features are absent (Dijkstra and Van Heuven 2002: 177). Next, activated letters will trigger words present in both languages, with the activated letters in their relative positions. At the same time, words that do not match this letter combination are inhibited (Dijkstra and Van Heuven 2002: 177). Activated word nodes found in the same language continue activation by sending excitatory messages to the corresponding language node (Dijkstra and Van Heuven 2002: 177). Alongside this, the language nodes activated at that moment send inhibitory information to all word nodes in the other language (Dijkstra and Van Heuven 2002: 177–178).

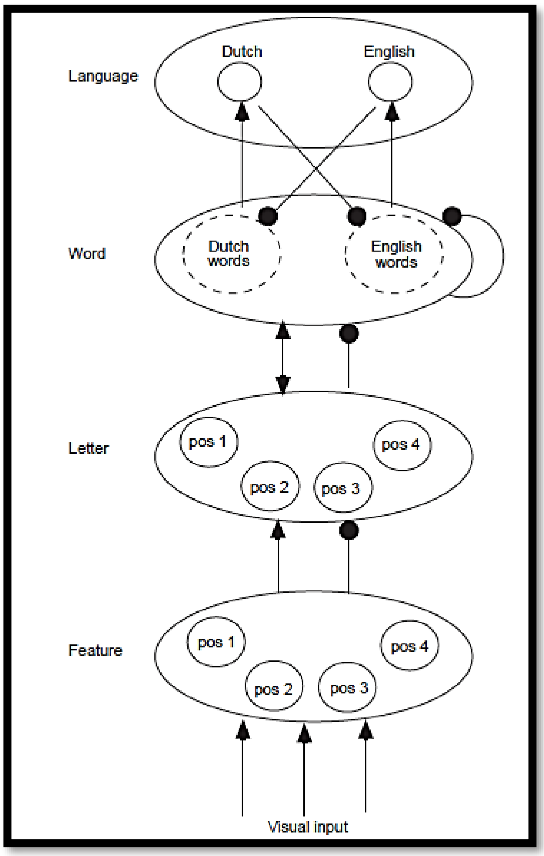


Figure 4. Dijkstra and Van Heuven's (1998) Bilingual Interactive Activation model representing the orthographic word-recognition mechanisms in Dutch-English bilinguals. The arrows indicate excitatory connections, and black-filled circles indicate inhibitory connections. The smaller circles found on each level of language processing represent the language nodes.

3.9 The Bilingual Interactive Activation Model Plus

Dijkstra and Van Heuven (2002: 175) extended the BIA based on empirical findings, adding phonological and semantic lexical representations to the previously obtained orthographic ones, and assigning a different function to the language nodes. Additionally, the newly extended model, termed the "Bilingual Interactive Activation Model Plus" (BIA+), distinguishes between the effects of the non-linguistic context (which could include instruction and stimulus list arrangement) and the linguistic context (semantic and syntactic sentence context). This makes the BIA+ applicable to more and different tasks and modalities (Dijkstra and Van Heuven 2002: 175).

Dijkstra and Van Heuven (2002: 181) highlight a list of aspects of the BIA that are not accounted for, seeing as there are no phonological or semantic demonstrations in the model. These aspects include:

- the representation of between-language homographs (cognates) as not specified well enough;
- the ambiguity of functional aspects with respect to the language nodes;
- the narrow explanation of how non-linguistic and linguistic contexts influence bilingual word recognition;
- the lack of comprehensive descriptions on how participants are to perform lexical-decision tasks, and
- the lack of specification of the relationship between word identification and task demands.

The BIA+ creates a distinction between a word identification system and a decision system, which considers a greater and more varied set of empirical findings (Dijkstra and Van Heuven 2002: 176). The linguistic information received from the input signal or the sentence context can have an effect on the word identification system, but the non-linguistic context information (one's possible expectations and approaches) has more of an influence on the parameter settings in the decision system (Dijkstra and Van Heuven 2002: 176). The BIA+ therefore adopts interactivity within the word identification system and the higher-order system (like syntactic analysis, for example) – see Figure 5. However, the model also proposes that the lexical activation levels within the word identification system itself are not affected by the task/decision system and, therefore, not by sources of non-linguistic information either (Dijkstra and Van Heuven 2002: 176). For example, when working with the English word *sang*, lexicon activation is merely within the letter, phoneme, and word feature similarities (of the word identification system) but non-linguistic information, such as *sang* being the past tense of *sing*, is not activated simultaneously. Rather, such non-linguistic information of the decision system is interactive with the word identification system in creating an interpretation of the correct word being referred to.

A main assumption of the BIA+ seems to be non-selectivity, but whether bilingual language processing is truly non-selective during sentence processing is unclear as much of the data are mixed (Basnight-Brown 2014: 14). However, this model does not deliver much clarification for what happens during L2 development and learning (for example, when new lexical entries other than the L1 are established, and how new entries change over time with the acquisition of a new language; Basnight-Brown 2014: 14). Developing from the BIA+, Shook and Marian's (2013) BLINCS model clarifies the intricacy of bilingual language cognition, stepping into the explanation of parallel activation.

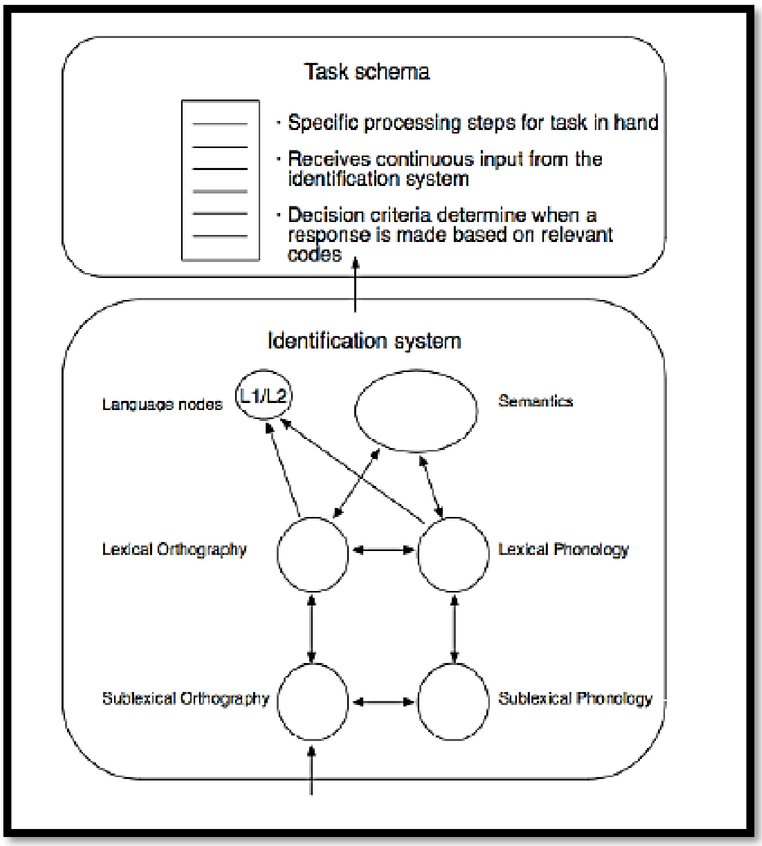


Figure 5. Dijkstra and Van Heuven's (2002) Bilingual Interactive Activation Model Plus (BIA+). The arrows indicate activation flows between representational pools, while inhibitory connections within nodes are omitted. Non-linguistic context is explained only to affect the task schema level.

3.10 The BLINCS model

Shook and Marian's (2013: 19) BLINCS is described as a highly interactive network of dynamic, self-organising systems created to capture the natural phenomena associated with the processing of spoken language in bilinguals.

BLINCS is one of an interconnected network of self-organised maps (SOMs; Shook and Marian 2013: 306). Kohonen (1995) defines SOMs as a type of unsupervised learning algorithm where, upon receiving information, the input maps onto the minimum Euclidean distance from the input (the node of the best match). Then, the value of the selected node is altered to become more like the input (Shook and Marian 2013: 306). Within this structure, nodes nearby are also restructured (to a lesser extent), with the result that the space around the selected node becomes more consistent (Shook and Marian 2013: 306). This allows for the same input, when presented again to a bilingual, to settle upon the same node (Shook and Marian 2013: 306). In addition, the reworking of the nearby nodes results in similar inputs (e.g., words) mapping together in the same SOM space (Shook and Marian 2013: 306).

BLINCS also encompasses numerous interconnected levels of representations (phonological, phono-lexical, ortho-lexical, and semantic), with each level described as independently constructed using the SOM algorithm (Shook and Marian 2013: 306). Unlike previous models, BLINCS allows the influence of visual information on language processes though networks to both the phonological and semantic levels (Shook and Marian 2013: 306). BLINCS, being an interactive model of processing, allows the various levels within the system to interact in a bi-directional manner (Shook and Marian 2013: 306).

Shook and Marian (2013: 306) explain that this model works within and between levels. Within the levels, there is communication (and competition) between languages as a result of language-specific and language-shared representations existing in the same system space. This is due to lateral links between translation equivalents and proximity on the SOM (i.e. items that map together are simultaneously active but one will eventually inhibit all the others; Shook and Marian 2013: 306). Additionally, there are bidirectional, excitatory connections between the levels, where more connections between items that activate together are strengthened through self-updating algorithms (Shook and Marian 2013: 306). Thus, when a lexeme and its semantic representation are accessible to the model simultaneously (during model training), their weighted construction is reinforced. As Shook and Marian (2013: 306) have already noted, this extensive degree of interconnectivity found both between and within levels of processing creates a dynamic and highly interactive language system of word recognition.

An example of BLINCS in practice can be seen in Spanish and English phoneme structures. The BLINCS structure assumes a shared phonological system, with no clear allocation or distinguishing of Spanish and English phonemes (Shook and Marian 2013: 319). Research results, such as parallel activation of bilinguals' languages within VWP spoken-word recognition tasks, are suggestive of shared phonological representations which can then be explained by BLINCS (Roelofs 2003; Roelofs and Verhoef 2006). However, the structure of this type of phonological level can still create language-specific activation (Shook and Marian 2013: 319). When faced with the phonemes /x/ and /ɣ/, which are phonemes only present in Spanish (and not in English), Spanish words will be activated at the phono-lexical level more so than any English words (Shook and Marian 2013: 319–320). Additionally, as these two phonemes map closely in phonological space and can activate one another, there is reinforcement of a predisposition in favour of Spanish word activation. This accounts for times when two languages have distinct and non-overlapping phonological features, as "pockets" of language specificity might show more separation at the phonological level (Shook and Marian 2013: 320).

With regard to the lexical level, BLINCS assumes that a bilingual's two languages are separated immediately from one another , but still exist together and are integrated in the larger SOMs network space (Shook and Marian 2013: 320). The model remains interactive as it does not separate the languages with such strict division (Shook and Marian 2013: 320). Whilst there are distinct language "pockets" within the map, the cross-language items that intersect in phonological form (e.g., cognates and false cognates) tend to be positioned at the boundaries between language sections (meaning that these language "pockets" are not completely separate to one another), which can explain the facilitative advantages observed for cognates (Shook and Marian 2013: 320). Thus, cognates may be less vulnerable to diminishing effects of linguistic context (e.g., suppression of an unused language) by advantage of facilitation from nearby items in their own language, as well as cross-language items (Shook and Marian 2013: 320).

Similarly, at the ortho-lexical level, there is a separate but integrated structure through a higher amount of overlap than is seen in the phono-lexical SOM (Shook and Marian 2013: 320). The structure of the ortho-lexical level is influenced by the extent of difference between the two languages' orthographies, allowing for those languages with more similar orthographies to have a larger integration of ortho-lexical forms (Shook and Marian 2013: 320).

On the semantic level, as in the BIA+ (Dijkstra and Van Heuven 2002), BLINCS assumes a single semantic level that includes a common set of abstract depictions across languages. Shared meanings in semantic structures among translation equivalents are supported by empirical research suggesting that semantic depictions are shared across languages (Kroll and De Groot 1997; Salamoura and Williams 2007; Schoonbaert, Hartsuiker and Pickering 2007). However, languages can carry cultural information which may influence conceptual feature representations, and allow for semantic contexts that only relate to one or the other language (Shook and Marian 2013: 320).

Furthermore, BLINCS models language activation in bilingual speech comprehension as this activation plays out over time. Language activation simulations in this model show that it is skilled in explained, and making predictions concerning:

(i) the stimulation of initial competitors both within and between languages,
(ii) rhyme contestants both within and between languages,
(iii) the influence of ortho-lexical information on phono-lexical comprehension,
(iv) the interaction between semantic and phono-lexical depictions, and
(v) increased or faster activation for cognates and false-cognates.

(Shook and Marian 2013: 320).

Additionally, and fundamentally, BLINCS allows for material from the visual field to impact the word-recognition processes (Shook and Marian 2013: 320).

A modification of BLINCS in future applications is considered by Shook and Marian (2013) so that the model may be improved for greater vocabularies, different couples of spoken languages, or structural details (such as VOT), merely by altering the quantity or method of the input. Overall, models like BLINCS could hypothetically encompass subtle deviations in activation patterns due to individual differences in bilingual experience, and thus have the potential to improve our conception of both the construction and function of the bilingual language mechanisms and system (Shook and Marian 2013: 321).

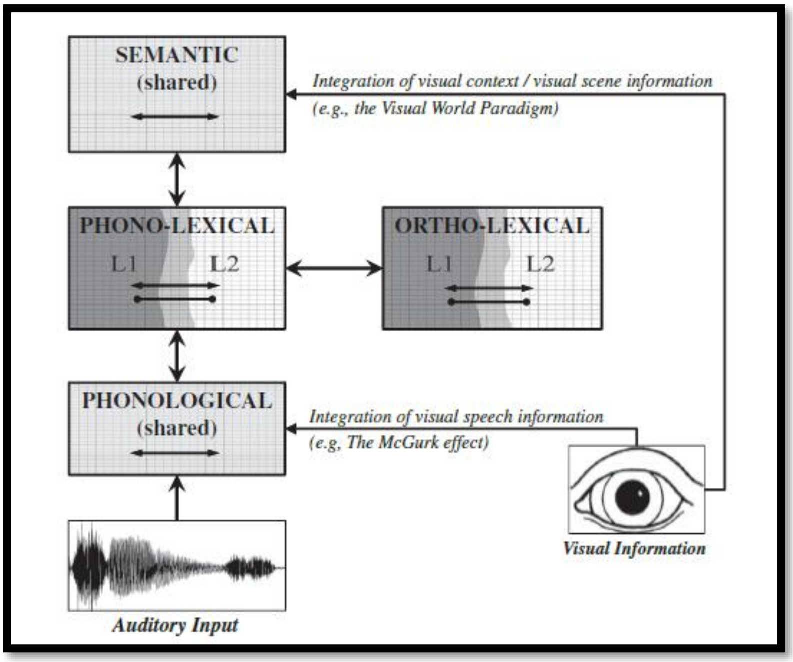


Figure 6. Shook and Marian's (2013) BLINCS model

3.11 Summary of theory relevant to the current research

The phenomenon of parallel activation was first shown to depend on assumptions such as the eye-mind assumption and the Language Mode hypothesis. The VWP was also expanded on, helping to grasp the theory behind perceptual-cognition link, when working with auditory input and testing eye-movements. After these fundamental phenomena underlying parallel activation were explained, cognitive processing mechanisms in the monolingual's and bilingual's language comprehension and interactions were expanded on (the Input Switch Theory, IA model TRACE model, the BIA and BIA+). Although the models mentioned before BLINCS offered some explanation into bilinguals' parallel activation and were useful in the development of understanding language cogntion, they do not give an overall understanding of bilingual cognition and parallel activation. BLINCS is used in the current study to interpret the phenomenon of bilingual parallel activation , yet is dependent on the VWP (Huettig et al. 2011) and the eye-mind assumption (Just and Carpenter 1980),. Therefore, BLINCS is used in interpreting the bilinguals' mechanisms underlying spoken-word recognition in the VWP. Alongside these, the Language Mode hypothesis (Grosjean 2001) is fundamental in explaining a new, proposed theory, explaining how the activation of bilinguals' languages can exist on a continuum, from single language activation to the activation of both languages. Although BLINCS is useful to understand bilinguals' parallel activation and general cognition, this study is lead to a more elaborative theory that considers more variables that influence cogntion. Variables that influence the extent to which an irrelevant language (the L1 in the current study) is activated are further explained with reference to the continuum proposed by this study, using the Grosjean's (2001) Language Mode hypothesis as a foundational theory.

