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Two languages, one mind: How accent and lexical stress modulate bilingual language activation

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Chapter 1

Abstract & Introduction

1.1. Abstract

Bilingual cross-language activation has been the subject of substantial research over the last two decades. Evidence supporting the idea that when a bilingual processes speech in one language, the other language is activated has been fundamental in shaping our understanding of whether these languages are discrete systems, or represented jointly in an integrated lexicon.

A growing body of evidence for bilingual language co-activation has used electrophysiological methods (ERPs) to reveal implicit activation of the native (L1) language in the absence of conscious awareness and behavioural effects. Here, I investigate how two aspects of spoken language phonology, namely accent and lexical stress, influence activation of the native language when highly-proficient bilinguals process second language speech. Furthermore, based on a review of key aspects of recent literature on bilingual language co-activation and phonological processing, I propose that reconsideration of our current understanding of the ERP correlates of phonological mapping may be required.

In Studies 1 and 2 we explored how accent influences activation of L1 phonological and semantic representations. In Study 1, Welsh-English bilinguals made relatedness decisions on English word pairs, unaware that some concealed a phonological overlap via Welsh translation. We found a facilitatory effect of accent, such that priming between these otherwise unrelated word pairs was facilitated by the presence of a Welsh accent. Results suggest that for these Welsh-English bilinguals, activation of the L1 was elicited by the presence of a Welsh accent. In Study 2, we went on to investigate whether this same facilitatory effect occurred for translation links at the semantic level. German-English bilinguals listened to English sentences produced by a native English or native German speaker that ended in a visually presented target word. In the critical condition, target words that were unexpected in English translated to polysemous German words. The alternate meaning of these words was congruent in the context of the English sentence. We found no effect of accent, nor a difference in responses to correct-via-polysemy targets as compared to a control condition. Results are discussed both in terms of study design and models of bilingual language activation.

In Studies 3 and 4 we investigated how suprasegmental lexical stress influences L1 activation. Languages that feature stress are generally divided into those in which stress is variable, that is, occurring on any given syllable, or fixed according to certain linguistic rules. This difference in stress systems is thought to affect the mechanisms by which bilinguals process lexical stress. In Study 3 we tested native English and Welsh-English bilingual participants to determine whether the presence of Welsh stress patterns heightened the activation of L1 representations. Our findings were inconclusive. Based on limitations in the design of Study 3, we designed and conducted Study 4, in which we tested how stress influences L1 activation, and incorporated an accent manipulation to explore how the two factors may differentially influence this effect. We found that whilst accent heightened L1 activation, lexical stress did not. However, we found a significant main effect of stress compatible with prior findings, suggesting that stress-deaf individuals process lexical stress on the basis of stored pre-lexical templates.

Considered together, our results suggest that suprasegmental cues such as accent and lexical stress play a role in bilingual language processing, and that this role may be underrepresented in current models of bilingual lexical access. Furthermore, our results highlight that the differential influence these factors have may depend on language background, proficiency, and exposure, suggesting that bilingual word recognition mechanisms may differ substantially across different bilingual populations.

1.2. Introduction

It is thought that when a bilingual individual hears a word in their second language (L2), they experience activation of their native language (L1). The research encompassed in this thesis intends to further develop our understanding of this cross-language activation, exploring the contributions of accent and lexical stress. Through four studies investigating the nature of cross-language lexical access, in particular its constraints, facilitators and limitations, this thesis asks the following questions:

Firstly, does L1 accent heighten activation of first-language representations in a solely L2 context? In Studies 1, 2 and 4, we explore the potential influence of L1 accent on bilingual cross-language activation. Over the last two decades, a host of EEG and eye-tracking studies have shown the activation of a bilingual's native language when they process words in their second language (Marian & Spivey, 2003; Spivey & Marian, 1999; Thierry & Wu, 2007; Wu & Thierry, 2010). In particular, this access to the L1 has been demonstrated to occur for L1 translation equivalent of the L2 word (Thierry & Wu, 2007). In three studies, we explore how native language features, specifically L1 accent, influence this process. Current research suggests that the presence of an L1 accent in L2 speech may either reduce overall speech intelligibility, or increase activation of the L1 (Lagrou et al., 2011, 2013). Despite this, most activation models overlook the potential for language-specific cues within the acoustic input to modulate language co-activation in bilinguals. In these three studies we tease apart the effects of accent on L2 intelligibility, and explore how the presence of an L1 accent modulates the activation of L1 language representations.

Secondly, how does lexical stress affect cross-language activation? And, more specifically, how is variable stress processed by L1 speakers of a fixed-stress language? Individuals for whom native language stress patterns are based upon phonological rules, such as syllabic structure, are thought to acquire their stress systems pre-lexically, that is, prior to the establishment of a lexicon (Dupoux, Peperkamp, & Sebastián-Gallés, 2010; Peperkamp, 2004; Peperkamp & Dupoux, 2002). Furthermore, recent research suggests that this manner of acquisition may result in the formation of pre-lexical stress templates, in which lexical stress is applied based on pre-set patterns, rather than encoded in individual lexical entries (Domahs et al., 2012; Honbolygó et al., 2004; Honbolygó & Csépe, 2013). In Studies 3 and 4, we explore three aspects of lexical stress processing in a stress-deaf population. Considering effects of suprasegmental stress cues in word recognition, we set out to determine (Cooper, Cutler, & Wales, 2002; Alexandra Jesse, Poellmann, & Kong, 2017): (a) The degree to which lexical stress affects word processing in stress deaf individuals; (b) How stress-processing strategies of stress-deaf bilinguals (i.e., who are thought to have pre-lexical templates) affect the processing of stress in the L2; and (c) The potential of L1-approximate stress patterns in a second language to result in heightened activation of L1 representations.

The third question asked in this thesis regards the extent of cross-linguistic translation activation in bilinguals. A common marker of the goodness of fit in word recognition models is their ability to account for the effects of cross-linguistic overlap on non-target language activation. However, there is a paucity of studies investigating whether L1 access in an L2 context is restricted to the activation of phonological and orthographic representations, or whether this spreads to the semantic level. Whilst certain models of bilingual language activation (e.g., BLINCS, see Chapter 2 for a review) posit an integrated semantic and conceptual network, evidence to support this notion is limited and, in part, conflicting. Study 4 asks how language activation spreads through an integrated lexicon, investigating whether accent drives the spread of coactivation beyond the phonological and orthographic levels to the semantic network, in an attempt to further understanding of semantic activation relevant to a number of bilingual lexical activation models.

Finally, alongside a review of recent literature on how phonological retrieval and processing fit within an electrophysiological timeline of word recognition, the combined work in this thesis aims to offer novel insight into the ERP correlates of phonological processing. I discuss the degree to which new evidence challenges the notion of a specific electrophysiological correlate of phonological expectations formed by the human brain, i.e., the phonological mapping negativity (PMN), and instead highlight a general sensitivity to phonological processing within a time window range encompassing the PMN.

Chapter 2

Models, constraints & methods

2.1. Language processing

Lexical access is one of the basic processes that underpin language comprehension, through which the sound-semantic connections within the brain are activated. Each word, and corresponding information about its form is stored within the ‘lexicon’, or mental vocabulary. Lexical entries within this system are thought to consist of two parts; form and lemma, with the former concerning orthographic and phonological representations, and the latter concerning the word’s syntactic properties and a range of semantic representations (Levelt, 1993; Levelt et al., 1999). During a conversation we hear series of phoneme combinations, which result in the activation of representations within the lexicon that fit this limited input. The process of narrowing down these activated, competing lexical entries is subject to contrasting theories outlined by a number of models that attempt to explain the process of spoken word recognition.