Chapter 4: Methodology

4.1 Introduction

The present study is a quantitative one, guided by previous studies using word-recognition VWP tasks to investigate parallel activation of bilinguals' languages through phonological overlap (such as Blumenfeld and Marian 2007; Canseco-Gonzalez et al. 2010; Marian and Spivey 2003a, 2003b; Shook and Marian 2012, 2017; Spivey and Marian 1999). Firstly, this chapter outlines the participants who qualified for the present study (section 4.2), as well as the ethical and recruitment processes involved in their participation (section 4.3). The instruments used for the study are then discussed, from the eye-tracker (EyeLink® 1000 Plus) and its physical setup (subsection 4.4.1) to the standardised auditory and visual stimuli utilised (subsections 4.4.2 and 4.4.3, respectively). With the design and procedure of the eye-tracking experiment explained in detail, the steps involved in the data analysis are then outlined (subsection 4.5.2).

4.2 Participants

Sixty-two participants took part in this study: 31 early bilinguals (mean age: 20.6 years, SD: 1.5 years; 20 females; English mean AoA: 3.7 years; English AoA range: 1–9 years, with an SD of AoA: 2,74) and 31 English monolingual participants forming the control group (mean age: 22.2 years, SD: 3.6 years; 20 females). All participants were either current or former university students. Both languages are present to a great degree in Stellenbosch, even though this may vary between individuals. A number of these participants were initially recruited by word-of-mouth, but were also invited by means of an Instagram post on the "Multilingualism Cognition Lab" (MultiCog) account, and a post on the Department of General Linguistics' Facebook account (see Appendix A for the invitation to participate).

In order to control for language setting, these posts were the only mention of a bilingual background, and participants were only spoken to from this point onwards in English. Upon initial contact from the prospective participant, s/he was screened over the phone, via messages (telephonically), to assess his/her fluency in both languages, much like Canseco-Gonzalez et al.'s (2010: 684) study. Questions asked telephonically included: "what is your favourite colour/ food?", "what languages can you speak and when did you learn to speak them?" and "how old are you now?". These were asked to establish if the participant met the required language group specifications (ie. were they speaking Afrikaans from birth?) and if the prospective participant generally had a good command of the English language. The follow-up LexTALE proficiency test (Lemhöfer and Broersma 2012) indicated a high English proficiency in these bilinguals, with a mean English proficiency score of 84.56%. This screening conversation was held by a native South African English speaker who only spoke English to the prospective participants. Participants were asked the critical question, “When did you first learn any languages and what were these languages?” in addition to a set of 10 filler questions such as, “How old are you now?”, “What is your favourite food?”, and “What colour do you wear most often?”. The purpose of these filler questions was to distract the participants from the language questions, and to maintain a monolingual environment. The participants were informed that the test was in English, and that they would need to be proficient in English in order to complete it.

4.3 Ethical considerations

Each participant filled out a consent form (see Appendix B) before beginning the eye-tracking experiment. Participants were informed that they were able to leave the experiment at any point, without any repercussions for them. This point was made clear on both the consent form as well as verbally before beginning the experiment. It is important to mention, though, that the eye-tracking experiment itself is non-invasive and non-harmful in any way. Participants were asked simply to listen to the audio while keeping their eyes on the screen, and to avoid moving their heads too much. If at any point the participant became uncomfortable with this process, s/he was aware of being able to exit the experiment immediately.

As it is a frequently-asked question with these instruments, it is important to note here that the eye-tracker’s camera can only record co-ordinated points on the screen. It only receives data of the co-ordinated points on which an eye (or the various participants’ eyes) focuses when looking at the screen. There is no way to identify any participant, or even the appearance of their eyes.

In terms of keeping confidential any personal data collected from each participant, the researcher is the only person with access to the participants’ raw data. This data saved on the researcher’s personal computer to which only she has knowledge of the login details. Each participant also received a code in order to maintain their anonymity throughout the experiment, as well as during and after the data analysis. This coded number allows for complete de-identification of the participant as, after being coded, not even the researcher can de-code or re-identify the participant. The coded number is also used throughout all parts of the study (i.e. the eye-tracking exercise, the LexTALE fluency exercise (see Appendix D) and the Language History

Questionnaire (LHQ; see Appendix E) – see section 4.4 below for all instruments used in the study. Alongside this, the LHQ's participant background questions are designed to be neutral, allowing the participant to share non-discriminatory information. The responses provided to the researcher give a general overview of each participant's linguistic background.

4.4 Materials and apparatus

4.4.1 EyeLink® 1000 Plus

The main instrument used for this study was the EyeLink® 1000 Plus. In addition to this instrument, the SR Research Experiment Builder and Data Viewer were used to create the experiment and collect the data.

Figure 7 below displays the physical setup of the EyeLink® 1000 Plus. As can be seen in this figure, the eye-tracker's head-mount (on the left) is fixed to the table, as per installation guidelines. The eye-tracking camera and infrared light is placed below the monitor, angled upwards towards the stabilised but adjustable head-mount. In terms of physical dimensions, the camera and monitor are positioned 65cm and 82cm away from the head-mount, respectively. In adjusting the height of the eye-tracker for each participant, the entire table can be adjusted higher or lower electronically, to maintain consistency of the eye-tracker's placement throughout the study. The screen resolution of the monitor was 1920×1080 pixels.

Figure 7. The physical setup of the EyeLink® 1000 Plus eye-tracker in Stellenbosch University's MutliCog Laboratory

When using the EyeLink® 1000 Plus in testing a participant, one needs to be mindful of calibration and accuracy measures. In order to determine the accuracy of the subject's gaze (ie. the average difference between the true and the measured/ recorded gaze position) the EyeLink® 1000 Plus works on a per-subject basis, assessed per individual participant (Conklin, Pellicer-Sánchez and Carrol 2018: 23). To do this on the EyeLink® 1000 Plus, one would initially calibrate (test the current eye-position of the participant with dots that move all over the screen while the participant's eyes follow the dots) and then validate such calibration (test again with another dot-moving screen). In order to gain an accurate gaze measure, initially and throughout the eye-tracking procedure/ test, the degree of error in calibration and validation (the average gaze error) needs to be within 0.5° - 1.0° (Conklin, Pellicer-Sánchez and Carrol 2018: 24). The SR Research Experiment Builder automatically embeds this accuracy measure upon starting the test, and will only proceed to the test when the participant has gained a good or acceptable accuracy degree (if not, the participant continues to calibrate until their average gaze error degree is within acceptable degrees).

The SR Research Experiment Builder was used to build this study's experiment setup with 4 calibrations and validations (upon the start of the experiment and thereafter, every 15 trials). This study's experiment includes a second monitoring screen as well, in order to view a live feed (and visually measure if accuracy has dropped at any point), which allows for spontaneous re-calibration by the experimenter. Alongside this, the drift correction (deviations from the calibrated gaze position) is automatically corrected during the experiment on an EyeLink® 1000 Plus.

4.4.2 Auditory stimuli

The auditory stimuli were recorded in a soundproof room and were produced by a female, native, monolingual South African English speaker, raised by parents who were also L1 English speakers. The woman recorded for the auditory stimuli had lived in South Africa her entire life (23 years).

The Audacity® application (version 2.2.2, Audacity Team 2019) was used to record and edit the auditory stimuli. This application allowed for recordings to be cut, spoken-words to be amplified, and background noise to be reduced in order to create a similar sounding and integrated set of recordings.

The initial recording, *Click on the*, was cut to 1173ms, and was recorded alone. This recording was placed at the start of every stimulus recording of target words. Every trial included this phrase before each object was mentioned in order to allow the participant to familiarise him-/herself with the images on the screen before selecting an object. Critical targets of the critical trials (trials in which an English object needed be identified as well as an object that, when translated into Afrikaans, had an initial identical phonological overlap) were recorded in a randomised order alongside filler target words of the filler trials (trials that used completely unrelated images with initial phonological overlap). Each target word (both critical targets and filler targets) was recorded, individually and alone. The words of the target objects have an onset time of 1373ms in every recording, exactly 20ms after *Click on the* ends. This process created a normalised and unified set of auditory stimuli, using Shook and Marian's (2012) study as guidance in this regard.

4.4.3 Picture stimuli

There were 240 black-and-white pictures used in this study, of which 80 were used in the critical trials and 160 were used in the filler trials. Each trial consisted of four images, with each image displayed in its own corner quadrant on the display screen (see Figure 8 in section 4.5). Each image was only ever used once throughout the entire experiment so as not to be seen more than once by the participant. The pictures used as stimuli were standardised and controlled for salience, as is expanded on below, thereby ensuring that the participants' fixations on these items would be purely as a result of the linguistic activation of Afrikaans.

The black-and-white pictures used in this study were taken from the International Picture-Naming Project (IPNP) which conducted a series of picture-naming studies to create an online database for future cross-linguistic research (Szekely, Jacobsen, D'Amico, Devescovi, Andonova et al. 2004: 247; see Appendix F for the list of studies included in the IPNP). The sources used for the IPNP include: Abbate and La Chappelle (1984a, 1984b), Dunn and Dunn (1981), Kaplan, Goodglass and Weintraub (1983), Oxford Junior Workbooks (1965), and Snodgrass and Vanderwart (1980; see Appendix G for the full list of sources used in the creation of the pictorial dataset for this study).

The primary database of the IPNP, created by the University of California San Diego's Center for Research in Language, contains 795 picture stimuli of which 520 are common objects and were used in this study (Crl.ucsd.edu, 2019). All the pictures are black-and-white line drawings and the 520 common objects have obtained object-naming norms (including indices of name agreement and latency) in seven different languages (American English, German, Mexican Spanish, Italian, Bulgarian, Hungarian, and the variant of Mandarin Chinese spoken in Taiwan). Any target objects that could not be found in this dataset were drawn in black and white, and in the same style as the other stimuli. To ensure appropriate functioning of these added pictures, 20 monolingual English speakers were asked, telephonically (over the phone, via messaging), to label the researcher's 16 added images (nouns). These 20 monolingual English speakers spontaneously labelled the images with an 87.5% accuracy rate in matching the correct target word to the image (see Appendix H for the IPNP examples, and Appendix I for the researcher's added stimuli).

4.4.4 Word frequency measures

In previous research, it has been shown that spoken/written words with higher frequencies can have an effect in triggering parallel activation in bilinguals. This frequency phenomenon was initially documented in monolingual studies such that of Dahan, Magnuson and Tanenhaus (2001). Dahan et al. (2001) found that higher frequency picture names (e.g., *window*) more commonly produced eye fixations than lower frequency picture names (e.g., *windmill*). There are also examples of this phenomenon occurring in the bilingual setting, as seen in Spivey and Marian (1999) and Marian and Spivey (2003a) as their later study aimed to eradicate the asymmetry in their results. Marian and Spivey (2003a) hypothesised that their previous study's asymmetry was influenced by their neglect of word frequencies. Lexical frequency has been shown to have an influence on eye movements in VWP studies (Magnuson, Dixon, Tanenhaus, and Aslin 2007). Magnuson et al. (2007), through time-course measures, also found that word frequency facilitates word recognition in an early and continuous effect. This means that, for the current study, the word frequencies of the English critical targets needed to be comparable to the frequencies of the Afrikaans competitor words in order to function as suitable competitors.

A current, standardised measure of word frequency is the simply-interpreted, logarithmic Zipf-scale, ranging from 1 (most infrequently used) to 7 (most frequently used; Van Heuven, Mandera, Keuleers and Brysbaert 2014). This scale still incorporates the item's frequency per million words (fpmw), as previous logarithmic Zipf-scale frequency scales tend to do, but it is more user-friendly and interpretable (Van Heuven et al. 2014). The SUBTLEX-UK database for British English, consisting of 201.3 million words, informed the Zip Frequency of English critical targets. As there are no standardised frequency databases for Afrikaans, the Zip Frequency of each critical target Afrikaans word was calculated by the researcher, and was informed by the Virtuele Instituut vir Afrikaans (VivA) corpus (Viva-afrikaans.org, 2019)[5]. Therefore, the same formula used to calculate the Zip Frequency for English ([*log10(fpmw)+3* or *log10(fpmw*1000)*]; Van Heuven, Mandera, Keuleers and Brysbaert 2014) was implemented for the Afrikaans competitors within the VivA corpus of 212.8 million words. After consulting the SUBTLEX-UK Zip Frequencies for each English target word and calculating the Zip Frequencies of each Afrikaans competitor word, the auditory stimuli words were comparable across languages (see Table 1).

Table 1: Zip Frequencies of the English critical target items and the Afrikaans competitors (with a mean of 4,11 in the critical targets and 4,28 in the competitor targets)

English Critical Target	Zip Frequency	Afrikaans Competitor	Zip Frequency
Lion	4,45	*laai* ("drawer")	4,64
Bath	4,65	*baba* ("baby")	4,92
Beard	3,98	*besem* ("broom")	3,39
Fairy	4,16	*venster* ("window")	4,7
Skirt	3,81	*skoen* ("shoe")	3,81
Vase	4,27	*wyn* ("wine")	4,91
Spoon	4,29	*spieël* ("mirror")	4,31
Mushroom	3,87	*matroos* ("sailor")	3,53
Slide	4,17	*slang* ("snake")	4,35
Slipper	3,19	*slak* ("snail")	3,32
Button	4,46	*bank* ("sofa")	5,03
Fist	3,68	*vis* ("fish")	4,88
Ladder	4,16	*lekker* ("sweet")	5,4
Sun	5,01	*sak* ("bag")	5,02
Lettuce	3,81	*lem* ("blade")	3,67
Oak	4,23	*ouma* ("grandma")	4.95
Highway	3,79	*haai* ("shark")	4,19
Knight	4,19	*naaimasjien* ("sewing machine")	3,08

[5] The VivA corpus consists of Afrikaans words collected from newspaper articles, blogs, academic writings, and fiction and non-fiction books.

Desert	4,3	*deksel* ("lid")	4,11
Saddle	3,79	*serp* ("scarf")	3,44
	4,113		4,283

4.4.5 Phonological overlap of critical targets

A fundamental factor in the current study is that of phoneme overlap, serving as the trigger for possible parallel activation of South African English and Afrikaans. It is also widely recognised that cross-linguistic effects seem to be sensitive to the degree of phonological overlap (see Marian et al. 2008). Table 2 below was created by the researcher in order to stimulate the simultaneous triggering of Afrikaans and English, and to create consistency in the number of phoneme overlaps (mean number of phonemes as 1.95).