2.1.1. Models of language activation

Two main types of language processing models have been put forward: distributed or localist models. Thomas & van Heuven (2005) define localist models as those generally featuring interconnected hierarchical structures, with excitatory or inhibitory bottom-up or top-down connections. Bottom-up connections are those which originate from sensory input, whilst top-down refers to responses driven by cognition. Such excitatory or inhibitory connections are hardwired and permanent, and through these structures the trajectory of activation post-input can be studied. As such, no learning occurs, as connectivity is pre-established (Filippi et al., 2014). Localist models are generally evaluated based on two forms of output; accuracy (the proportion of trials for which the model generates the correct solution) and response time (the number of cycles required in order for the model to generate a solution). In contrast to the development of activation over time featured in localist models, in distributed models this is replaced with a single pass through the network. As opposed to cycling activation, resulting in response time data, distributed models use a specific set of calculations in order to compute activation values (Thomas & Van Heuven, 2005: 221). In distributed models, connections are learnt, as opposed to being hardwired, and are thus more compatible with investigations into development and change within language systems (Thomas, 2002).

The current chapter outlines a number of prominent distributed and localist models of word recognition, initially focussing on monolingual models that serve as a foundation for the bilingual processing models subsequently outlined.

2.1.2. Monolingual lexical access

2.1.2.1. The Cohort Model

The Cohort Model of lexical retrieval (Cole & Jakimik, 1980; Marslen-Wilson, 1984; Marslen-Wilson & Tyler, 1980) proposes that lexical retrieval involves three key stages; access, selection, and integration. During speech perception, each segment of auditory input results in the activation of a cohort of competing candidates. As additional phonological information becomes available (i.e. as the spoken word unfolds), the successive reduction in compatible words means that this set of lexical competitors decreases, with recognition occurring when only one candidate remains. For example, the word 'butterfly' becomes recognisable at the point that the speaker produces 'butterf', as no other word fits with this string of sounds. Up until this stage, called the recognition point, a number of lexical entries featuring initial phonemic strings that are compatible with the target word, i.e. 'button', 'butter', 'buttercup' etc. compete with 'butterfly'.

In the Cohort Model, competition effects are bottom-up, occurring only among words that overlap from the initial phonemes onwards (competing words form a 'cohort'). Support for the model comes from a number of studies demonstrating that the processing of a word is affected when it is preceded by an orthographically or phonologically overlapping prime, e.g., the target *cat* preceded by the prime *car* (Dumay et al., 2001; Praamstra, Meyer, & Levelt, 1994; Praamstra & Stegeman, 1993; Radeau, Besson, Fonteneau, & Castro, 1998). Similarly, the model is compatible with findings that words with greater neighbourhood density; that is, words which share their sound form with multiple other similar sounding words; result in greater rates of speech errors (Luce & Pisoni, 1998; Vitevitch, 2002; Vitevitch & Sommers, 2003). Such evidence supports the notion that interference results from multiple items competing for recognition, manifesting as greater speech errors and increased reaction time.

Despite this, the Cohort model struggles to explain effects found for other forms of overlap (e.g. onset vs rhyme), and for lexical frequency. Both onset overlap (e.g., *car* – *cat*) and rhyme overlap (e.g., *cone* – bone) have been shown to influence language processing (O'Seaghdha & Marin, 2000). Thus, the view that competition arises solely for words sharing the initial phonemes appears too restrictive. However, the possibility that onset overlap results in greater competition than rhyme overlap is supported in part by research demonstrating that competitors sharing word-initial features result in greater periods of lexical competition than rhyme overlap (Sevald & Dell, 1994; Sullivan, 1999). For example, Sevald and Dell (1994) tested participants in a word recitation task, observing that when words shared initial phonemes, task performance decreased, but was facilitated when final phonemes were shared. Despite this, evidence of rhyme overlap competition (Wheeldon, 2003) does contradict the assumption that competition only occurs between words that overlap in onset, with competition dissipating following the rejection of cohort-overlap competitors. Similarly, the model struggles to account for the influence of lexical frequency on word recognition in the case of words matched for their recognition point (Taft & Hambly, 1986). Instead, alternative models that permit competition from a greater range of lexical competitors, incorporating effects of phonological competition beyond the onset and lexical frequency information provide a more comprehensive account.

2.1.2.2. Neighbourhood Activation Model

The Neighbourhood Activation Model (NAM; Luce & Pisoni, 1998) broadens the Cohort Model to incorporate a greater range of lexical competition. The NAM was presented as an attempt to specify to a greater degree the factors responsible for discrimination of competitor words based upon phonological patterns. This discrimination is defined as a function word intelligibility, neighbourhood confusability, and lexical frequency that enable the differentiation of a target word from similar acoustic-phonetic representations within memory.

According to the NAM, the process of word recognition involves three stages post stimulus-input: activation of acoustic-phonetic information, activation of word decision units, and retrieval of higher-level lexical information such as frequency. The initial activation of acoustic-phonetic information includes all patterns irrespective of correspondence to real words. This pattern activation, irrespective of lexicality, was intended to address the Cohort Model's inability to explain listeners' capability to recognise the acoustic-phonetic form of both novel words and non-words (Luce & Pisoni, 1998). Following this, word decision units associated with acoustic-phonetic patterns that correspond to words in memory are activated. These word decision units are then responsible for incorporating and monitoring both bottom-up input information and higher-level information such as lexical frequency, and operate by gating the lexical information available to the system (Morton, 1979).

In the NAM, competitors are defined as words that differ maximally from the target lexeme through a change affecting a single phoneme through deletion, addition or substitution (Greenberg & Jenkins, 1964). As such, the model succeeds in accounting for the greater range of competitors empirically shown to influence lexical activation. Despite this, the NAM can only extend to discrete input in the form of single words. In speech, breaks do not consistently correspond to word boundaries, and as such activation deriving from embedded words spanning over boundaries (e.g., *thin* embedded in the utterance *both inside*) is not fully explained by a model limited to single word recognition. Instead, a model able to account for activation of words matching any part of speech input is required to fully explain naturalistic spoken word recognition.

2.1.2.3. TRACE

TRACE (Elman & McClelland, 1988; McClelland & Elman, 1986) was the first highly interactive model of spoken word recognition to be computationally implemented. Computational modelling enables the simulation of environments in which factors can be manipulated in order to predict their effects on language processing (Shook & Marian, 2013). TRACE has three nodes (processing units), namely a feature, a phoneme, and a word layer. The model was seminal given its ability to instantiate activation of multiple word candidates matching any part of speech input (Weber & Scharenborg, 2012). In TRACE, the three nodes are linked via excitatory and inhibitory connections that increase or decrease activation based on speech input. At the feature level, phonemic strings within the input are converted into multidimensional vectors based upon the acoustic-phonetic properties of the sounds. Activation is proportional, relative to the degree of fit between input and nodes, and proposed to spread from the feature to the phoneme layer via bottom-up activation (**see Fig. 1**). At the phoneme level, both bottom-up information from the feature layer and top-down inhibitory connections from the word layer narrow down the spread of activation. Finally, inhibition of incompatible targets, and the highest level of activation of a particular candidate results in word identification. Whilst the model improves upon the NAM's limitation of single word recognition, the plausibility of its architecture has been called into question. Whilst the recognition and retrieval of individual spoken, or written words is simplified by ease with which the word's onset is identifiable, this is not the case for speech. To overcome the lack of reliable onset cues, TRACE proposes that for each possible word-onset point in a string of speech, a new lexical network begins. Thus, a spoken sentence consisting of 40 phonemes, would require up to 40 lexical networks in order to process it. Within this duplication of networks, the activation of lexical competitors occurs continually. The plausibility of this duplication of the lexical network, and in particular the limitations it would put upon utterance length has been called into question (Norris, 1994).

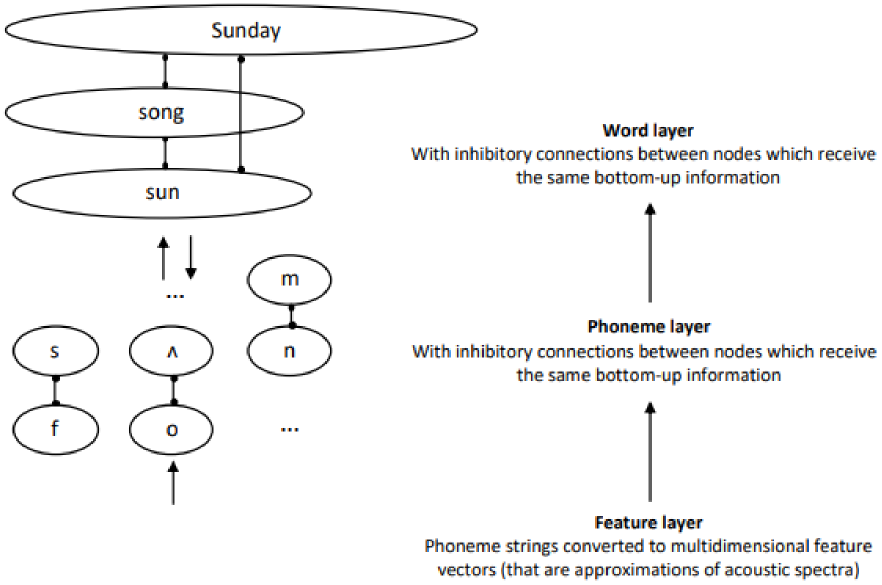

Figure 1. Recognition process of the word *sun* by TRACE adapted from Weber & Scharenborg (2012: 391)

2.1.2.4. Shortlist

Whilst very similar to TRACE, Shortlist (Norris, 1994) is a feed-forward only model featuring no top-down connection from the word to phoneme level. Instead, the model has bidirectional connections within its levels. Shortlist features two stages of word recognition: (a) the establishment of a short list of a maximum of 30 lexical candidates matching the speech input based on bottom-up activation, with a unique shortlist established for each phoneme activated, and (b) the entering of candidates into an interactive network of word units, in which words activated by the same segment of input are connected through inhibitory links and compete to narrow down contenders until word recognition is achieved (Weber & Scharenborg, 2012). There are a number of distinct advantages of the Shortlist model. Firstly, it improves upon the architecture of TRACE in which each possible word-onset point generates a new lexical network by presenting with a considerably more manageable structure in which the generation of a shortlist of word candidates (and resulting competition) is separated into two distinct stages of processing.

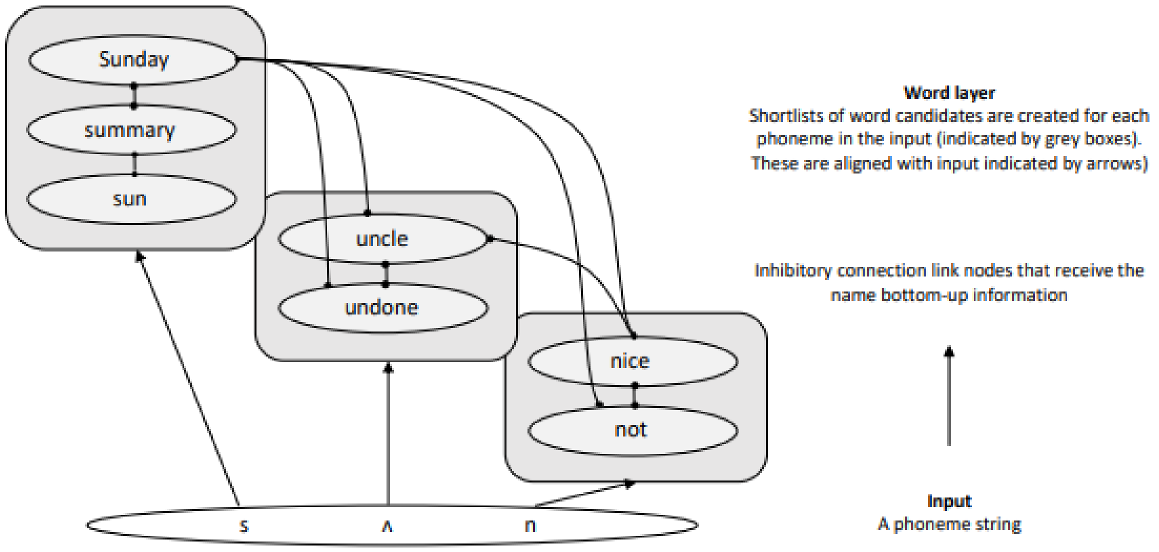

Figure 2. Recognition process of the word *sun* by Shortlist (adapted from Weber & Scharenborg, 2012: 392)

Furthermore, the model is able to account for a number of features overlooked in most models of word recognition, namely that of context and stress. This said, Shortlist is not without limitations and issues, in particular when it comes to for lexical frequency, with the model unable to take into account word frequency effects.

Instead, Shortlist-B (Norris & McQueen, 2008) presents as an updated version of the Shortlist model, hereon in referred to as Shortlist A. Shortlist-B was developed as a Bayesian model of continuous speech recognition, based upon a number of shared theoretical assumptions with Shortlist A. That is, whilst both models propose, amongst other assumptions, a feedforward architecture and the generation and competitive evaluation of a shortlist of word candidates, Shortlist-B is based on Bayesian principles. Furthermore, phoneme probabilities are generated over three time-windows per segment. Thus, Shortlist-B retains a number of key advantages of Shortlist A, whilst additionally accounting for the influence of lexical frequency and mispronunciations.

2.1.3. Bilingual lexical access

The models of word recognition introduced above concern lexical access in a single-language context. The same processes underpinning lexical retrieval in a number of monolingual models have been incorporated into models dealing with multiple languages. An originally highly debated question was whether the language systems of a bilingual are fully interconnected and should thus be represented within a single model, or whether they can be considered two discrete systems, such that bilingual language access follows the same trajectory as represented in models discussed previously, but separately for each language.

2.1.3.1. One or two language systems?

Over the last twenty years, a substantial amount research has been devoted to determining whether bilingual word recognition involves retrieval from a single, integrated lexicon in which both L1 and L2 representations are stored, or multiple discrete systems separated by language. More recently, the discussion has moved away from the idea of an “input switch”, by which the bilingual brain would activate or deactivate the non-target language. This shift was initially driven by visual language processing research into cross-linguistic orthographic priming (Bijeljac-babic et al., 1997). Lexical priming refers to a technique in which the processing or recognition of a certain word is enhanced by prior exposure to perceptually, semantically, or conceptually related stimuli. Priming is easily visible on the behavioural level, generally indexed by significantly faster responses and higher accuracy for primed or related target stimuli (Praamstra, Meyer, & Levelt, 1994; Radeau, Besson, Fonteneau, & Castro, 1998; Slowiaczek, McQueen, Soltano, & Lynch, 2000). Work in the auditory domain, whilst initially less conclusive, was strongly influenced by the seminal research of Spivey and Marian, who demonstrated cross-linguistic activation in a series of eye-tracking experiments (Marian & Spivey, 2003; Spivey & Marian, 1999). In their 1999 study, Spivey & Marian demonstrated that when listening to instructions in their L2, late Russian-English bilinguals looked briefly at distractor items that shared their phonological onset with the L2 target item in the L1. For example, upon hearing the word *marker*, bilingual participants showed increased eye movements to the picture of a stamp, which is *marka* (мáрка) in Russian. Replicating and further confirming cross-linguistic competition, the authors ran two further eye-tracking experiments controlling for language mode (Marian & Spivey, 2003), or "the state of activation of the bilingual's languages and language processing mechanisms at a given point in time" (Grosjean, 2008: 39). Examining spoken language processing in Russian-English bilinguals, the first study intended to place bilingual participants as close to a second language monolingual mode as possible, whereas their latter experiment placed participants as close to a native-language monolingual mode as feasible. The authors monitored participants' eye movements whilst they were instructed to 'pick up' one of four objects placed on a whiteboard. In four conditions, the target object was either surrounded by filler objects, or a between-language or within-language competitor. Competitor words either presented within-language phonological similarity, or cross-language phonological similarity through translation. Results of both experiments showed that, whether they were tested in their native language or their second language, Russian-English bilinguals showed within- and between-language competition. The results demonstrated that despite vigorous control of language-mode and a perceivably monolingual environment, parallel activation of the contextually inappropriate language occurred.