Table 2: Critical trials phoneme overlap

English Critical Target	Afrikaans Competitor	Number of Phonemes Overlapping	Phoneme Overlap
Lion	*laai* ("drawer")	2	/lʌɪ/
bath	*baba* ("baby")	2	/ba:/
Beard	*besem* ("broom")	2	/bɪə/
Fairy	*venster* ("window")	2	/fɛ/
skirt	*skoen* ("shoe")	2	/sk/
Vase	*wyn* ("wine")	2	/veɪ/
Spoon	*spieël* ("mirror")	2	/sp/
Mushroom	*matroos* ("sailor")	2	/mʌ/
Slide	*slang* ("snake")	2	/sl/
Slipper	*slak* ("snail")	2	/sl/
Button	*bank* ("sofa")	2	/bʌ/
Fist	*vis* ("fish")	3	/ fəs/
Ladder	*lekker* ("sweet")	2	/læ/
Sun	*sak* ("bag")	2	/sʌ/
Lettuce	*lem* ("blade')	2	/lɛ/
Oak	*ouma* ("grandma")	1	/əʊ/
Highway	*haai* ("shark")	2	/hʌɪ/
Knight	*naaimasjien* ("sewing machine")	2	/nʌɪ/
Desert	*deksel* ("lid")	2	/dɛ/
Saddle	*serp* ("scarf")	2	/sa/
	Mean Overlapping Phonemes	**1.95**	

4.4.6 Language background measures

4.4.6.1 LexTALE proficiency test

The LexTALE fluency test – Lemhöfer and Broersma's (2012: 340) established, standardised, useful, and valid proficiency measure (see Appendix D) – was used to establish the English proficiency of participants across groups. Specifically created for medium- to highly-proficient English-L2 speakers, this was the ideal fluency measure for the bilinguals for the current study. The test was also used in the English monolingual group in order to compare the groups' proficiencies at a later stage. This measure is a quick lexical-decision task taking roughly five to 10 minutes. In this task, which takes place on a laptop, the participants indicate whether they recognise the words on the screen as existing English words or as non-existent English words by clicking on the "Yes" or "No" icons, respectively.

4.4.6.2 Language history questionnaire

Another language background measure is Li, Sepanski and Zhao's (2006) online language history questionnaire (LHQ; see Appendix E). Li et al. (2006) developed this measurement tool by combining the most commonly asked questions from 41 published questionnaires on language backgrounds for participants, forming a general L2-background questionnaire to be utilised for research. This measure is useful to define what languages the participant speaks, which of these languages are their native language(s), the participant's age of acquisition of these languages, their frequency of language use, as well as the age and gender of each participant. Although developed for L2 speakers in general, the questionnaire has been used across language groups for the purpose of this study, as it is relevant to the language backgrounds of the monolingual English speakers. All of this information provided by each participant, as well as the LexTALE results, are stored anonymously as participant codes (as mentioned in section 4.3).

4.5 Procedure

The experiment comprised of multiple components, such as the main eye-tracking task, the LexTALE proficiency test, and the LHQ for obtaining information on each participant's language background. The step-by-step procedure of the running of the whole experiment (with all of its components) is explained in detail subsection 4.5.2. However, the main eye-tracking task and its design is first expanded upon.

4.5.1 Experimental design

The current study's design consisted of 20 critical trials and 40 filler trials. Stimulus displays in the critical trials consisted of four objects: (i) the English critical target object; (ii) the Afrikaans competitor object, of which the Afrikaans label overlapped phonetically with the English critical target object; (iii) a distractor object adjacent to the competitor object, and (iv) a second distractor object. Both the third and fourth distractor objects had no phonetic overlap with the target object, Afrikaans competitor object, or each other. In the filler trials, an English target object was accompanied by three distractor objects, also with no phonetic similarities to the target object or one another. The filler trials were included in order to distract participants from any similarities or overlap across critical target objects and competitor items, ensuring that the aim of the study remained obscured.[6]

To begin each trial, participants were first presented with a cross in the centre of the screen display, and were instructed to fixate on this cross. This was then followed by a 1500ms interval before the stimulus pictures appeared on the screen, with each picture in its own quadrant. The participants were free to scan the objects for 500ms before the auditory stimulus began (see Figure 8).

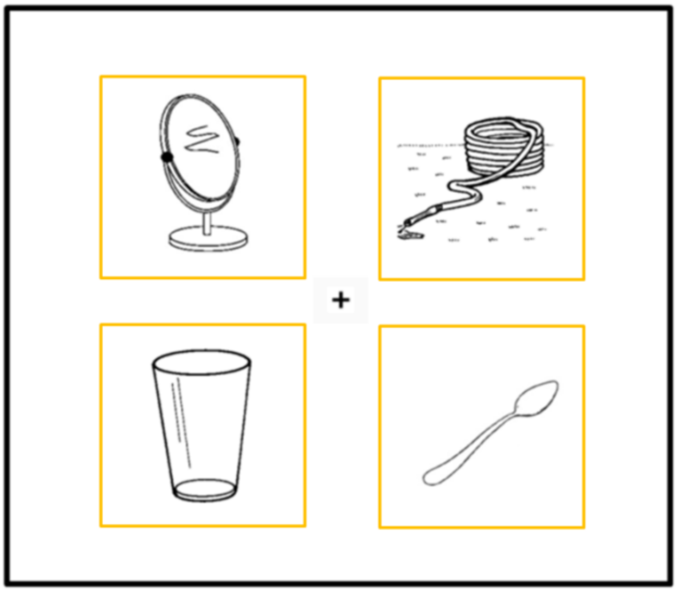


Figure 8. The display of the eye-tracking experiment. The orange selection boxes capture the location space for eye fixations falling into these areas, but the participant does not see these boxes.

[6] In the controlling of VOT for auditory stimuli, unvoiced stops (such as [p], [t], and [k]) in Afrikaans were avoided as stimuli, as they tend to be shorter in the English VOT. However, the voiced [b], [d], and [g] sounds are found to be of the same English VOT (Niesler, Louw and Roux 2005).

The location of the English critical target, the Afrikaans competitor, and the phonologically-unrelated distractor items were counterbalanced across trials. Basically, the images rotated in the 4 positions that sometimes the critical target would be found next the target object, other times this would be positioned diagonally. Therefore, all 4 positions were utilised by all types of images, throough their constant rotation. The experimental critical trials were completely randomised within the filler trials. The pictures used in the trials were designed so as not to overlap in categories – such as animals or creatures, objects that can be found in a room of a house, vocations, clothing items – nor form any Afrikaans cognates (for a full list of the matched pictures across trials, see Appendix J).

Careful consideration was made when choosing these objects as possible Afrikaans cognates (words that, when translated into Afrikaans, are the same or similar orthographically, share the same meaning, and/or are often pronounced the same way in English). An example for this study is the English *ball* – "bal" in Afrikaans – where both terms represent the same object and are similarly spelt and pronounced. Eradicating cognates is important as they have been shown to be direct influencers on parallel activation in bilinguals (Dijkstra et al. 1999; Van Hell and Dijkstra 2002). The eradication of category overlap was a decision made by the researcher simply to keep all objects completely semantically random to one another, and so as not to cause the participants to think that the images are linked to one another. The pictures used in this study were also never seen more than once throughout all the trials.

Figure 9 below is a visual diagram of the procedure of a trial including the duration of the display screens. In this example, the critical target was *spoon* and the competitor object was the image of the mirror (the Afrikaans *spieël*). The participant first sees a fixation cross in the centre of the screen; once their eyes are looking at this cross, the trial begins. Participants first see a blank screen and next the picture stimuli are displayed. After familiarising participants with the display images for 500ms, the audio clip begins to play (*Click on the*…). For each trial, 1673ms after seeing the images, the target word audio begins.

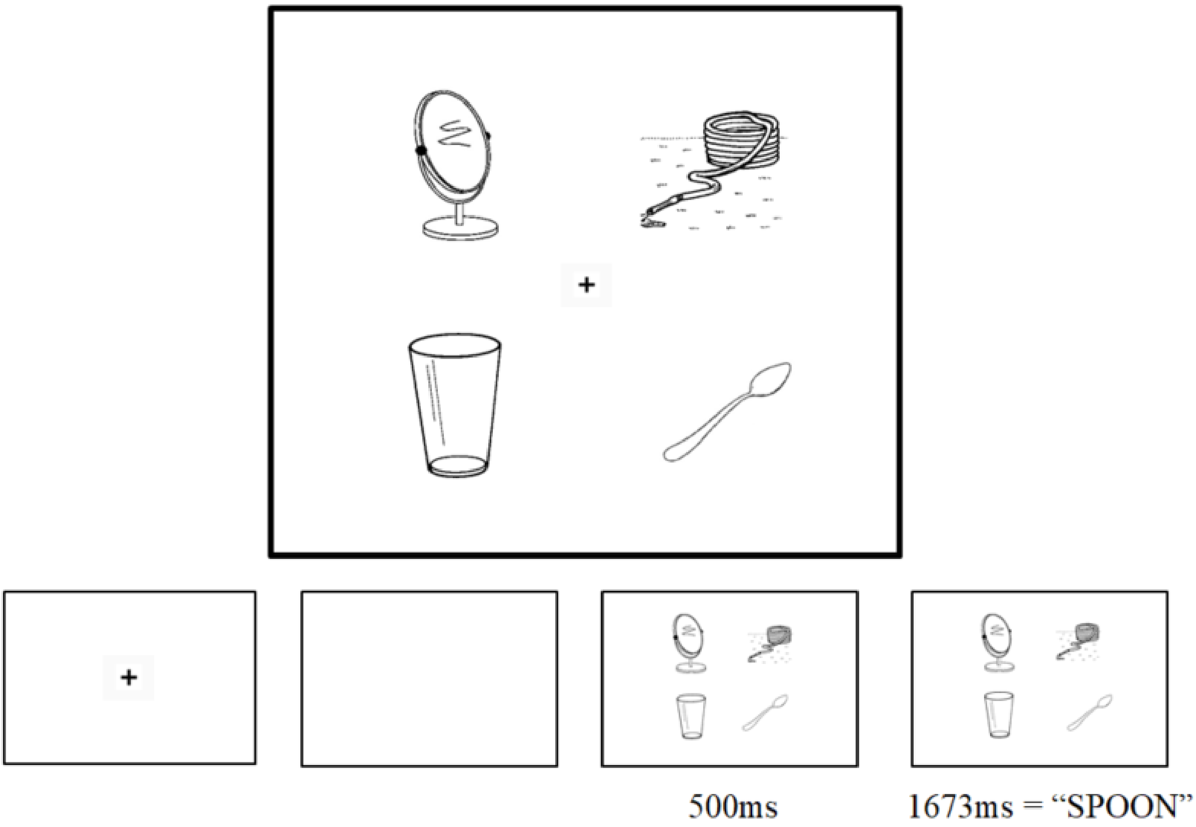


Figure 9. The procedure of a trial including the duration of the display screens

The raw data recorded for the experiment relies on the overall fixation counts, comparing the English monolinguals' proportion of fixations to the ROI across each experiment, to the Afrikaans bilinguals' fixation proportions. This recording of number and proportion of fixations is regularly used in VWP experiments, or any image-based eye-tracking experiments (Conklin, Pellicer-Sánchez and Carrol 2018: 67-69). Subjects will also be compared on the basis of overall reaction time, defined as the time taken to select the an object (after mention of the target word, audibly), as to test that both English monolinguals and Afrikaans bilinguals understand the instructions of the task, are paying attention throughout the experiment, and answer consistently with the correct English target object mentioned.

4.5.2 A step-by-step account of the full experiment

Upon arrival, each participant would first fill out a consent form (see Appendix B) and were informed that they may leave at any point, as well as being allowed to take breaks. The participant was seated and made sure to be comfortable in front of the eye-tracker (the height is adjustable, and the participant could move the chair).

Once given instructions (see Appendix C) on how to use the mouse to click on an object, the participant would read through the written instructions and put the headphones on. Once the participant was comfortable, s/he began the experiment and completed his/her selections of the target objects upon hearing each auditory input instance of *Click on the* [target object of the current slide]. At the start of each of the four sections, consisting of 15 trials each (which included 10 auditory sentences and object selections), the participant was asked if they were still comfortable and whether they needed a comfort break.

Upon completion of the eye-tracking exercise, the participant then completed the LexTALE test on the laptop placed next to the eye-tracker. The participants were informed that they could work at their own pace. Lastly, the participant completed the LHQ on the same laptop. The participant was again informed that they could work at their own pace and could stop at any point as well as leave out any questions they did not feel relevant to their language usage. An example of the latter was the section on language mixing for a monolingual participant; many participants asked if they could leave this section out as they would never mix languages. The participants were then informed that they may take a copy of their consent form (an information sheet) if they wished to do so.

In order to further control for language mode, the eye-tracker was set up in a single, soundproofed room, and the researcher did not make any reference to multilingualism. The only language used by the researcher, throughout the experiment, was English.

4.5.3 Results predictions

Upon analysing the overall critical target fixations (looks) in comparison to competitor target fixations as well as the adjacent distractor target fixations, it is hypothesised that the competitor target (upon the onset of the target item audio) will be briefly considered by bilinguals as a possible target object. Additionally, it is hypothesised that there will be an increased proportion of fixations made by bilinguals, in comparison with their monolingual counterparts, to the competitor objects than to the target objects. If this hypothesis is correct, parallel activation of both English and Afrikaans can be said to take place in the bilinguals, as these bilinguals recognise the phonetic similarity in the Afrikaans competitor and fixate on it in its activation.

4.6 Methodological Challenges

The methodological challenges of this experiment were, mainly, a lack of data on Afrikaans lexical frequency and an insufficient number of black-and-white line drawn pictures for common nouns (there were not enough common noun pictures in the IPNP to find a match on the basis of phonetic structure across Afrikaans and English).

Firstly, a lack of Afrikaans lexical frequency data was faced as, currently, there is no standardised frequency record for this language. However, there was a large database of Afrikaans words, when consulting the VivA corpus online (Viva-afrikaans.org, 2019), consisting of 212.8 million Afrikaans words. With some research and understanding of how the Zip Frequency is calculated for other languages ([*log10(fpmw)+3* or *log10(fpmw*1000)*]; Van Heuven, Mandera, Keuleers and Brysbaert 2014), the Afrikaans critical target words used in this study's experiment were individually calculated. Although the execution of calculating each critical target word in Afrikaans was not a lengthy process, the challenge was finding the right, large and credible Afrikaans corpus alongside an accurate frequency calculation for such a dataset.

Secondly, a lack of black-and-white line drawn, simple images proposed another challenge as not only would one need to design / draw more pictures consistent with the IPNP database, but the added images would also need to be standardised. There were 16 new images of black-and-white line drawing designs, which were spontaneously named by 20 monolingual English speakers over the phone, via messaging. These 20 monolingual English speakers were not used in the current experiment but merely to ensure that the images depicted the English noun, both immediately and without confusion. Finding an 87.5% accuracy rate in, spontaneously, naming the correct target word to the image, the images could be used in the experiment (see Appendix H for the IPNP examples, and Appendix I for the researcher's added stimuli).