More recently, studies using event-related potentials in bilinguals have built a corpus of evidence for parallel access within an integrated lexicon. In their seminal papers, Thierry and Wu (2007; Wu and Thierry, 2010) demonstrated unconscious L1 access in an entirely L2 context. Whilst inter-lingual homophone and masked priming paradigms have produced strong evidence for unconscious L1 activation, a major drawback of such paradigms is that L1 activation occurs after exposure to L1 stimuli. For example, in masked priming paradigms, prime words are displayed for a very short duration, rending the word consciously imperceivable. Despite participants having no conscious knowledge of exposure to the masked word, activation results from subconscious processing and artificial activation of the L1. Similarly, in priming studies using interlingual homophones and homographs, participants are exposed, albeit in an L2 context, to the phonological or orthographic form of an existing L1 word. Consequently, although they have no explicit awareness of the process, participants are in fact exposed to the L1.

Thierry and Wu (2007) tested Chinese-English bilingual participants in a wholly L2 context in which participants were presented with English prime words, which, via translation into Chinese, concealed an orthographic and phonological overlap with critical target words. The authors observed that Chinese character repetition resulted in an N400 reduction, an event-related potential effect highly sensitive to repetition effects. The effect was interpreted as indicative that participants had accessed L1 translation equivalents in the absence of any L1 reference, and despite the absence of any behavioural effects. To disentangle the effects of character and sound-form overlap, Wu and Thierry (2010) presented participants with a similar L2 semantic relatedness paradigm and separately tested orthographic and phonological priming through the L1, finding that whilst prime-target phonological overlap in Chinese significantly modulated N400 amplitudes, orthographic overlap failed to produce a significant priming effect. The authors concluded that bilinguals access the sound form rather than the orthographic representations of L1 words when functioning in their L2.

This evidence for concurrent activation of L1 and L2 words provides the foundation for models of bilingual word recognition representing a system that is, on some level, integrated. These multilingual processing models, rather than adding further languages to a pre-existing architecture, build upon monolingual models to represent interactions between a bilingual's two languages (Shook & Marian, 2013).

2.1.3.2. *Bilingual Model of Lexical Access (BIMOLA)*

The Bilingual Model of Lexical Access (Lewy & Grosjean, 1997) is a model of bilingual auditory word recognition originally inspired by TRACE (McClelland & Elman, 1986). In BIMOLA, languages are split into discrete language-specific modules at the phoneme and lexical levels that are independent yet interconnected.

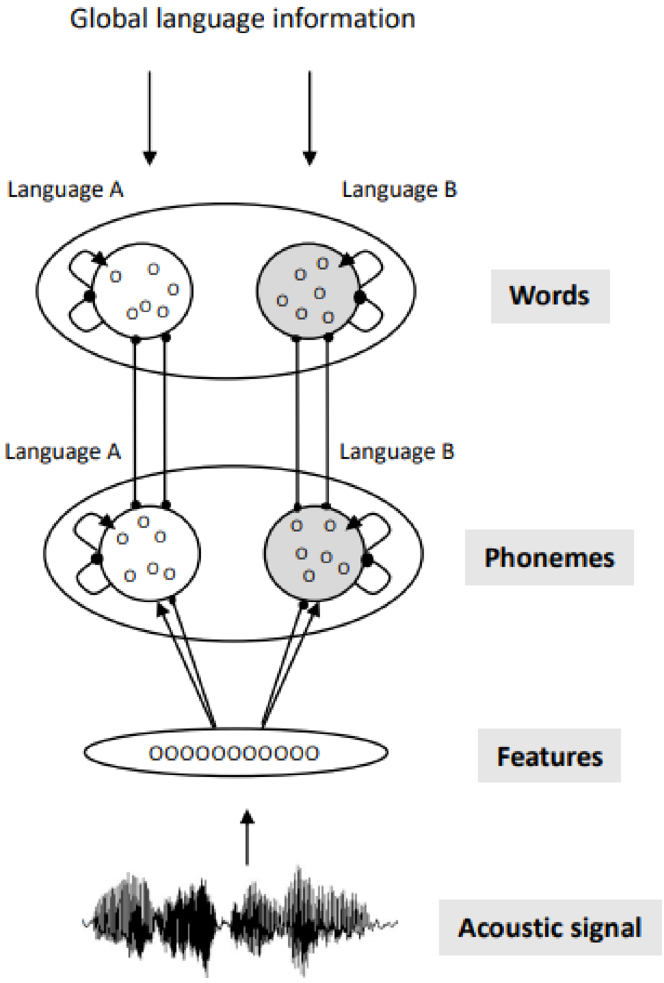

Figure 3. BIMOLA (adapted from Thomas & van Heuven, 2005)

Unlike TRACE, representations are not duplicated continuously as input unfolds. BIMOLA is a localist model, with an architecture of distinct layers consisting of feature units or words, and a language distinction from the phoneme level upwards. On a functional level, this results in competition at the lexical and phonemic levels that occurs solely between units within the same language. This presents a potential limitation in the ability of BIMOLA to account for both contextual effects and that of interlingual homographs and cognates (Thomas & van Heuven, 2005). This is resolved by the incorporation of a global top-down language information level, which serves as a mechanism to activate words from a target language. This top-down mechanism has been suggested to effectively act as an implicit implementation of language nodes, albeit with a solely inhibitory function (Thomas & van Heuven, 2005).

2.1.3.3. The Bilingual Interactive Activation Models (BIA, BIA+)

The Bilingual Interactive Activation model (BIA; Dijkstra, Jaarsveld, & Brinke, 1998; Grainger & Dijkstra, 1992) began as a development of the monolingual Interactive Activation model. The model, which assumes language-nonselective access, features an integrated lexicon and focusses on the visual and orthographic aspects of speech processing. Similar in structure to TRACE, the BIA comprises three levels; a feature, letter, and word node, which are linked via inhibitory and excitatory connections. Activation flows upwards, with nodes consistent with the input activated, whilst incompatible nodes are inhibited. Words are recognised once the target word achieves the necessary activation criterion. Whilst words from both a bilingual's languages are incorporated in a single integrated lexicon, the model posits a language node above the lexical level, in which Welsh words (as exemplified in Figure 4) activate the Welsh language, whilst inhibitory language connections inhibit English language words. The model has been demonstrated to account for both intra- and interlingual neighbourhood density and, perhaps more interestingly considering the focus of this work, speaker proficiency, by assuming reduced frequency for second language words (Dijkstra et al., 1998). Furthermore, the model is able to account for the effects of context, with the language node influencing the correct reading of an ambiguous item such as an interlingual homograph (Thomas & van Heuven, 2005; Dijkstra et al., 1998). According to the BIA model, bottom-up information activates word nodes for both representations of a homograph.