Chapter 5: Results

5.1 Introduction to presentation and analysis of data

The current data analysis first looks at the accuracy and response time across both groups. This allows for a brief consideration of whether the participants understood the instructions and were paying attention during the experiment.

Next, two main eye-tracking data analyses were conducted, both using a Growth Curve Analysis (GCA). This GCA enables an examination of the change in fixation patterns over time, across the two language groups (Mirman 2014). These two analyses included: (i) comparing the effect of language group on the proportion of looks made to the target object in comparison to the competitor object, and (ii) comparing the effect of language group on the proportion of looks to the competitor object in comparison to the adjacent distractor object of each trial.

These analyses were conducted in order to obtain both a general overview of the bilinguals' fixation patterns in comparison to those of the English monolinguals, alongside a more in-depth comparison of the fixation proportions of each language group to the target object, competitor object, and the adjacent distractor object. An analysis of the first 250ms timeframe (post word-onset) was conducted as a follow-up to the first GCA, comparing the bilinguals to the monolinguals in their proportions of fixations to the competitor vs. the target object.

Lastly, two subject-specific design analyses of, firstly, the bilinguals' English AoA and, secondly, these bilinguals' English proficiency results were performed to test if differences in these variables were influential in exhibiting more fixation proportions to the competitor object. The AoA was retrieved by means of the LHQ, and the proficiency results by means of the LexTALE fluency test (as discussed in subsection 4.3.6).

5.2 Accuracy and response times

During the eye-tracking experiment, the participants were instructed via the auditory stimuli to *Click on the* [target object of the current slide] whilst looking at the screen displaying four different images. The displays of the 20 critical trials contained four objects: (i) the English critical target object; (ii) the Afrikaans competitor object, of which the Afrikaans label overlapped phonetically with the English critical target object; (iii) a distractor object adjacent to the competitor object; and (iv) a second distractor object. In the filler trials, an English target object was accompanied by three distractor objects.

The accuracy of both bilinguals and English monolinguals was exceedingly high, with an overall accuracy of 99.8%. The bilinguals scored 100% accuracy overall, and the English monolinguals scored 99.7%. The reaction time, based on the time taken to decide on and select an object (after mention of the target word audibly), across groups was also similar, with the bilinguals' mean time being 1143ms (SD = 506ms) and that of the English monolinguals 1187ms (*SD* = 385ms). Therefore, with these very high results, it can be deduced that both the monolingual and bilingual groups understood the instructions of the task, were paying attention throughout the experiment, and answered consistently with the correct English target object in a short period of time.

5.3 Implementing the Growth Curve Analysis

The main tool utilised to interpret the eye-tracking data in this research was the GCA, a technique explicitly designed to assess change over time at both group and individual levels (Mirman, Dixon and Magnuson 2008). The assessment of change over time constitutes necessary VWP data, as there are two different variables pertaining to the current study, namely the dependent variable fixations (a categorical variable) and the independent variable of time (a continuous variable; Schlenter 2019).

Mirman et al. (2008) note that the GCA is ideal for VWP language-processing tasks (such as spoken-word recognition tasks) as it contributes significantly to our understanding of the time-course in which VWP language processing takes place. The statistical analysis of the GCA evaluates changes in proportion fixations over time as well as providing a grounding for the evaluation of between-participant differences (Mirman et al. 2008). In order to encapsulate the changes seen over time, this multiple regression model makes use of orthogonal time polynomials (Schlenter 2019).

5.4 Across-language eye-tracking analyses

The eye-tracking data was prepared in the R statistical computing environment with Dink and Ferguson's (2015) "eyetrackingR" package (version 0.1.8). All across-language analyses were also conducted in the R statistical computing environment (version 0.1.8), using Bates, Maechler, Bolker and Walker's (2015) "lme4" package. In the follow-up analysis, the fixations were first grouped into 10ms bins (groupings or frames of data every 10ms, beginning as the screen is displayed and ending at 2000ms after the target word was mentioned), and the average fixation proportion to each item (target object, competing object, and adjacent distractor object) at each 10ms bin was recorded. The reason the data is grouped into bins like this, is to make the data easier to work with as each participant's fixation patterns created a massive raw, excel output of data (roughly 4MB each). Furthermore, proportions were log transformed for analysis, in order to remove any possibly skewed data on account of calibration accuracy over the course of the experiment. The critical trials were the only trials analysed. In the follow-up mixed-effects analysis on the 250ms window of the first GCA, the researcher investigated the fixations proportions, per language group, made to the target object in comparison to the critical object.

5.4.1 Growth Curve Analysis

Two GCAs were run in order to compare the bilinguals' and monolinguals' proportions of fixations over time. The timeframe for the GCA was 1255.76ms, beginning with the word-onset time and ending at the mean time at which the participants clicked the mouse to select their answer in each trial. The first GCA focused on the target vs. competitor objects across languages, and the second GCA looked at the competitor vs. adjacent distractor objects across languages (see Figure 10 for an overview of fixation proportions to the critical target objects, competing objects, and adjacent distractor objects by both language groups).

The first GCA was implemented to examine the relationship between language group and object type over the timeframe in which participants first heard the critical stimuli and made their target-object decision with a mouse-click selection. If both Afrikaans and English are triggered in the bilinguals, the critical stimuli would cause an increased fixation proportion made by the bilingual group to the competitor object as opposed to the target object. In comparison, the monolingual group should be relatively unaffected by the critical stimuli if both Afrikaans and English are triggered. Therefore, in comparison to the bilingual group, the monolingual group's fixation proportions should be more towards the target object than the competitor object. The analysis tested the extent to which the triggering of both Afrikaans and English in the bilingual mind produced more fixations to the Afrikaans competitor object in comparison with the target object. In addition, the analysis tested these proportions overall in comparison to the monolingual English group.

The second GCA was then conducted in order to confirm that the fixation proportions made in the first GCA were not as a result of the experiment setup or another factor of the participants across groups. If there is an effect of the triggering of both languages on fixation proportions made to the competitor object, the same effect from distractor objects in the same trials' display screens should not be found. If anything, the distractor object, even when adjacent to the competitor object, should have much lower fixation proportions than the competitor object.

5.4.1.1 Language group fixations to target object vs. critical object

In this GCA, the fixed effects of the language group (monolinguals, bilinguals) and object type (target, competitive) were included. The effect of time on fixations was accounted for by means of orthogonal polynomials (see Mirman 2014). The model included random intercepts for participants and items (see the model's results in Appendix K).

The first effect of the language group indicated that the English monolinguals made more fixations overall, across both object types. The interaction effect between the language group and the object type indicated that the bilinguals made more fixations overall to the competitor object than the monolinguals did. This interaction effect was recognised as significant at each time point, as indicated by the three-way interactions between language group, object type, and time points (the full model output appears in Appendix K).

The data in Table 3 below indicate that the bilingual group made increased proportions of fixations to the competitor target over the target object. In this table, "L1 English" is the English monolinguals' language group, the "object type" is the target object, and "ot1–ot4" are the different time points at which the interactions between the language group and the proportion of fixations to the target object took place. The colon notation (:) represents the interaction between the variables.

Table 3: Language group fixations to target object vs. critical object

Model Term	**Coefficient (Standard Error)**
L1 English	28.63^{***} (1.69)
L1 English:Object Type Target	39.26^{***} (1.68)
L1 English:Object Type Target:ot1	1431.49^{***} (61.58)

L1 English:Object Type Target:ot2	974.65^{***} (42.14)
L1 English:Object Type Target:ot3	396.13^{***} (17.21)
L1 English:Object Type Target:ot4	77.74^{***} (3.38)

$^{***}p < 0.001$

To further explore these looks to the target objects, a follow-up analysis investigated the groups separately at the earliest time window of 250ms. In the monolingual English group, there was no effect of object type on the proportion of fixations (*Est.* = 0.01, *SE* = 0.009, *t* = 1.2, *p* = 0.2). However, the bilingual group showed significantly more fixations to the competitor object than the target object (*Est.* = -0.03, *SE* = 0.01, *t* = -3, *p* = 0.003).

5.4.1.2 Language group fixations to competitor object vs. adjacent distractor object

The second GCA included fixed effects of the language group (monolingual, bilingual) and the object type (competitor, adjacent). The effect of time on fixations was accounted for by means of orthogonal polynomials (see Mirman 2014), and random intercepts were included for participants and items.

The main effect of language group indicated that there were significantly less fixations made overall by the monolinguals than the bilinguals. The interaction effect between language group and object type showed that, compared to the monolinguals' fixation patterns, the bilinguals made an increased proportion offixations, overall, to the competitor object than the adjacent object. This same effect is present at all the different time points (the full model output appears in Appendix L).

The data in Table 4 below indicate that the bilingual group made increased proportions of fixations to the competitor target over the adjacent distractor object. In the table, "L1 English" is the language group of the English monolinguals, "object type" is the competitor object, and "ot1–ot4" are the different time points at which the interactions between the language group and the proportion of fixations to the competitor object took place. Once again, the colon notation (:) represents the interaction between the variables.

Table 4: Language group fixations to competitor object vs. adjacent distractor object

Model Term	**Coefficient (Standard Error)**
L1 English	-8.37^{***}(1.14)

L1 English:Object Type Competitor	-2.38*(1.13)
L1 English:Object Type Competitor:ot1	-87.37*(41.30)
L1 English:Object Type Competitor:ot2	-61.87*(28.26)
L1 English:Object Type Competitor:ot3	-26.91*(11.55)
L1 English:Object Type Competitor:ot4	-6.52**(2.27)

***$p < 0.001$, **$p < 0.01$, *$p < 0.05$.

As can be seen in Figure 10 (and a closer view of the plot in Figure 11), the bilinguals initially showed more fixations to the competitor object (in green), and then begin to fixate more on the target object (blue). The monolinguals, on the other hand, indicated more fixations to the target object (blue) than the competitor object (green) by 200ms and, from that moment on, fixated most to the target object.

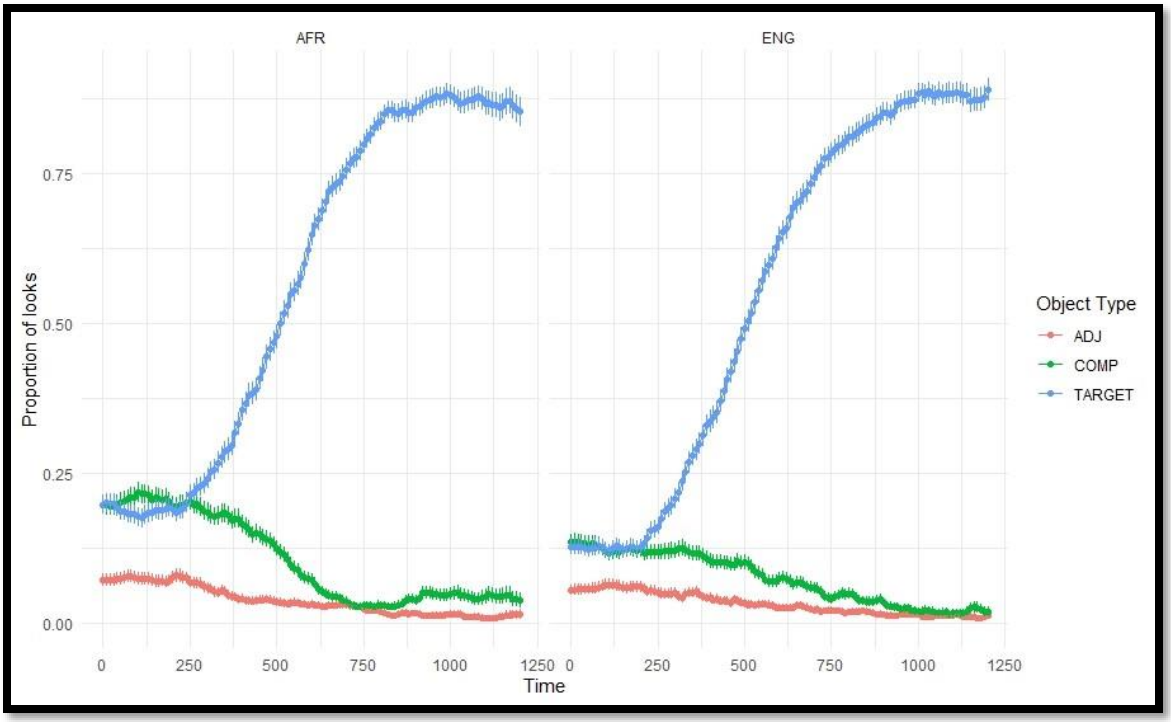


Figure 10. Fixation proportions of the bilingual group ("AFR") and the monolingual group ("ENG")

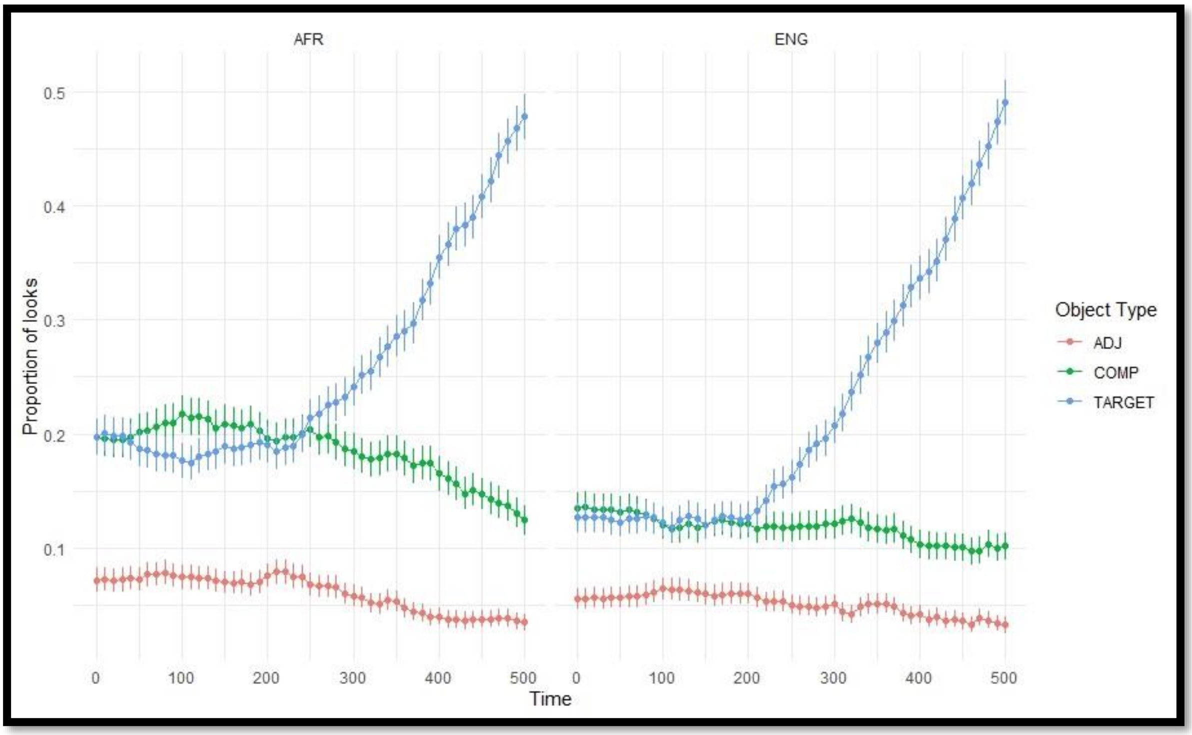


Figure 11. A closer look at the fixation proportions of the bilingual group ("AFR") and the monolingual group ("ENG")

5.5 Bilinguals' within-language eye-tracking analysis

This analysis of the results takes a more in-depth look at the bilingual participants and their language background variables (such as their English AoA and their English proficiency). These variables and their influence on proportion of fixations to object type (target, competitor) are anaylsed. As previously discussed in subsection 4.4.6, the participants reported their English AoA in the LHQ (Li et al. 2006) and their English proficiency was assessed by means of the LexTALE test (Lemhöfer and Broersma 2012).