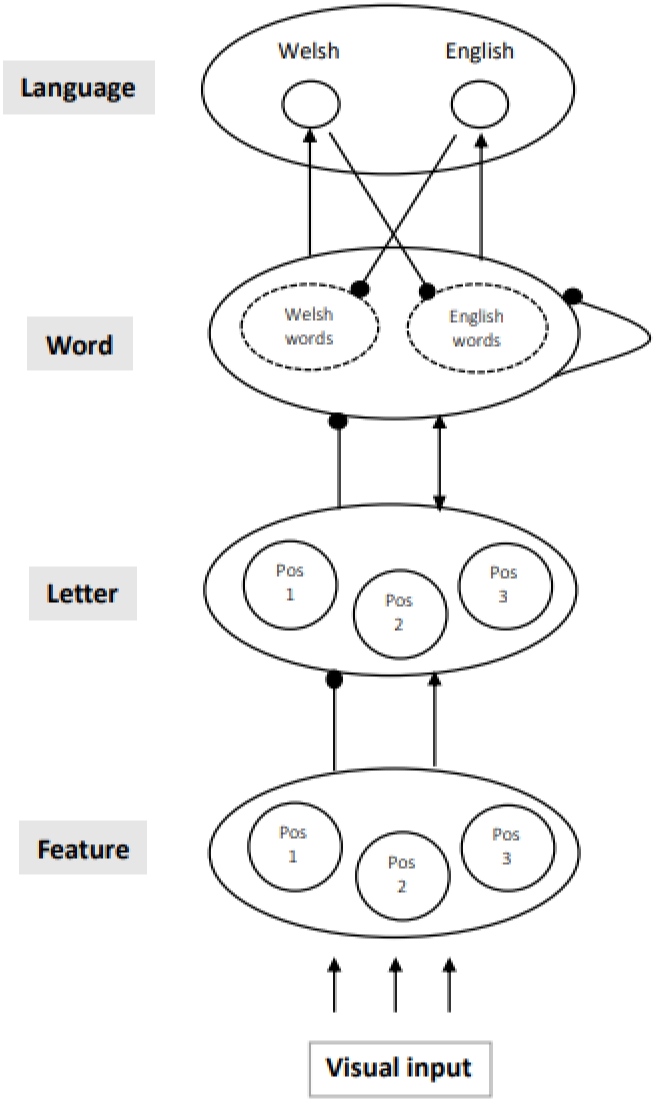

Figure 4. BIA (adapted from Dijkstra and Van Heuven, 2002). Arrows indicate excitatory connections whilst circles represent inhibitory connections.

At this level, competition between activated words results in inhibition, and as such both words remain below the recognition threshold. The inclusion of the language node level enables contextually driven top-down inhibition of the incorrect representation to take place, and consequently enables selection of the target word despite activation of its form at a sub-lexical level. More recently, Dijkstra & Heuven, (2002) adapted the BIA to form the BIA+, in which non-selective access is not only limited to orthography, but phonology and semantics. Consequently, the BIA+ model suggests that cross-linguistic overlap influences bilingual word recognition on the orthographic, phonological and semantic levels. An important distinction between the

BIA and BIA+ is the absence of top-down inhibitory connections between language nodes and word nodes, instead replacing the mechanism with a task/decision component. Dijkstra and van Heuven suggest that this task/decision system is influenced by non-linguistic context effects, defined as those arising from task demands, given instructions and expectations of the participant.

2.1.3.4. Bilingual Language Interaction Network for Comprehension of Speech (BLINCS)

The most recent of the models discussed, the Bilingual Language Interaction Network for Comprehension of Speech (BLINCS; Shook & Marian, 2013), is primarily concerned with auditory speech perception.

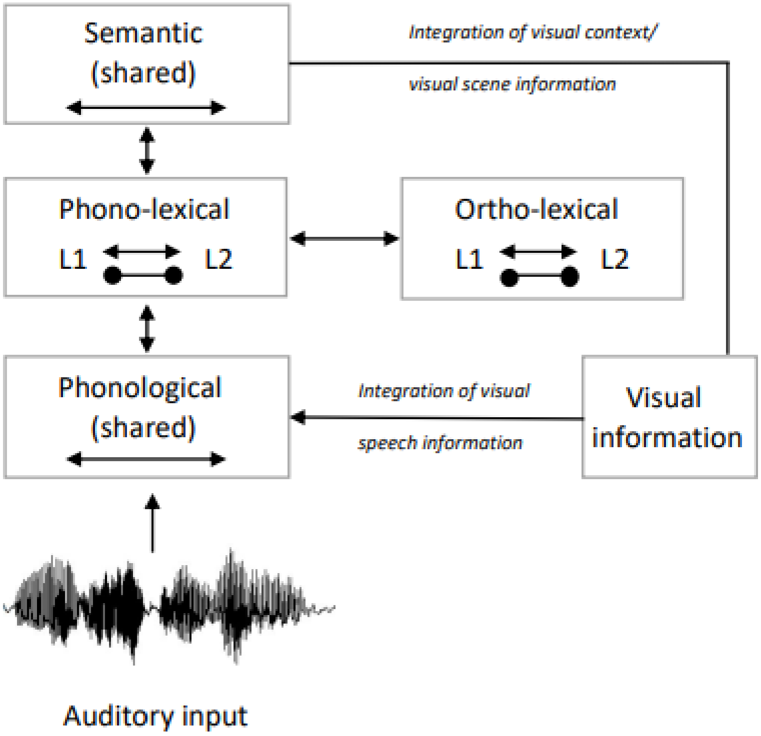

Figure 5. BLINCS (adapted from Shook & Marian, 2013).

The model features interconnected levels for phono-lexical, phonological, ortho-lexical and semantic representations, and combines the localist approach of models discussed so far with that of distributed approaches. Within the four interconnected levels that form the structure of BLINCS, word processing involves an interconnected network of self-organising maps (SOMs), a form of unsupervised learning algorithm (Kohonen, 1995). These SOMs provide input to the best-matching node through a two-way process by which the node itself is consequently amended so as to better match the input.

In contrast to distributed models, all nodes within BLINCS are bi-directionally interactive, enabling both bottom-up and top-down feedback. The model's architecture is such that both languages spoken by a bilingual share phonological and semantic networks, whilst the phono-lexical and ortho-lexical networks are separate but integrated. The shared phonological space remains consistent with evidence suggesting that language-specific phonology or orthography results in greater activation of the target language (Casaponsa et al., 2015), as the separation of languages at the phono-lexical level enables for greater activation of target language representations. At the semantic level, the model proposes an integrated semantic network, with shared representations across languages. Despite this, Shook and Marian (2013) note that evidence of an influence of cultural information on semantic representations (Ameel et al., 2005; Dong et al., 2005) necessitates further investigation into the degree of shared conceptual representations across languages and its potential influence on language processing. In simulation, BLINCS has been demonstrated capable of accounting for competition between activated words sharing onset and rhyme both within and across languages, cognates, effects of lexical frequency and that of neighbourhood size.

2.1.4. Auditory word processing: model limitations

Whilst the current chapter provides a relatively equal outline of both models of spoken and visual language processing, it is important to note that the vast majority of word processing models, both monolingual and bilingual, have primarily concerned visual language processing. Such models are quite often computationally modelled to determine, in simulated environments, how the manipulation of input (e.g., neighbourhood density, orthographic regularities, context) affects language processing. Despite this, the focus on visual language processing has, until fairly recently, left a paucity of work on auditory language processing. It is possible that this preference for visual word processing represents the relative ease with which these models can be implemented. Whilst visual word recognition involves the processing of orthographic features, their combinations and their statistical regularities, auditory word recognition may entail a host of variable, and often language specific cues. For example, considered in terms of bilingual language processing, features such as native accent, lexical stress, prosody and intonation (to name a few) may play a role in language identification, and consequently in word recognition. Thus, auditory language processing may enable a higher degree of constraint, by virtue of the multitude of cues signalling the target language of operation. In the following chapter, the notion of constraint and facilitation of word recognition is discussed, in particular in regards to two main features, lexical stress and native accent.

2.2. Constraints on Lexical Activation

The different architectures of bilingual word recognition models outlined in the previous section have important implications for an understanding of how bilinguals process more than one language. Whilst most models incorporate a lexical activation system that is to some degree integrated, the mechanisms underpinning bilinguals' successful functioning in a single-language context despite this integrated language system are still not fully understood. Consequently, recent work has begun to further explore factors that may constrain or facilitate cross-linguistic activation.

In visual word processing, studies exploring the mechanisms by which bilinguals prevent interference from a non-target language have predominantly pointed toward the role of language-specific orthography. In an early study, Rodriguez-Fornells, Rotte, Heinze, Nösselt, & Münte (2002) investigated whether word frequency in Catalan would modulate access to lexical representations of Spanish words when participants are asked to ignore Catalan words. Using ERPs and fMRI, the authors reported no effect of word frequency in Catalan, concluding that the semantic representation of ignored words can be inhibited. Such inhibition of the non-target language was proposed to have originated at the sub-lexical level, with participants using an indirect phonological access route to retrieve words from the lexicon of the target language and avoid interference. Following the publication, several papers were published highlighting the limitations of the paradigm and methodology used by Rodriguez-Fornells et al. Grosjean and Li, (2008) for instance proposed that explicit instruction to ignore Catalan words would most likely have resulted in heightened activation of the Spanish lexicon, and indeed a reduction in activation of the Catalan lexicon. Furthermore, the frequency of the Catalan words used in the study was substantially lower than that of the Spanish words (68.4 vs 95 occurrences per million). Finally, and perhaps most interestingly, the authors highlighted a series of graphemic cues that may have curtailed access to the non-target language. This idea that language-specific orthography may restrict lexical access has since been investigated in a number of additional studies providing independent support for the ability for sub-lexical orthographic cues to constrain language access.

Orfanidou and Sumner (2005) tested Greek-English participants involved in lexical decision tasks whilst manipulating orthographic specificity. Employing the partially overlapping alphabets of Greek and English to manipulate language specificity at the letter level, the authors measured switch-costs when stimuli either contained letters compatible with both languages, or letters that were uniquely Greek. Results demonstrated that reaction times in language-switch trials were significantly shorter for stimuli presented in a language-specific orthography. If word-recognition in one language can induce deactivation of lexical representations in the other, language-specific orthography may reduce the interference from non-target lexical representations. Such decrease in cross-language activation for marked words compared to unmarked words was supported more recently in research by Casaponsa et al. (2015), who investigated the influence of language-specific orthotactic regularities in a language priming task. The authors conducted a modified Reicher–Wheeler paradigm and masked translation priming experiment, in which participants were presented with naturalistically learnt L2 words that were either orthographically marked (containing language-specific bigram combinations), or unmarked (featuring orthotactic patterns acceptable in both languages). In the Reicher-Wheeler paradigm, participants were presented with a forward mask (e.g., ####) followed by a word or nonword, then a backward mask alongside two letters, and they were then asked to indicate which of the two letters appeared in the word. Results showed that reaction times (RTs) to marked stimuli (both words and nonwords) were significantly slower than those to unmarked stimuli. The authors interpreted the findings as indicative that orthography of marked stimuli received less reinforcement from spread of activation at the lexical level than unmarked stimuli containing orthographic patterns common to both Spanish and Basque. In the masked translation priming experiment, the same participants were presented with Spanish targets preceded by orthographically marked or unmarked Basque translations, and they made lexical decisions on the target words. Results revealed significant translation masked priming effects, but only for words preceded by orthographically unmarked primes, demonstrating that unconscious sensitivity to statistical orthographic regularities can yield language-selective access.

Assuming that language-specific orthographic patterns can restrict lexical access in visual word recognition, it follows that phonology may play a similar role in inhibiting or facilitating word activation in spoken word recognition. Exploring this in the context of code-switching, Fricke, Kroll, and Dussias (2016) analysed spontaneous speech production to determine whether upon anticipation of a code-switch, bilinguals were able to restrict their lexical search to the appropriate language. Analysis of production data demonstrated that in anticipation of code-switching, bilinguals produced speech at a slower rate, and with cross-language phonological influence on consonant voice onset times. Using eye-tracking, they then tested sensitivity of participants to the modulations in these features during comprehension. Reduced fixations on an interlingual distractor suggested that bilingual listeners exploited the presence of low-level phonetic cues to suppress activation of the non-target language. A similar reduction in language activation on the basis of phonetic information was reported by Ju and Luce (2004), who investigated the degree to which non-selective language activation is constrained by acoustic-phonetic information, specifically voice onset time (VOT). Voice onset time, a phonetic feature of stop consonant production, is the delay between the release of a stop consonant and the onset of glottal pulsing, or voicing, which varies in its realisation across languages. Distinctions arise in terms of the degree of aspiration present in stop consonants between languages, and the study intended to explore whether such fine-grained information could influence parallel activation in an eye-tracking experiment. The authors presented Spanish-English bilinguals with L1 words with initial voiceless stops, alongside interlingual distractors consisting of words phonologically similar to English, for example, the Spanish word *playa* (beach), which is similar to *pliers* in English. Across trials, participants heard spoken Spanish words either produced with English or Spanish-appropriate VOT. Results showed increased eye-fixations on the interlingual competitors compared to control distractors when Spanish words were produced with English-appropriate VOT. The authors noted that their results differed from prior research demonstrating parallel activation, finding that when words were produced with a Spanish-appropriate VOT, participants fixated equally on control and interlingual competitor distractors. The discrepancy in effects was attributed to the variety in onsets of the stimuli used in prior research (e.g. Spivey & Marian, 1999), and consequently a potential lack of strong acoustic cues such as voicing to inhibit cross-linguistic access. Albeit limited, the current evidence does suggest that sub-lexical phonological information plays a role in parallel access in word recognition and invites further questions as to the role of a range of acoustic-phonetic cues in lexical activation.

Whilst prior work has explored the effects of segmental phonology on lexical access, it is also possible that a range of sub-lexical suprasegmental cues might additionally influence the process of lexical activation. Behavioural research indicates that both L1 and L2 lexical access may be modulated by segmental and suprasegmental cues (Cooper et al., 2002; Jesse et al., 2017; Reinisch, Jesse, & McQueen, 2010; van Donselaar, Koster, & Cutler, 2005). Despite this, a large number of models of both monolingual and bilingual word recognition fail to take suprasegmental features into consideration in the lexical activation process. This thesis explores the role of two suprasegmental features, lexical stress and accent, and their potential to constrain or facilitate unconscious L1 activation.

2.2.1. Lexical stress

In many languages, the placement of lexical stress can fundamentally alter the perception of a word. It may be used to differentiate between the noun and verb forms of related words (*'in,sult* vs *in'sult*), or distinguish between otherwise unrelated concepts (*'con,tent* vs *con'tent*). Lexical stress is the accentuation of certain syllables in a word, rendering them more perceptually salient as a result (Cutler, 2005). In languages featuring stress, words typically have one syllable which is most prominent (primary stressed), although in some languages words of sufficient length can feature secondary, or non-primary stress. The realisation of stress varies both across and within languages and can be indicated segmentally by a reduction in the quality of unstressed vowels, or through suprasegmental alterations in fundamental frequency, duration and amplitude of the stressed syllable (Cutler et al., 1986). In certain languages, for example English, the absence of stress on a syllable is marked on the segmental level by vowel reduction, which involves changes in certain phonological qualities of the unstressed vowel sound resulting in reduced duration, intensity and salience (Harrington, 2010). Conversely, in Welsh, lexical stress is indicated by the non-prominence of the vowel, with the stressed syllable featuring shorter vowel duration relative to the ultima. Such a pattern marks Welsh as an atypical case, with reduced duration and salience generally indicating an unstressed syllable in most European languages (Cooper, 2015). Despite vowel quality distinctions appearing in a number of languages as a feature of lexical stress, vowel reduction is not a necessary a prerequisite for denoting the absence of stress. Beyond segmental indicators, suprasegmental cues such as frequency, duration and amplitude, perceptually correlating to pitch, timing and loudness (Cutler, 2005), can indicate stress placement. As such, in semantically distinct words differentiated by stress (*‘in,sight* vs *in’cite*), the placement of emphasis on a different syllable triggers the activation of distinct semantic representations in otherwise segmentally identical words, an effect purely driven by differentiation in suprasegmental features.

2.2.1.1. Stress systems across languages

Stress-systems vary across languages in their realisation, which in turn influences native speakers’ stress perception. Most evidence regarding the characterisation of stress and its phonological correlates comes from studies of West Germanic free-stress languages, limiting our understanding to stress systems which, albeit not identical, are very similar (Cutler, 2005). Although the stress systems featured within these languages constitute only a subset of overall stress systems, very little evidence exists regarding the acoustic and perceptual qualities of stress in non-Germanic languages (Culter, 2005).