5.5.1 Growth curve analyses

Two GCAs were run in order to engage separately with the bilinguals' background variables of AoA and proficiency, and the proportion of fixations made to object type as they occurred comparatively over time. The first GCA examined the influence of the bilinguals' proficiency on the proportion of fixations made to object type (target, competitor). Secondly, the effect of English AoA was analysed in relation to the proportion of fixations made to object type (target, competitor).

These two, more in-depth GCAs were conducted in order to determine the extent to which parallel activation of both Afrikaans and English takes place when observing differences in the bilingual group. This analysis allows for a deeper understanding of the influence of bilinguals'

AoA and L2 proficiency on the activation of the L1. Proficiency and AoA were independently analysed for their influences on parallel activation in the bilingual group, and no correlation was found (*r*= 0.13, *p*= .49).

5.5.1.1 Proficiency and object-type fixations

In this GCA, the fixed effects were the object type and English proficiency (in which proficiency scores were centred around the mean). The effect of time on fixations was accounted for by means of orthogonal polynomials (see Mirman 2014), and random intercepts were included for participants and items.

The effect of proficiency indicated that participants with higher English proficiency made more fixations overall. The effect of the object type highlighted more fixations overall to the target object. The interaction between proficiency and the object type indicated that the higher the proficiency, the more looks to the target object were made overall. The interaction between the object type, proficiency, and time was significant across all time points, where a relatively lower English proficiency caused significantly more fixations to the competitor object over all time points (the full model output appears in Appendix M).

The data in Table 5 below indicate that when the proficiency of the bilingual group was higher, increased proportions of fixations were made to the target object than to the competitor object. In the table, “proficiency” is the reported proficiencies of the bilingual group, “object type” is the target object, and “ot1–ot4” are the different time points at which the interactions between proficiency and the proportion of fixations to the target object took place in the bilinguals. Again, the colon notation (:) represents the interaction between the variables.

Table 5: Proficiency and object-type fixations

Model Term	**Coefficient (Standard Error)**
Proficiency	7.21^{***}(0.53)
Proficiency:Object Type Target	7.92^{***}(0.52)
Proficiency:Object Type Target:ot1	305.67^{***}(20.48)
Proficiency:Object Type Target:ot2	227.84^{***}(16.04)
Proficiency:Object Type Target:ot3	100.76^{***}(7.95)
Proficiency:Object Type Target:ot4	20.44^{***}(2.01)

$^{***}p < 0.001$

5.5.1.2 Age of acquisition and object-type fixations

In this GCA, the fixed effects of the object type and English AoA were included (where AoA was centred around the mean). The effect of time on fixations was accounted for by means of orthogonal polynomials (see Mirman 2014), and random intercepts were included for participants and items.

The main effect of English AoA was that participants with a relatively later AoA made less fixations overall. The main effect of the object type indicated more fixations to the target object overall. A marginally significant interaction between AoA and the object type indicated that a relatively later AoA was associated with more looks to the competitor object than the target object. The interaction between object type, AoA, and time was significant across all language points, showing that a relatively later AoA caused significantly more fixations to the competitor object over all time points (the full model output appears in Appendix N).

The data in Table 6 indicate that a later AoA of English in the bilingual group resulted in increased proportions of fixations to the competitor target over the target object. In the table, “AoA” is the age of acquisition of English, “object type” is the target object, and “ot1–ot4” are the different time points at which the interactions between AoA and the proportion of fixations to the target object took place in bilinguals. Once again, the colon notation (:) represents the interaction between the variables.

Table 6: Age of acquisition and object-type fixations

Model Term	**Coefficient (Standard Error)**
AOA	$-0.99^{*}(0.49)$
AOA: Object Type Target	$-0.84^{\circ}(0.49)$
AOA: Object Type Target:ot1	$-39.89^{*}(19.11)$
AOA: Object Type Target:ot2	$-39.20^{**}(15.04)$
AOA: Object Type Target:ot3	$-23.35^{**}(7.45)$
AOA: Object Type Target:ot4	$-5.99^{**}(1.86)$

$^{**}p < 0.01$, $^{*}p < 0.05$, $^{\circ}p < 0.1$

5.6 Results conclusion

The data analysis used in this study takes into account the accuracy and response times across both groups to establish that the participants all understood the instructions and test at hand, which indicated to a high accuracy and similar response time across both groups. Alongside this brief but foundational testing of understanding, there are two main raw eye-tracking data analyses, using the GCA. The results of these two analyses pointed to the fixation patterns of each group, seen as they took place over the time of each trial.

In comparing the two language groups in the first analysis, the Afrikaans bilinguals were shown to make more fixation proportions to the competitor object over the target object, than the monolingual English group. Even more so, the Afrikaans bilingual group showed an increased proportion of fixations to the competitor object over such competitor object's adjacent object in each trial, than the fixation proportions of the monolingual English group. These two, first analyses results showed an increased attention, focus and thinking placed on the competitor objects from Afrikaans bilinguals, than that seen in the English monolinguals. By testing the adjacent object's fixation proportions, it is ruled out that such fixations to the competitor can be as due to the object placement setup. In turn, the fixation proportions from the Afrikaans bilinguals are indicative of a focus and an interest in the competitor objects.

The analysis can then take an even deeper examination into the bilingual, yet in this analysis, a deeper look into the bilinguals' proficiency and AoA of English is investigated in comparison to the proportion of fixations to the competitor object. It was found that the higher the English proficiency, the more fixations were made to the target object than the competitor object, throughout the time-course of each trial. Lastly, this deeper analysis allowed for a marginally significant relationship to be unveiled in Afrikaans bilinguals, where a later AoA of English was indicative of increased fixations made to the competitor object over the target object. Again, this showed an increased attention, focus and thinking placed on the competitor objects from Afrikaans bilinguals, when such bilinguals were less proficient in English and had learnt English at a later age.

Chapter 6: Discussion

6.1 Overview

The present thesis attempted to determine whether early L1-Afrikaans L2-English bilinguals activate their L1 Afrikaans while being tested in English (Research Question 1), as well as the extent to which such activation is modulated by (2a) English proficiency (Research Sub-question 2a) and/or AoA of English (Research Sub-question 2b).

With reference to Research Question 1, the hypothesis was confirmed, as parallel activation was observed by means of more eye movements focusing on the phonetically-similar (competitor) Afrikaans object in bilinguals, in comparison to a lesser proportion of eye movements by monolingual English speakers to the same object. The hypothesis of Research Sub-question 2a was also confirmed, as a lower English proficiency in the bilinguals had a significant influence on Afrikaans activation, a similar finding from other parallel activation studies (e.g. Blumenfeld and Marian 2007; Elston-Güttler et al. 2005; Perani et al. 1998). Lastly, the hypothesis formulated in relation to Research Sub-question 2b was rejected. This is as a result of the later English AoA in the bilinguals showing an unexpected, significant effect on the extent to which Afrikaans was activated in parallel.

In this chapter, the documented effects of bilingual parallel activation are discussed and, as far as possible, explained by means Shook and Marian's (2013) BLINCS model. In the sections that follow, the individual variables of L2 proficiency and AoA, contextual variables of language setting and language immersion, as well as the structural/experimental variables (such as phoneme overlap and word frequencies) are discussed in relation to bilingual parallel activation. It is the original proposal of this thesis that parallel activation, much like Grosjean's (2001) Language Mode hypothesis, exists on a continuum, from purely sequential activation to purely parallel activation. In this proposed Parallel Activation Continuum, the background variables constitute elements that shape the bilingual mind which work with and/or rely on cues from the context and/or stimuli, thereby determining the extent to which parallel activation can take place. The extent of parallel activation is then, in turn, modulated by individual, contextual, and structural variables as well as their interactions.

6.1.1 Parallel activation in the Afrikaans-English bilingual group

The Afrikaans-English early bilingual group was found to exhibit parallel activation, with L1 Afrikaans influencing the English fixation patterns in the critical trials of the current eye-tracking study. This parallel activation was observed via the bilinguals' increased proportion of fixations, in comparison with the English monolingual group, to the phonetically-similar (when translated into Afrikaans) competitor object, over the English target object. This parallel activation of both Afrikaans and English was recognised as most salient in the first 250ms post word-onset, but the effect continued throughout the post-onset timeframe of 1255ms. A pronounced effect in the bilinguals, but less profound in the monolinguals, was an increased proportion of fixations to the competitor object in comparison to the adjacent distractor object in each critical trial. This secondary, across-language analysis indicated that parallel activation in the Afrikaans-English early bilinguals (through an increased proportion of fixations to the competitor object) was not a factor of the current experiment or the participants across groups (see subsection 5.4.1 on the second GCA).

6.1.1.1 Parallel activation from the L1 to the L2

This kind of parallel activation is in line with the predicted results, as parallel activation from the L1 into the L2 has been found by Canseco-Gonzalez et al. (2010), Marian and Spivey (2003a, 2003b), Shook and Marian (2012), and Spivey and Marian (1999). Across these studies, it was noted that there was not only a parallel activation from the L1 into the L2, but also a bidirectional one. Unlike these studies, the current research only focused on the extent to which the L1 was activated when placed in a monolingual L2 setting. However, there are controlled variables included in the current study that are noteworthy, as is discussed in the following subsection.

6.1.1.2 Parallel activation variables

In the current study, controlled variables of phoneme overlap, word frequencies, VOT, and monolingual language mode were implemented, unlike the early studies by Stroop (1935), Preston and Lambert (1969), Marian and Spivey (2003a), and Spivey and Marian (1999), which found that parallel activation had not controlled for all or even a few of these variables. In order to focus solely on the AoA and proficiency of English as language background variables in the bilinguals of the current study, these variables were controlled for as far as possible. The current study found an influence of relatively lower English proficiencies and relatively later English AoA of bilinguals on parallel activation.

There are multiple variables that have been found to be influential in parallel activation, such as phoneme overlap (Colomé 2001; Marian and Spivey 2003a), word frequencies (Magnuson et al. 2007; Marian and Spivey 2003a), VOT (Ju and Luce 2004), and language immersion (Spivey and Marian 1999; Weber and Cutler 2004). To recap, control of phoneme overlap, as explained in subsection 4.3.5, was implemented by using target words and competitor words that only overlapped by roughly one to two phonemes. Word frequencies of the target and competitor objects were also comparatively accounted for, as discussed in subsection 4.3.4, through the use of the logarithmic Zipf-scale. This logarithmic Zipf-scale was calculated with the SUBLEXUS-UK database, for the English target word frequencies, and the VivA Afrikaans corpus, for the Afrikaans competitor-object word frequencies. The VOTs of both target and competitor objects were controlled by avoiding the Afrikaans unvoiced stops (e.g., [p], [t], [k]), as these tend to be shorter in the English VOT. The language mode, as explained in subsection 4.4.2, was controlled by only talking to and testing the bilinguals in English, and ensuring that all other contact with the participants was in English only.

6.1.2 The influence of language background variables

A GCA of the bilinguals' language backgrounds highlighted the effect of English AoA and English proficiency on the extent to which parallel activation took place. A slightly later English AoA was found to show increased parallel activation. There was also an increase in parallel activation, in bilinguals with lower English proficiency. In turn, these within-bilingual differences of proficiency and AoA were, independently, representative of the extent to which parallel activation takes place in these bilinguals (similar to Blumenfeld and Marian 2007; Canseco-Gonzalez et al. 2010; Jared and Kroll 2001; Silverberg and Samuel 2004). However, the current research found that the effect of proficiency is more influential than the AoA on the extent of parallel activation, a similar finding to that of Perani et al. (1998). The effect of AoA may have been seen as having a lesser influence as due to the very slight difference in English AoA in the current participant group.

6.1.2.1 High vs. low proficiency

As mentioned in Chapter 2, there are a number of studies that have looked at the influence of proficiency on parallel activation in bilinguals. Many of these studies found that when bilinguals are tested in their L2, a lower L2 proficiency increases the parallel activation of L1 (Blumenfeld and Marian 2007; Elston-Güttler et al. 2005; Perani et al. 1998; Van Heuven et al. 1998). In the current research, where bilinguals were tested in a spoken-word recognition task, the role of proficiency in parallel language activation was examined, with the result that a lower English (L2) proficiency increased the parallel activation of Afrikaans (L1). This result is compared to findings of bilinguals from other studies who, when listening to words from their lower-proficiency language (usually the L2), reliably showed a co-activation of their higher-proficiency language (the L1) (Marian and Spivey 2003a, 2003b; Weber and Cutler 2004).

The current study's results can be compared to those of Blumenfeld and Marian (2007), Canseco-Gonzalez et al. (2010), Elston-Güttler et al. (2005), Marian and Spivey (2003a, 2003b), Perani et al. (1998), and Weber and Cutler (2004). In this thesis, the participants' language proficiencies were determined via the standardised LexTALE proficiency test (Lemhöfer and Broersma 2012). However, many of these previously mentioned studies, with similar findings of parallel activation of the L1 in bilinguals when tested in the L2, used differing proficiency measures, such as self-rated scales and reference to the L1 backgrounds of bilinguals. Having such differing proficiency measures and still observing similar correlations between proficiency and parallel activation speaks to the robustness of the proficiency effect.

Perani et al. (1998) explain that proficiency is more effective than AoA in parallel activation as observed during PET scanning of the participants in this study. With this method, different cortical brain representations were observed to compare higher- and lower-proficiency speakers of languages as they processed auditory narratives. The PET scans in Perani et al.'s (1998) study indicated that the activation areas of both early and late highly-proficient learners were similar across their L1 and L2, but this was not observed in the lower proficiency group. A similar finding of the effectiveness of proficiency was established in the current research, but in the examination of eye movements instead.

The effect of English proficiency was still recognised despite the differences in methodologies of Canseco-Gonzalez et al. (2010) and Elston-Güttler et al. (2005) in comparison to the current eye-tracking research on Afrikaans-English bilinguals. In the current study, a relatively lower proficiency correlated with the lower proportion of fixations that were made to the English target object. This indicates that a lower English proficiency triggered a stronger parallel activation of the L1 Afrikaans. Elston-Güttler et al. (2005) explained that although bilingual word recognition is seen as non-selective, the L2 proficiency can significantly influence the access to such recognitions. Essentially, the higher L2 proficiency a bilingual has, the more likely the bilingual avoids or dismisses any L1 influences on L2 processing, as seen in Elston-

Güttler et al.'s (2005) results of electrophysiological and behavioural patterns across bilinguals' L2 proficiencies. In a similar explanation by Canseco-Gonzalez et al. (2010), it was hypothesised that the activation of one's L1 when working with one's L2 is suppressed on account of being a proficient early bilingual, as one is accustomed to moving back and forth regularly between the two languages (Canseco-Gonzalez et al. 2010).

In a different kind of developing L2 group (the foreign language learners), results from Van Heuven et al. (1998) found that, in highly proficient participants, there was lesser parallel activation from the L1 on the L2. Again, no standardised measures were used to group the participants of Van Heuven et al.'s (1998) study by proficiency levels. A highly-proficient speaker was classified as a result of (i) being a student of the language, or (ii) being a student who had visited and/or stayed in an English-speaking country for a short period. In comparison to the abovementioned, similar parallel activation studies (Blumenfeld and Marian 2007; Canseco-Gonzalez et al. 2010; Elston-Güttler et al. 2005; Marian and Spivey 2003a, 2003b; Perani et al. 1998; Weber and Cutler 2004), Van Heuven et al. (1998) seemed to be working with "highly proficient" foreign language learners rather than highly proficient L2 learners. However, even as a foreign-language-learning group, influences of proficiency on parallel activation of L1 were still observed, with a lower proficiency increasing parallel activation of L1 in an L2 situation.

In the current research, it was observed that the more proficient the Afrikaans-English early bilinguals were in their L2 of English, the more they were able to suppress any influence of their Afrikaans L1 and fixate more on the English target word. This allows the Afrikaans-English, highly-proficient L2 speakers to act almost as L1 speakers in their L2. In short, as the L2 proficiency of the Afrikaans-English early bilinguals increased, the parallel activation decreased.

6.1.2.2 Age of acquisition of the second language

There have been multiple studies that investigated language activation and parallel processing in bilinguals, factoring in the AoA of both the L1s and L2s (Canseco-Gonzalez et al. 2010; Jared and Kroll 2001; Silverberg and Samuel 2004). For this thesis, studies that looked at the L2 AoA were examined (Canseco-Gonzalez et al. 2010; Silverberg and Samuel 2004).

In the current research on Afrikaans-English early bilinguals, the GCA of AoA and the proportion of fixations to the competitor object demonstrated that bilinguals with a relatively later AoA for English had an increased proportion of fixations to the competitor object than the target object. The effect of a later AoA of English created an increased parallel activation of Afrikaans in these bilinguals. The current study focused on early bilinguals and came to similar conclusions as Canseco-Gonzalez et al. (2010) and Silverberg and Samuel (2004), as the early bilinguals of the current VWP spoken-word recognition research were shown to have increased parallel activation of their L1 when their AoA of their L2 was relatively older.

It is noted that Canseco-Gonzalez et al.'s (2010) classification of early bilinguals consisted of a younger group of bilinguals in comparison to the current thesis' early bilingual group. To elaborate, Canseco-Gonzalez et al. (2010) classified early bilinguals as younger than six years of age, however, in the current study on Afrikaans-English early bilinguals, these participants had to be younger than nine years to be classified as early bilinguals. Furthermore, Silverberg and Samuel's (2004) study classified late bilinguals as having learnt their L2 after seven years of age. With these classifications in mind, the current study's Afrikaans-English early bilinguals are placed between Canseco-Gonzalez et al.'s (2010) early bilinguals and Silverberg and Samuel's (2004) late bilinguals.

When looking at the Afrikaans-English early bilinguals of the current study, Silverberg and Samuel's (2004) evidence of the L1 and L2 sharing a conceptual level in early bilinguals is similar to the earlier AoA of the current study's Afrikaans-English bilinguals. Most importantly, the early L2 learners in Silverberg and Samuel's (2004) study exhibited no effects of the cross-language form primes (primes that were similar in initial phonemes). In the current study, a similar finding was established in the Afrikaans-English early bilinguals who had a relatively younger AoA, as these bilinguals demonstrated less parallel activation of the form kind, in comparison to the bilinguals with a later AoA. Although Silverberg and Samuel's (2004) bilinguals can be compared to the Afrikaans-English early bilinguals in this regard, Silverberg and Samuel's (2004) study did not make use of eye-tracking methodology. However, Canseco-Gonzalez et al.'s (2010) study, in comparison to the current research, made use of the same VWP spoken-word recognition task.

As already mentioned, Canseco-Gonzalez et al. (2010) hypothesised that the English-Spanish early bilingual group was somewhat more skilled at changing between their two early-acquired languages. Canseco-Gonzalez et al. (2010) hypothesised that the English–Spanish early bilingual group was more skilled in working between two languages and avoiding Spanish interference or activation because it was irrelevant in the English setting. In turn, the authors hypothesise that an early bilingual can suppress his/her L1 when being tested in his/her L2 as a result of being skilled in moving between two languages (Canseco-Gonzalez et al. 2010). This hypothesis is strengthened by the current research findings on early bilinguals, as the Afrikaans-English early bilinguals were found to significantly activate Afrikaans (L1 – the unused language in the experiment) when they had an older AoA of English.

Although there are similarities found in the current research to that of Silverberg and Samuel (2004) and Canseco-Gonzalez et al. (2010), the current research deals with bilinguals that live in a multilingual setting with Afrikaans and English. This setting is unlike the previous two studies, as the AoA of Silverberg and Samuel's (2004) participants is defined as having moved from one linguistic setting (a country in which the L2 was not spoken natively) to another. The participants in Canseco-Gonzalez et al.'s (2010) study also differed in terms of linguistic setting, as these bilinguals, again, only began learning English (the L2) in the context of another country where their L2 is a native language. Therefore, the same immersion in the L2 environment does not occur in the current research, and yet there are still AoA effects. These diverse linguistic settings all indicate an influence of AoA, thereby denoting the significant role that this variable plays.

The bilinguals and L2 learners of Canseco-Gonzalez et al.'s (2010) and Silverberg and Samuel's (2004) studies were likely to have received considerable input from native speakers as a result of their immersion in a L2 setting. In comparison, English is more often a lingua franca in the linguistic setting of South Africa meaning that, as a L2 speaker, Afrikaans-English early bilinguals are not always exposed to native-speaker input. However, again, there is an influence of AoA in parallel activation, further strengthening the AoA variable.

The result of a later L2 language AoA influencing further L1 parallel activation is one that was originally expected to have less of a significant effect, as smaller effects of AoA have previously been reported in the literature. However, it is noted that there are various factors at play in parallel activation, and the extent to which the AoA of an L2 is influential requires experiments that are focused only and specifically on the influence of this variable in order to determine the exact extent to which this factor triggers the L1 in interaction with other factors.

6.1.3 Parallel activation and BLINCS

BLINCS explains the mechanisms of the Afrikaans-English early bilingual and their exhibition of parallel activation of Afrikaans during spoken-English language processing. As the previous models, such as the IA and TRACE, only focused on the monolingual context, and the BIA on orthographic representations, these models were useful for the foundations of word-recognition tasks and language processing but could not explain the phenomenon of parallel activation in the bilinguals' spoken-word recognition task. The BIA+ came closer in explaining this activation in the spoken-word recognition task, as phonological and semantic lexical representations are included alongside orthographic representations. The BIA+ also explained language nodes to be interactive, however, this model does not clarify what happens during L2 development and learning of new materials.

As such, BLINCS is the most useful model in bilingual language processing explanations, as it is inclusive of the above models as foundations but extends just that much more to incorporate the idea of SOMs. As explained in Chapter 3, BLINCS uses SOMs which can be recognised in the current research when participants are listening to auditory inputs that phonologically label both an Afrikaans and an English item on the display screen. Therefore, BLINCS is explanatory for the bilinguals in the current research, as it assumes a shared phonological system within SOMs and without distinctions regarding which phonemes belong to Afrikaans and which to English. With results in this research that are indicative of parallel activation of Afrikaans in an English context, one can comprehend how there is a single, shared phonological processing system. Furthermore, instances of zero parallel activation as an effect of dissimilar phonology across languages can still be explained by the same model.

On the lexical level, BLINCS also assumes that a bilingual's two languages are both separate and integrated (Shook and Marian 2013: 320). The model has distinct "pockets" of language specificity within the map, yet the model remains interactive. An Afrikaans "pocket" of language specificity would include examples of words containing the unique Afrikaans voiceless velar fricative /x/. As there are no sounds in English similar to the Afrikaans /x/ sound, no English activation is necessary, thus retaining this sound in the Afrikaans "pocket" of language specificity. However, there are still points at which the model's interaction occurs in that languages are not separated with strict division but merely by means of the "pockets" mentioned (Shook and Marian 2013: 320). There are phonological crossovers placed at the boundaries between language regions, and thus there are instances when the cross-language items intersect in phonological form (such as cognates and false cognates as well as the phonological-similarity labelling in the experiment of this research).

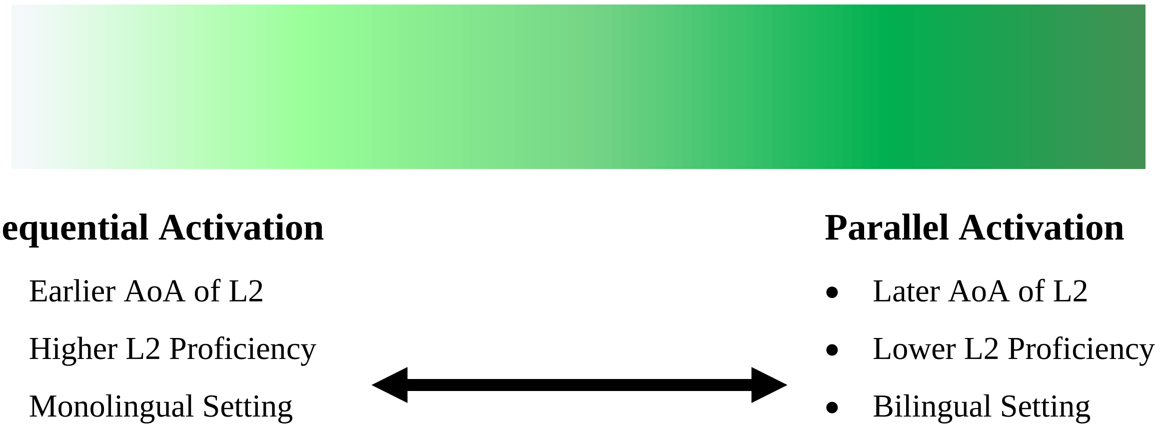
In addition, BLINCS is said to capture the smaller and subtle changes in activation patterns because it includes individual differences in experiences with language. This inclusion comes about by means of the SOMs specific to language experience. Noting that there are multiple individual, contextual, and structural variables at play in the activation of a language, as seen throughout the current research, BLINCS is useful as it highlights individuals' differences in SOMs, and thus differences in instances of parallel activation.

However, BLINCS can be criticised for its ability to specify the different variables found on the group level relationship with parallel activation. An example would be similar patterns of parallel activation found in bilinguals who learnt their L2 at a later age, as is observed in the current thesis. Some individual, contextual, and structural variables that can affect the extent to which parallel activation takes place in a bilingual cannot be addressed by SOMs and their interactions. As has been noted in the current thesis, there are multiple variables that need to be considered in the activation of a language. Although how the variables interact with one another has not yet been discovered, there are definite individual, contextual, and structural variables that can cause the phenomenon of parallel bilingual activation. This is where the Continuum for Parallel Activation in Bilinguals is proposed.

6.1.4 The Continuum for Parallel Activation in Bilinguals

Considering the variables described above, as an original contribution in the interpretation of parallel activation, The Continuum for Parallel Activation in Bilinguals is proposed. In this Continuum, the extent to which parallel activation takes place is dependent upon a combination of variables that are individual-, context-, and experiment-specific, as well as the interactions of these variables with and amongst one another. By means of the interaction of these individual, contextual, and structural variables across the Continuum, bilinguals find themselves in different states of language activation. On the one end of the spectrum, where parallel activation always takes place, one finds the individual variables of a later L2 AoA and a lower L2 proficiency, contextual variables of an L2 immersion and bilingual language setting, as well as structural variables of more phonological overlap, similar word frequencies and VOTs across languages, and the presence of cognates.

On the other end of the spectrum, where sequential activation takes place, individual factors are observed such as an earlier L2 AoA and higher L2 proficiency levels. Alongside these, contextual variables, such as a monolingual language immersion and monolingual language setting, are also on the sequential-activation end of this Continuum. Lastly, structural variables, such as fewer phoneme overlaps, dissimilar word frequencies and VOTs across languages, and the absence of cognates, place a bilingual on the sequential-activation end of the Continuum.



Sequential Activation

- Earlier AoA of L2
- Higher L2 Proficiency
- Monolingual Setting
- Monolingual Immersion
- Less Phoneme Overlap
- Dissimilar Word Freq.
- Dissimilar VOTs
- Cognates Absent

Parallel Activation

- Later AoA of L2
- Lower L2 Proficiency
- Bilingual Setting
- Bilingual Immersion
- More Phoneme Overlap
- Similar Word Freq.
- Similar VOTs
- Cognates Present

Figure 12. The Continuum for Parallel Activation in Bilinguals

These factors are believed to be interactive and to influence one another, creating situations where parallel activation is explicitly taking place as well as instances during which only one language is active. This Continuum serves to explain the current research findings, as the bilingual exhibits parallel activation even with many of the variables being controlled for. As such, it is expected that variables of proficiency or AoA may have a stronger influence on parallel activation. Alternatively, the Continuum could explain the interactions between these variables (inclusive of proficiency and AoA) which still result in parallel activation. The interaction and influences of each and every variable is not within the scope of the current research, nor can they be explained by the literature to date. Note that BLINCS also does not fully explain the interactions and influences of these variables either.

Even though the exact understanding of how factors interact to either cause or inhibit parallel activation is not yet known, each of the abovementioned variables has a part to play in the parallel activation in bilinguals (as seen throughout the literature in this thesis). Each variable included has been shown to have an effect on the activation of language, yet, with time and more studies, the strength of each variable can be defined. The extent to which each of these variables, alone or in interaction, influences parallel activation is also unknown. It is also possible that the variables of AoA and proficiency overrule or dominate the effects of the other variables, and such variables are revealed when these variables are held constant. The current Continuum for Parallel Activation in Bilinguals is tentatively proposed, based on the findings of parallel activation up to this point, recognising the challenges as due to a lack of controlled variables (across studies). Future research would need to isolate each of the individual, contextual, and structural variables in order to observe their effects in parallel activation.

Chapter 7: Conclusion

This study mainly focused on determining whether Afrikaans-English early bilinguals activated their L1 of Afrikaans while being tested in their L2 of English (Research Question 1). This study also attempted to determine the extent to which L1-Afrikaans activation in Afrikaans-English early bilinguals takes place (Research Question 2) as modulated by proficiencies in English (Research Sub-question 2a) and AoAs of English (Research Sub-question 2b).

The current thesis aimed to address the gap in testing South African Afrikaans-English early bilinguals for cross-linguistic (parallel) or sequential (separate) language activation. This thesis succeeded in addressing this gap, finding parallel activation of both Afrikaans and English in the bilingual participants tested. This parallel activation was explored through spoken-word recognition tasks within a VWP eye-tracking experiment. Furthermore, served to answer Research Question 2a was answered as this study found that relatively lower proficiencies in the early bilingual group increased parallel activation. Unexpectedly, Research Question 2b was also answered with significant effects of a relatively older AoA of L2 on increased parallel activation in the present study.

The secondary research aim met by the study was that, through this research, there was minimal evidence of parallel activation in non-WEIRD language groups. The WEIRD bias has been found in the field of psycholinguistics, creating overgeneralised sets of theories on bilingual cognition overall. Therefore, by including the South African, Afrikaans-English early bilingual in parallel activation studies, the field can slowly begin to move into a non-WEIRD-biased field.