For languages in which stress is a feature, distinctions in salience and prominence mark certain syllables as stressed. Within these languages, a major contrast is the degree of predictability that stress patterns present with, with languages such as Welsh, Polish, and Arabic featuring fixed stress with a high degree of predictability, whilst others languages such as English and German feature free variable stress. In fixed stress languages, phonological properties including syllable location and shape often dictate where stress reliably falls within words (van der Hulst, 2014). Fixed stress is either quantity-insensitive; occurring on a certain syllable in reference to the start or end of the word (e.g., initial, penultimate, final), or quantity-sensitive; influenced by the internal structure or ‘weight’ attributed to each syllable by that language (Gordon, 2007; Hayes, 1989; van der Hulst, 2014). However, evidence suggests that fixed stress languages cannot be treated as, or assumed to be a unitary category. In a series of experiments investigating the development of sensitivity to stress cues, Dupoux and Peperkamp (2002; Peperkamp, 2004; Peperkamp & Dupoux, 2002) categorised fixed stress languages based upon the degree to which their stress rules would be accessible during language acquisition in infancy. Their results suggest that for fixed stress languages in which stress that is based on phonological rules (such as syllabic structure or vocalic peaks), as opposed to morphological rules, speakers are likely to acquire the stress of their languages pre-lexically, that is, the stress system is established prior to the development of a lexicon, rather than encoded in each lexical entry.

In the following sections an overview is given of the contrasting stress systems of the two languages focussed upon in this work, namely English and Welsh.

2.2.1.2. English Stress

English is a variable stress language, in which stress is lexically contrastive, and marked through cues on the segmental and suprasegmental level. Whilst minimal pairs of words that are distinguished through stress alone are uncommon (e.g. ‘*con,tent* vs *con’tent*), stress plays a substantial role in the language’s derivational morphonology. Derivational morphology is the process by which new, but related, forms of words are construed by the addition of a derivational affix. For example, primary stress in the word *‘com,plex* shifts to the penultimate syllable when the word *com’plex,ity* is derived by adding the suffix *-ity*. The affixation of *-ic* and *-ity* require primary stress of the derived word to fall on the pre-suffix syllable, irrespective of primary stress placement in the stem word (Jarmulowicz, 2002). Furthermore, secondary stress placement is generally dictated by the avoidance of successive stressed syllables, such that English speech production is characterized by the alternation of stressed and unstressed syllables (Beier & Ferreira, 2018).

Although the stress-system in English generally conforms to certain rules, primary stress may appear on any syllable within a given word. Lexical stress can be conveyed segmentally and suprasegmentally, with vowel quality a common indicator. On the segmental level, contrasts between full and reduced vowels can alter the syllable’s phoneme, with stressed syllables consistently produced with a full vowel, whilst unstressed syllables are typically produced with vowel reduction. Schwa [ə] is the most common reduced vowel sound in English (e.g., in the unstressed syllables of gorilla /ɡəˈrɪlə/; the first syllable of potato /pəˈteɪtəʊ/; and the final syllable of pointless /ˈpɔɪntləs/), and results phonologically from collapsed vowel space due to reduced subglottal pressure and muscular effort (Byers & Yavas, 2017). This decrease in articulatory effort results in the localisation of the schwa in the mid-central space, generally underutilized in English (Byers & Yavas, 2017), resulting in changes to the segmental properties of the word. Although vowel reduction is not a necessary prerequisite for an unstressed syllable, syllables with a reduced vowel cannot bear stress (Cutler, 1999). On the suprasegmental level, research into stress realisation and perception has consistently pointed towards F_0 (Fry, 1958) and duration (Fry, 1955) as the two main cues guiding identification of the stressed syllable, with mixed research regarding amplitude (Turk & Sawusch, 1996, cited in Culter, 2005). Generally, it is the combination of these features, as opposed to a single acoustic cue that indicates lexical stress (Lieberman, 1960).

2.2.1.3. Stress in Welsh

Welsh, in contrast to English, is a language with highly regular stress, predominantly fixed on the penultimate syllable in polysyllabic words. Irregular stress, which occurs in a few highly uncommon exceptions, generally result in stress occurring on the final syllable or antepenultimate syllable, e.g., in the case of certain English loanwords (Mennen et al., 2015). Welsh is spoken by 874,700 speakers in Wales (Office for National Statistics, 2018), and whilst this figure appears to be steadily rising, the language lacks the same quantity of research on its features and form that English, the second official language of Wales, benefits from. There remains a paucity in research on the suprasegmental structure of Welsh (Williams & Ball, 2001), and as such there is a considerable deficit in our knowledge about the realisation and perception of Welsh stress. Consequently, the current understanding of certain aspects of Welsh lexical stress, in particular its phonetic correlates, remain subject to debate. In perhaps the most comprehensive research of Welsh stress, Williams (1983) states that its defining characteristic is rhythm, with pulse indicated through duration of segments, in particular the shorter duration of the stressed vowel, and longer post-stress consonant. In preliminary research into the acoustic correlates of Welsh stress, Williams acquired Welsh and English participants' judgements of stress placement in regularly stressed words. English participants identified syllables with greatest amplitude, pitch change and the longest duration as stressed, generally corresponding to the final syllable. Conversely, Welsh speakers chose syllables with shorter duration, lower amplitude and minimal F_0 change during the vowel. Williams concluded that the unstressed ultima is most characteristically similar to the English stressed syllable in its increased intensity and duration. But Williams' study presents with a number of limitations. Firstly, target words were either recorded in insolation or sentence-final position, then presented to participants in isolation, thus rendering it difficult for the English listeners to determine whether differences may have been due to phrasal position (Liu, 2018). An additional confound may have been phrase-final lengthening, resulting in the perception of stress on the ultima due to phrasal prosody, as opposed to stress characteristics. Secondly, it is important to consider that schwa distribution in Welsh generally occurs in the ultima position, but, in tri-syllabic words, is able to occupy the stressed penult (Dogil & Williams, 1999; Hannahs, 2013). As the only description of Williams' stimuli are 'polysyllabic words', it is possible that these tri-syllabic words may have featured schwa in the stress position, thereby providing English listeners with a mixture of L1-like segmental and suprasegmental cues.

Focussing to a greater extent on the role of F_0, Bosch (1996) highlights the tendency for Welsh lexical stress to occur on a lower pitch, with the post-stress syllable produced at a higher pitch. Similarly, Jones (1949) observes that whilst the prominence of the penult and ultima appear not to differ substantially, the ultima consistently features higher pitch than the preceding syllable in disyllabic words.

Webb (2011) examined the realisation of stress in terms of segment duration, analysing the productions of standard southern British English speaking monolinguals, and a group of Welsh/English bilinguals. English-Welsh word pairs were selected as sharing a similar initial syllable, and post-stress consonant phoneme (e.g. English: *Panel*; Welsh: *Panad*). English words were inserted into the phrase *Say [word] again*, or the equivalent *Dudwch [word] eto* for Welsh words, and were read one at a time. For the target words, stressed vowel and post-stress consonant duration were measured as a percentage of total word duration. For post-stress consonants, a significant difference in duration was found between Welsh and English, with Welsh post-stress consonants significantly longer than those produced in English. Conversely, for the stressed vowel, durations in Welsh were found to be significantly shorter than in English. Whilst the results imply that post-stress syllable duration is a key cue to Welsh stress, Webb's research unfortunately fails to report whether any duration differences between the stressed vowel and post-stress consonant were significant within words. Although the research serves as an interesting pointer that

Welsh words do indeed appear to feature a long ultima, the comparison of syllable duration between different words as opposed to between syllables within Welsh words unfortunately limits the findings. Furthermore, research suggests that in addition to phrase-final lengthening, word-final segments are also often produced with greater duration (Lehiste, 1972). As the study by Wells involved only target words featuring penultimate stress, it is possible that the comparison of penultimate and ultimate syllables may have been influenced by syllabic position, as opposed to stress characteristics (Cooper, 2015).