The final aim of the present research was to add to the body of knowledge within the psycholinguistics field of early bilingual cognitive functioning, in addition to producing research on early bilingual groups, as the latter too is somewhat lacking. The participant group of the current study comprised early bilinguals, adding to the psycholinguistics field in general as early bilinguals are not regularly studied. Although current literature leans to supporting the idea of parallel activation in bilinguals, there has been a general lack of consensus as to whether the bilingual works with both languages in a parallel or a sequential manner. The current research adds to this discussion on parallel or sequential processing in bilinguals, proposing a Continuum in which bilinguals either exhibit more parallel activation or more sequential activation.

In adding to the debate on parallel vs. sequential activation in bilinguals, this thesis proposed that language activation is based on a continuum, much like Grosjean's (2001) Language Mode hypothesis. The Continuum for Parallel Activation in Bilinguals proposed in this thesis is recognised to have multiple variables influencing the bilingual's activation of his/her languages at any given point. It is important to note that the extent to which these factors influence the triggering of parallel activation is not yet known, nor do we know, at this stage, the interaction between these variables. These are therefore suggestions for future research.

7.1 Challenges and suggestions for future research

The challenges of this methodology provide insight into the novelty of studying South African Afrikaans-English bilinguals, as these languages have included in studies involving spoken-word recognition tasks. A few notable challenges of this study include the lack of word frequency databases and picture stimuli relevant to the South African context, as well as rigorous and detailed experiment building. In order to move forward in this field of parallel activation in South African bilinguals, one would need, firstly, to establish more standardised measures for the country. Alongside this, there needs to be more isolated, variable studies on parallel activation to determine the extent to which each variable has an influence on parallel activation. This is necessary as it has been found that parallel activation in bilinguals includes a set of factors that either exhibit it or inhibit the salience of the activation.

The most notable challenge was the lack of word frequency databases accessible for Afrikaans, and the overwhelming set of resources for English (yet often limited to either American or British English). In general, South African languages are understudied, and the result is that basic tools such as word frequency databases tend to be unavailable in the 11 (official) languages of this country. However, it is exciting to note that there are indeed organisations that are in the process of creating more valid and trustworthy databases for both Afrikaans and English in the South African setting, such as the Virtuele Instituut vir Afrikaans (VivA), the corpus of which was utilised for this study.

Another option that could extend bilingual studies in South Africa would be to develop all standardised measures that are relevant to the South African context. This would include word frequency databases, a relevant set of imagery data, and proficiency tests. This may seem a bold and extensive process in order to study the languages of South Africa, but it is necessary as the measures currently in place are specific to languages found outside of the South African borders. Upon establishing relevant standardised measures, the resulting data will be more relevant within the variation of South African English as well as South African culture.

A further challenge of the study was avoiding possible variables that may have influenced this dataset in particular, such as cognates and VOT. If the variables of word frequency, phonetic overlap, avoidance of cognates, VOT, audio salience as well as picture salience are to be controlled (especially in languages that do not have the standardised tools specific to the language), there must be highly rigorous and thorough pre-experiment planning.

In addition to English and Afrikaans, there are at least another nine South African languages that may constitute the linguistic repertoires of South Africa's bilingual and multilingual citizens. (South African languages include isiXhosa, isiZulu, Setswana, isiNdebele, Xitsonga, Sesotho, Sepedi, Siswati and Tshivenda.) By researching these bi-/multilingual individuals, a more universal understanding of language comprehension and mechanisms can be investigated and established. With the abovementioned, extensive, standardised measures in place, many more of South Africa's bilinguals and multilinguals could be tested. As such, African languages (having been neglected in the past) would then be able to test previous claims from WEIRD societies in the field of bilingual language activation.

A more realistic study that could be implemented in the near future would test the parallel activation of one's L2 (English) when situated in an L1 monolingual context (Afrikaans). This would be an interesting study for Afrikaans-English bilinguals in testing the bidirectional activation of languages. However, as noted above, there is a lack of standardised measures for South African languages, and a study of this kind would be more valid if it utilised standardised measures.

As seen in this research, there is an overwhelming number of individual, contextual, and structural variables that are shown to be tied to parallel activation in bilinguals. As such, there is a need for more isolated variable studies on parallel activation in order to test the extent to which each variable influences parallel activation. Although, again, it is a difficult and considerable task to isolate such interactive and interdependent variables, these attempts could inform the Continuum for Parallel Activation in Bilinguals. These informative measures could also help better understand bilingual cognitive functioning which, in turn, provides valuable insights into language capacity and how the brain encodes language (Schreuder and Weltens 1993; De Groot and Kroll 1997).

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Appendices

Appendix A – Invitation for Participation

DO YOU SPEAK AFRIKAANS AND ENGLISH?
The General Linguistics Department is looking for participants for an hour-long eye-tracking exercise. Participants will be paid R50 in cash upon completion of the exercise.
Possible times include: 8am – 3pm (Monday-Friday).
If interested, please contact Jayde McLoughlin, student email: 19123965@sun.ac.za

Appendix B - Consent Form

STELLENBOSCH UNIVERSITY
CONSENT TO PARTICIPATE IN RESEARCH

You are invited to take part in a study conducted by Jayde Caitlyn McLoughlin, from the General Linguistics Department at Stellenbosch University. You are a possible participant as you have an Afrikaans-English bilingual background (your first language spoken was Afrikaans but you can also speak English) or you are a monolingual English speaker (you only speak English).

1. PURPOSE OF THE STUDY

This is an eye-tracking study that focuses on the bilingual language functioning of the Afrikaans-English participant (i.e. How does one who speaks both of these languages naturally engage in their second language?).

2. WHAT WILL BE ASKED OF ME?

If you agree to take part in this study, you will be asked to make use of an eye-tracker, which will monitor how you naturally watch a screen of black and white, simple object pictures go by, while listening to an audio of an individual speaking about the pictures seen.

3. POSSIBLE RISKS AND DISCOMFORTS

There are no risks with this experiment, however if the participant at any point is uncomfortable or unable to complete the picture-watching experiment, he/she may stop and leave the experiment without any repercussions.

4. POSSIBLE BENEFITS TO PARTICIPANTS AND/OR TO THE SOCIETY

The participant also helps society and the field of Linguistics in understanding how an individual interacts and responds in the languages they speak, which is highly beneficial in a South African society as its civilians often make use of and speak multiple languages.

5. PAYMENT FOR PARTICIPATION

Each participant will receive payment for their participation, which will be R50 paid in cash as the participant completes their experiment. If the participant decides to withdrawal, he/she will be paid (in cash) for the number of minutes spent taking part in the study initially. The expected participant will take 60 minutes to complete the study, therefore it equates to just under a Rand per minute of participation.

6. PROTECTION OF YOUR INFORMATION, CONFIDENTIALITY AND IDENTITY

Any information you share with the researcher during this study and that could possibly identify you as a participant will be protected. This will be done by participants responding with complete anonymity as they do not reveal their names or background besides their age, gender and languages they speak.

Alongside this, each participant is coded before being entered into the dataset. Thus, there is no possible way to link a participant to a survey response. In terms of access to responses, only myself, as the researcher, will have access to information shared by participants. This is done by means of a password/ locked eye-tracking computer, laptop and hard-drive. Both my laptop and hard-drive will constantly be safely stored and locked away, and in the event of either being stolen, any information is firstly locked with a password on my laptop and secondly, is coded and thus cannot be interpreted by a third party (and in fact, once coded, it is impossible for myself as the researcher to even decode to whom the information belongs).

It is possible that the data collected from this study will at some point be published. However, again, there will be no means to identify an individual from the data collected for the study. Participants will only be referenced in terms of giving an overall picture of the results found and never in the particular identification of an individual as this will not be accessible once data has been pooled.

The only recordings used in this experiment are the co-ordinated points at which an eye (the various participants' eyes) focuses on when looking at the screen. There is by no means a capability to identify who this participant was, or even what their eyes looked like.

7. PARTICIPATION AND WITHDRAWAL

You can choose whether to be in this study or not. If you agree to take part in this study, you may withdraw at any time without any consequence. You may also refuse to answer any questions you don't want to answer and still remain in the study. The participant may withdraw from this study immediately if uncomfortable with any of the measurement tools and aspects to the experiment taking place.

8. RESEARCHERS' CONTACT INFORMATION

If you have any questions or concerns about this study, please feel free to contact Jayde Caitlyn McLoughlin at 19123965@sun.ac.za and/or the supervisor and/or the Supervisor, Prof Emanuel Bylund, at mbylund@sun.ac.za.

9. RIGHTS OF RESEARCH PARTICIPANTS

You may withdraw your consent at any time and discontinue participation without penalty. You are not waiving any legal claims, rights or remedies because of your participation in this research study. If you have questions regarding your rights as a research participant, contact Ms Maléne Fouché [mfouche@sun.ac.za; 021 808 4622] at the Division for Research Development.

DECLARATION OF CONSENT BY THE PARTICIPANT

As the participant I confirm that:

- I have read the above information and it is written in a language that I am comfortable with.
- I have had a chance to ask questions and all my questions have been answered.
- All issues related to privacy, and the confidentiality and use of the information I provide, have been explained.

By signing below, I ________________________________ *(name of participant)* agree to take part in this research study, as conducted by Jayde Caitlyn McLoughlin.

____ ______________________

Signature of Participant **Date**

DECLARATION BY THE PRINCIPAL INVESTIGATOR

As the **principal investigator,** I hereby declare that the information contained in this document has been thoroughly explained to the participant. I also declare that the participant has been encouraged (and has been given ample time) to ask any questions. In addition I would like to select the following option:

	The conversation with the participant was conducted in a language in which the participant is fluent.
	The conversation with the participant was conducted with the assistance of a translator (who has signed a non-disclosure agreement), and this "Consent Form" is available to the participant in a language in which the participant is fluent.

____ ______________________

Signature of Principal Investigator **Date**

Appendix C – Eye-tracking Experiment Instructions

Welcome!

This is a simple task in which you will hear a sentence and be asked to click on an image.

Please make use of the mouse to click on each image.

You may put your arms on the table, to access the mouse, and your head resting on the blue cushion of the head-mount.

In each set, you will also need to focus your eyes on the crosses before each trial begins, sometimes these crosses will move but try not to guess where they are moving to, rather just fixate on them as they appear.

Once the trial begins, please refrain from moving your head too much or shuffling around in your seat. There are allocated breaks for this session.

This being said, if you are uncomfortable in anyway, please make yourself comfortable now and note that you are allowed to leave the experiment at any point without any repercussions.

Enjoy!

Appendix D – LexTALE (Participant Fluency Test)

Word list and instructions for use with other software

Materials

Below you find the items for the English version of the LexTALE test. You can implement the test in any experimental software, or as a paper and pencil test.

The columns contain the following information:

- First column: Item number. (Note that the first three items are dummies.)
- Second column: Item.
- Third column: word status; 0=nonword, 1=word.

0	platery	0
0	denial	1
0	generic	1
1	mensible	0
2	scornful	1
3	stoutly	1
4	ablaze	1
5	kermshaw	0
6	moonlit	1
7	lofty	1
8	hurricane	1
9	flaw	1
10	alberation	0
11	unkempt	1
12	breeding	1
13	festivity	1
14	screech	1
15	savoury	1
16	plaudate	0
17	shin	1
18	fluid	1

19	spaunch	0
20	allied	1
21	slain	1
22	recipient	1
23	exprate	0
24	eloquence	1
25	cleanliness	1
26	dispatch	1
27	rebondicate	0
28	ingenious	1
29	bewitch	1
30	skave	0
31	plaintively	1
32	kilp	0
33	interfate	0
34	hasty	1
35	lengthy	1
36	fray	1
37	crumper	0
38	upkeep	1
39	majestic	1

40	magrity	0
41	nourishment	1
42	abergy	0
43	proom	0
44	turmoil	1
45	carbohydrate	1
46	scholar	1
47	turtle	1
48	fellick	0
49	destription	0
50	cylinder	1
51	censorship	1
52	celestial	1
53	rascal	1
54	purrage	0
55	pulsh	0
56	muddy	1
57	quirty	0
58	pudour	0
59	listless	1
60	wrought	1

Implementation

Please present the participants with the items in exactly this order. As this is a standardised test, the order of the items should not be changed or randomized.

Instructions

Please present the participants with the following instructions before the test:

"This test consists of about 60 trials, in each of which you will see a string of letters. Your task is to decide whether this is an existing English word or not. If you think it is an existing English word, you click on "yes", and if you think it is not an existing English word, you click on "no".

If you are sure that the word exists, even though you don't know its exact meaning, you may still respond "yes". But if you are not sure if it is an existing word, you should respond "no".

In this experiment, we use British English rather than American English spelling. For example: "realise" instead of "realize"; "colour" instead of "color", and so on.

Please don't let this confuse you.

This experiment is not about detecting such subtle spelling differences anyway.
You have as much time as you like for each decision. This part of the experiment will take about 5 minutes.
If everything is clear, you can now start the experiment."

Procedure

The procedure should be as follows:

- Provide the participants with the written instructions provided above.
- Present the items one by one on a computer screen or, in a paper and pencil test, below each other on a sheet of paper.
- Participants should respond to each item with 'yes'/'no'.

The task should not be speeded.

Scoring

The LexTALE score consists of the percentage of correct responses, corrected for the unequal proportion of words and nonwords in the test by averaging the percentages correct for these two item types.

We call this measure $\%\ correct_{av}$ (averaged % correct). It is calculated as follows:
((number of words correct/40*100) + (number of nonwords correct/20*100)) / 2
Note that the first three items are dummies; responses to those items should not be taken into account for the calculation of the score! (See also www.lextale.com/scoring.php.)

Appendix E - Language History Questionnaire

Please answer the following questions to the best of your knowledge.

PART A

1. Age (in years):

2. Sex (circle one): Male/Female

3. Education (degree obtained or school level attended):

4 (a). Country of origin:

4 (b). Country of Residence:

5. If 4(a) and 4(b) are the same, how long have you lived in a foreign country where your second language is spoken?

If 4(a) and 4(b) are different, how long have you been in the country of your current residence?

6. What is your native language? (If you grew up with more than one language, please specify)

7. Do you speak a second language?___ YES my second language is______________________________.___ NO (If you answered NO, you need not to continue this form)

8. If you answered YES to question 6(b), please specify the age at which you started to learn your second language in the following situations (write age next to any situation that applies).

At home _____

In school _____

After arriving in the second language speaking country _____

9. How did you learn your second language up to this point? (check all that apply)

Mainly through formal classroom instruction _____

Mainly through interacting with people _____

A mixture of both _____ Other (specify) _____

10. List all foreign languages you know in order of most proficient to least proficient. Rate your ability on the following aspects in each language. Please rate according to the following scale (write down the number in the table):

very poor	poor	fair	functional	good	very good	native-like
1 _____	2 _____	3 _____	4 _____	5 _____	6 _____	7 _____

Language	Reading proficiency	Writing proficiency	Speaking fluency	Listening ability

11. Provide the age at which you were first exposed to each foreign language in terms of speaking, reading, and writing and the number of years you have spent on learning each language.

Language	Age first exposed to the language			Number of years learning
	Speaking	Reading	Writing	

12. Do you have a foreign accent in the languages you speak? If so, please rate the strength of your accent on a scale from 1 (not much of an accent) to 7 (very strong accent).

Language	**Accent (circle one)**	**Strength**
	Y N	
	Y N	
	Y N	

PART B

13. What language do you usually speak to your mother at home? (If not applicable for any reason, write N/A)

14. What language do you usually speak to your father at home? (If not applicable for any reason, write N/A)

15. What languages can your parents speak fluently? (If not applicable for any reason, write N/A) Mother: ____________________________ Father: _____________________________

16. What language or languages do your parents usually speak to each other at home? (If not applicable for any reason, write N/A)

17. Write down the name of the language in which you received instruction in school, for each schooling level:

Primary/Elementary School __________Secondary/Middle School __________High School _________ College/University _________

18. Estimate, in terms of percentages, how often you use your native language and other languages per day (in all daily activities combined):
Native language _____%Second language ______%Other languages ______% (specify: ____________________)(Total should equal 100%)

19. Estimate, in terms of hours per day, how often you watch TV or listen to radio in your native language and other languages per day.

Native language _____ (hrs) Second language ________ (hrs) Other languages ___________________________ (specify the languages and hrs)

20. Estimate, in terms of hours per day, how often you read newspapers, magazines, and other general reading materials in your native language and other languages per day.

Native language _____ (hrs) Second language ________ (hrs) Other languages ___________________________ (specify the languages and hrs)

21. Estimate, in terms of hours per day, how often you use your native language and other languages per day for work or study related activities (e.g., going to classes, writing papers, talking to colleagues, classmates, or peers).

Native language _____ (hrs) Second language ________ (hrs) Other languages ___________________________ (specify the languages and hrs)

22. In which languages do you usually:

Add, multiply, and do simple arithmetic? _______________ Dream? ________________Express anger or affection? _________________________

23. When you are speaking, do you ever mix words or sentences from the two or more languages you know? (If no, skip to question 25).

23. When you are speaking, do you ever mix words or sentences from the two or more languages you know? (If no, skip to question 25).

24. List the languages that you mix and rate the frequency of mixing in normal conversation with the following people, on a scale from 1 (mixing is very rare) to 5 (mixing is very frequent). Write down the number in the box.

Relationship	**Languages mixed**	**Frequency of mixing**
Spouse/family members		
Friends		
Co-workers		

25. In which language (among your best two languages) do you feel you usually do better? Write the name of the language under each condition.

	At home	At work
Reading	_______	_______
Writing	_______	_______
Speaking	_______	_______
Understanding	_______	_______

26. Among the languages you know, which language is the one that you would prefer to use in these situations?

At home _______ At work ______ At a party _______

In general _______

27. If you have lived or travelled in other countries for more than three months, please indicate the name(s) of the country or countries, your length of stay, and the language(s) you learned or tried to learn.

28. If you have taken a standardised test of proficiency for languages other than your native language (e.g., TOEFL or Test of English as a Foreign Language), please indicate the scores you received for each.

29. If there is anything else that you feel is interesting or important about your language background or language use, please comment below

Appendix F– International Picture Naming Project (IPNP) Studies

Bates, E., D'Amico, S., Jacobsen, T., Székely, A., Andonova, E., Devescovi, A., Herron, D., Ching Lu, C., Pechmann, T., Pléh, C., Wicha, N., Federmeier, K., Gerdjikova, I., Gutierrez, G., Hung, D., Hsu, J., Iyer, G., Kohnert, K., Mehotcheva, T., Orozco-Figueroa, A., Tzeng, A. and Tzeng, O. (2003). Timed picture naming in seven languages. *Psychonomic Bulletin and Review*, 10(2), pp.344-380.

Szekely, A., Daminico, S., Devescovi, A., Federmeier, K., Herron, D., Iyer, G., Jacobsen, T., Arevalo, A., Vargha, A. and Bates, E. (2005). Timed action and object naming. *Cortex*, 41(1), pp.7-25.

Székely, A., D'Amico, S., Devescovi, A., Federmeier, K., Herron, D., Iyer, G., Jacobsen, T. and Bates, E. (2003). Timed picture naming: Extended norms and validation against previous studies. *Behavior Research Methods, Instruments, and Computers*, 35(4), pp.621-633.

Szekely, A., Jacobsen, T., D'Amico, S., Devescovi, A., Andonova, E., Herron, D., Lu, C., Pechmann, T., Pléh, C., Wicha, N., Federmeier, K., Gerdjikova, I., Gutierrez, G., Hung, D., Hsu, J., Iyer, G., Kohnert, K., Mehotcheva, T., Orozco-Figueroa, A., Tzeng, A., Tzeng, O., Arévalo, A., Vargha, A., Butler, A., Buffington, R. and Bates, E. (2004). A new on-line resource for psycholinguistic studies. *Journal of Memory and Language*, 51(2), pp.247-250.

Appendix G – International Picture Naming Project (IPNP) picture sources

Abbate, M.S., and La Chappelle, N.B. (1984a). *Pictures, please! A language supplement.* Tucson, AZ: Communication Skill Builders.

Abbate, M.S., and La Chappelle, N.B. (1984b). *Pictures, please! An articulation supplement.* Tucson, AZ: Communication Skill Builders.

Dronkers, N. (personal communication.) Picture set used by N. Dronkers.

Dunn, L.M., and Dunn, L.M. (1981). *Peabody Picture Vocabulary Test - Revised.* Circle Pines, MN: American Guidance Service.

Kaplan, E., Goodglass, H., and Weintraub, S. (1983). *Boston Naming Test.* Philadelphia: Lee and Febiger.

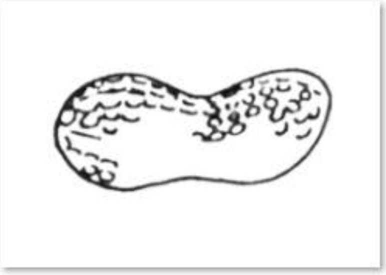
Max Planck Institute for Psycholinguistics, Postbus 310, NL-6500 AH Nijmegen, The Netherlands.

Obler, L.K. and Albert, M.L. (1986). *The Action Naming Test.* Boston: VA Medical Center. https://crl.ucsd.edu/experiments/ipnp/sources.html

Oxford Junior Workbooks. (1965). Oxford: Oxford University Press.

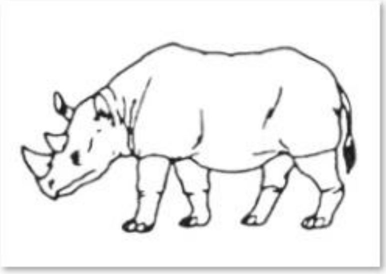
Snodgrass, J.G., and Vanderwart, M. (1980). A standardized set of 260 pictures: Norms for name agreement, familiarity and visual complexity. *Journal of Experimental Psychology: Human Learning and Memory*, 6, pp.174-215.

Appendix H – IPNP Stimuli Examples

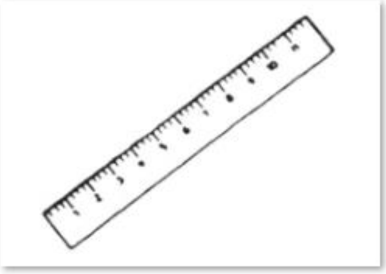


peanut

pencil



rhino

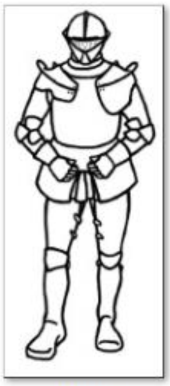


ruler

Appendix I – Added Stimuli (Researcher's Insert)

fairy

fist



Knight

Laptop

Appendix J – Eye-Tracking Experiment Image List

Critical Trial Pairs are seen in Bold

Image 1 (Critical Target)	Image 2 (competitor/ distractor)	Image 3 (distractor)	Image 4 (distractor)
Lion	**Drawer**	Fish-tank	Backpack
Bath	**Baby**	Band-Aid	Church
Beard	**Broom**	Car	Bat
Fairy	**Window**	Hose	Crab
Skirt	**Shoe**	Jump-rope	Clock
Vase	**Wine**	Crib	Map
Spoon	**Mirror**	Nail	Hamburger
Mushroom	**Sailor**	Boat	Microscope
Slide	**Snake**	Curtains	Pumpkin
Slipper	**Snail**	Pants	Box
Button	**Sofa**	Rocket	Hair
Fist	**Fish**	Queen	Fire hydrant
Ladder	**Candy/ Sweet**	Crackers	Nest
Sun	**Bag**	Bone	Mailbox
Lettuce	**Blade**	Parrot	Brush
Oak	**Grandma**	Panda	Sink
Highway	**Shark**	Lamp	Hoof
Knight	**Sewing machine**	Dress	Spaghetti
Desert	**Lid**	Girl	Globe
Saddle	**Scarf**	Shell	Comb
Arrow	Balloon	Hat	Squirrel
Bench	Anchor	Horse	Square
Bird	Axe	Carrot	Stairs
Bomb (cognate)	Turkey	Jug	Star
Bridge	Aeroplane	Key	Stove
Bucket	Camel	Toothbrush	Strawberry
Cactus	Bear	Peanut	Swing
Canoe	Bell	Lobster	Teapot
Castle	Belt	Iron	Tank
Chain	Bottle	Mountain	Turkey
Cheese	Butterfly	Pillow	Tennis racket
Drum	Bread	Necklace	Tent
Dustpan	Bow	Peacock	Thumb
Egg	Coat	Mop	Tiger
Elephant	Barrel	Peas	Telescope
Fan	Chicken	Pool	Lock
Fire	Plate	Ladybug	Tractor
Ghost	Cherry	Tree	Penguin
Helmet	Chair	Pig	Toaster
Ice-Cream	Candle	Pencil	Turtle
Jacket	Cloud	Fox	Trophy
King	Flower	Piano	Truck
Kite	Ear	Rhino	Toilet
Knot	Cow	Banana	Towel
Lawnmower	Crocodile	Safety pin	Triangle

Leaf
Letter
Lighthouse
Lizard
Llama
Magnet
Monkey
Mouse
Music
Needle
Octopus
Pear
Puzzle
Tie
Wood

Duck	Purse	Whistle
Dog	Plug	Umbrella
Doll	Scissors	Wolf
Door handle	Roller-skate	Volcano
Crown	Rope	Vacuum
Circle	Rose	Whale
Eye	Present	Watering can
Fence	Pizza	Watch
Saw	Robot	Worm
Corn	Sheep	Wheelchair
Fridge	Skateboard	Waiter
Frog	Skis	Witch
Giraffe	Soldier	Tweezers
Gun	Snowman	Zebra
Handcuffs	Spider	Cake

Appendix K – Language Group Fixations to Target Vs. Critical Object

(Intercept)	27.63***
	(1.69)
L1 English	28.63***
	(1.69)
Object Type Target	40.51***
	(1.68)
ot1	1037.17***
	(61.94)
ot2	712.34***
	(42.38)
ot3	297.03***
	(17.32)
ot4	47.65***
	(3.40)
L1 English:Object Type Target	39.26***
	(1.68)
L1 English:ot1	1042.72***
	(61.94)
L1 English:ot2	708.71***
	(42.38)
L1 English:ot3	288.73***
	(17.32)
L1 English:ot4	55.42***
	(3.40)
Object Type Target:ot1	1431.96***
	(61.58)
Object Type Target:ot2	979.46***
	(42.14)

Object Type Target:ot3	402.16***
	(17.21)
Object Type Target:ot4	61.17***
	(3.38)
L1 English:Object Type Target:ot1	1431.49***
	(61.58)
L1 English:Object Type Target:ot2	974.65***
	(42.14)
L1 English:Object Type Target:ot3	396.13***
	(17.21)
L1 English:Object Type Target:ot4	77.74***
	(3.38)
***p < 0.001, **p < 0.01, *p < 0.05, °p < 0.1	

Appendix L – Language Group Fixations to Competitor Object Vs. Adjacent Distractor Object

(Intercept)	-11.00***
	(1.14)
L1 English	-8.37***
	(1.14)
Object Type Competitor	-2.33*
	(1.13)
ot1	-319.06***
	(41.54)
ot2	-219.46***
	(28.43)
ot3	-92.68***
	(11.62)
ot4	-15.19***
	(2.28)
L1 English:Object Type Competitor	-2.38*
	(1.13)
L1 English:ot1	-312.26***
	(41.54)
L1 English:ot2	-219.94***
	(28.43)
L1 English:ot3	-92.16***
	(11.61)
L1 English:ot4	-19.48***
	(2.28)
Object Type Competitor:ot1	-89.02*
	(41.30)
Object Type Competitor:ot2	-61.46*
	(28.26)

Object Type Competitor:ot3	-27.05*
	(11.55)
Object Type Competitor:ot4	-4.41°
	(2.27)
L1 English:Object Type Competitor:ot1	-87.37*
	(41.30)
L1 English:Object Type Competitor:ot2	-61.87*
	(28.26)
L1 English:Object Type Competitor:ot3	-26.91*
	(11.55)
L1 English:Object Type Competitor:ot4	-6.52**
	(2.27)
***$p < 0.001$, **$p < 0.01$, *$p < 0.05$, °$p < 0.1$	

Appendix M – Proficiency and Object-Type Fixations

(Intercept)	0.62***
	(0.13)
Proficiency	7.21***
	(0.53)
Object Type Target	2.96***
	(0.12)
ot1	58.33***
	(4.78)
ot2	53.71***
	(3.90)
ot3	32.73***
	(2.12)
ot4	-1.91**
	(0.67)
Proficiency:Object Type Target	7.92***
	(0.52)
Proficiency:ot1	280.13***
	(20.62)
Proficiency:ot2	208.01***
	(16.17)
Proficiency:ot3	89.84***
	(8.02)
Proficiency:ot4	17.29***
	(2.03)
Object Type Target:ot1	69.20***
	(4.76)
Object Type Target:ot2	59.99***
	(3.87)
Object Type Target:ot3	33.33***
	(2.10)

Object Type Target:ot4	-10.06***
	(0.66)
Proficiency: Object Type Target:ot1	305.67***
	(20.48)
Proficiency: Object Type Target:ot2	227.84***
	(16.04)
Proficiency:Object Type Target:ot3	100.76***
	(7.95)
Proficiency:Object Type Target:ot4	20.44***
	(2.01)
***p < 0.001, **p < 0.01, *p < 0.05, °p < 0.1	

Appendix N – Age of Acquisition (AoA) and Object-Type Fixations

(Intercept)	-1.61***
	(0.31)
AOA	-0.99*
	(0.49)
Object Type Target	0.69*
	(0.30)
ot1	-31.59**
	(11.91)
ot2	-19.39*
	(9.22)
ot3	-4.01
	(4.51)
ot4	-10.83***
	(1.15)
AOA: Object Type Target	-0.84°
	(0.49)
AOA:ot1	-45.03*
	(19.24)
AOA:ot2	-39.01*
	(15.17)
AOA:ot3	-19.49**
	(7.51)
AOA:ot4	-4.37*
	(1.88)
Object Type Target:ot1	-24.04*
	(11.81)
Object Type Target:ot2	-18.22*
	(9.14)

Object Type Target:ot3	-7.55°
	(4.47)
Object Type Target:ot4	-20.43***
	(1.14)
AOA: Object Type Target:ot1	-39.89*
	(19.11)
AOA: Object Type Target:ot2	-39.20**
	(15.04)
AOA: Object Type Target:ot3	-23.35**
	(7.45)
AOA: Object Type Target:ot4	-5.99**
	(1.86)
***p < 0.001, **p < 0.01, *p < 0.05, °p < 0.1	