Despite the limitations of the aforementioned studies, the insight offered into Welsh stress, albeit incomplete, provides us with the following information: Lexical stress in Welsh generally results in a lower pitch of the stressed syllable, and potentially shorter duration relative to the ultima. As such, the acoustic correlates of stress in Welsh appear to conflict with that of most European languages (Cooper, 2015), which involve the stressed syllable featuring higher F_0, and greater duration, loudness, and salience on the vowel. As a fixed stress language with stress based on phonological rules (syllable structure), it is likely that in light of research by Dupoux and Peperkamp (2002; Peperkamp, 2004; Peperkamp & Dupoux, 2002), Welsh speakers establish their L1 stress pattern pre-lexically. Despite co-existing in long-term close contact, the results of Mennen et al. (2015) suggest that stress realisation in Welsh has not converged to resemble that of English, resulting in an opportunity to compare stress perception and its influence on first and second language word processing in the two separate systems of Welsh-English bilinguals.

2.2.1.4. Stress and word processing

Research examining the use of prosodic information, such as stress, highlights the importance of its use in spoken word comprehension and processing (Cooper et al., 2002; Jesse et al., 2017; Slowiaczek et al., 2000; van Donselaar et al., 2005). Van Donselaar et al. (2005) explored the role of lexical stress in word recognition by native Dutch listeners. Participants were tested in three cross-modal priming experiments comparing recognition of visually-presented target words. In two conditions, they viewed targets that were preceded by monosyllabic and disyllabic auditory primes produced with either an appropriate ('oktober preceded by 'okto-) or an inappropriate ('oktober preceded by ok'to-)

stressed prime. When targets were preceded by either disyllabic or monosyllabic appropriately stressed primes, RTs to targets were significantly faster, whilst inappropriately stressed disyllabic fragments produced inhibition. Inappropriate monosyllabic fragments or disyllabic primes compatible with only one word caused neither facilitation nor inhibition. Results were interpreted by the authors to suggest that competition arose between simultaneously activated phonological representations of lexical candidates, and that this occurred prior to activation of discrete conceptual representations. Furthermore, both segmental and suprasegmental input modulated this activation. More recently, Jesse et al. (2017) tested English monolinguals in an eye-tracking study examining the time-course of suprasegmental information processing in spoken-word recognition. Participants heard the sentence *Click on the x*, and were presented with words that shared two segmentally identical initial syllables, but that differed at a suprasegmental level. Target and competitor items either began with primary lexical stress (e.g. ˈ*admiral*) or secondary lexical stress (e.g. *admiˈration*). Participants were found to fixate target words with initial primary stress to a greater degree than their stress competitors prior to hearing the segmentally distinguishable third syllable. The results are indicative that the presence, but not absence, of suprasegmental cues to primary lexical stress guide word recognition in English speakers.

The degree to which stress influences language perception in bilinguals remains less established. Exploring effects of stress on word recognition across different language backgrounds, Cooper et al. (2002) tested English and Dutch participants on four cross-modal priming and two forced-choice identification experiments. In the forced-choice identification experiments participants were asked to select target words to complete non-constraining sentences, such as *We were sure the word was…* ending in fragmental primes. Primes consisted of truncated monosyllabic (e.g., mus- from ‘*music/mu’seum*) or bysyllabic (admi- from *‘admiral/admi’ration*) portions of words differing in stress in the first two syllables, and participants were asked to indicate the matching visually-presented lexeme. In the cross-modal priming experiments, participants heard the same truncated words used in the forced-choice identification experiments, and selected the word that they deemed to be the source of the fragment on paper. Results found that both native English and non-native listeners were able to use suprasegmental information in order to facilitate word recognition, selecting the target word from only the fragmental prime provided, though remarkably Dutch participants performed significantly better than native English-speaking participants. The authors concluded that suprasegmental information, whilst exploited by both groups in spoken-word recognition, was likely to be influenced by language background. The superior performance of non-native Dutch listeners relative to native English listeners, may be attributed to the paucity of segmentally ambiguous but suprasegmentally distinguished words within the English language. With vowel reduction a key cue to English stress placement, English speakers may consequently be afforded limited experience processing suprasegmental stress cues. Conversely, native speakers of Dutch, in which vowel reduction and segmental contrasts are less common, use suprasegmental stress contrasts to a far greater extent.

Despite evidence of the use of suprasegmental stress cues in word recognition by both native and non-native listeners, it is important to consider that the breadth of our understanding of lexical stress predominantly comes from Germanic languages. However, the stress systems of these languages, albeit varying to some degree, represent only a small subset of stress systems across world's languages. In particular, processing of lexical stress by native speakers of fixed-stress languages is known to differ substantially from that of native speakers of variable-stress Germanic languages.

Native speakers of fixed stress languages generally struggle to perceive the stress contrasts of variable-stress languages. This 'stress-deafness' is thought to originate from early language acquisition in infancy, during which the presence or absence of contrastive stress in the native language is detected (Peperkamp, 2004). The process of acquiring the native language stress system is thought to particularly influence overall sensitivity to stress for speaker of languages with stress systems based on phonological rules (e.g., syllabic structure, vocalic peaks) as opposed to morphological rules. For such languages, it is thought that infants develop their stress systems pre-lexically, that is, prior to the establishment of the lexicon (Williams, 1983). As such, lexical stress is not encoded in the lexical entries of specific words, but has instead been suggested be based on pre-lexical templates. Considered in light of models of word recognition positing an integrated lexicon, and findings showing unconscious activation of the L1 in an L2 context, a question arises as to how such pre-lexical stress templates may influence L1 access. In particular, if these templates are, in their nature, unconnected to L1 lexical representations, the presence of similar stress patterns in an L2 context may have implications for unconscious L1 activation.

2.2.2. Accent

The second feature explored in this thesis in relation to bilingual word recognition and language activation is accent. The term accent is used to refer to two distinct concepts within linguistics. On the one hand, it is often used synonymously with stress, referring to the combination of stress and tonal features used to assign prominence to a syllable or certain part of speech. The second sense of the word, and the one with which this thesis is primarily concerned when referring to accent, is the pattern of pronunciation with which a speaker of a certain background, community, or area produces speech. This includes the phonology, intonation and prosodic features, and rhythmic patterns that constitute both a speaker's mental lexicon and vocabulary (Wells, 1982), and the suprasegmental characteristics of their speech.

Since the 1960s, the role of accent in assisting or hindering comprehension and intelligibility in bilinguals listening to their second language has been a focus of investigation. Early studies generally reported a beneficial role of L1 accent (Bent & Bradlow, 2003; Brown, 1968; Flowerdew, 1994; Wilcox, 1978). Two main interpretations arose from these results; that hearing an L1 accent may result in speech that is more intelligible, or alternatively that the degree of familiarity with the accent, being greater for the L1 accent than that of the L2, is sufficient to aid comprehension (Gass & Varonis, 1984; Pihko, 1997). Despite this, a number of methodological inconsistencies have been highlighted, in particular the notable variability in L2 proficiency, comprehension test difficulty and dialectal differences in such studies (Hardman, 2014). Indeed, more recent research has called into question the notion of a consistent effect of L1 accent in speech comprehension. In a large-scale study of 400 speakers of English from varying linguistic backgrounds, (Major, Fitzmaurice, Bunta, & Balasubramanian, 2002) demonstrate such variable results. Four groups of participants, Chinese, Japanese, Spanish and Standard American English-speaking participants, were presented with a specially designed version of the TOEFL listening comprehension test in which each group heard an audiotape of lectures delivered by different speakers. In their English listening proficiency scores, Spanish participants demonstrated a significant advantage of L1 accented speech in English comprehension when compared to other varieties of accented speech, but the advantage was not consistently observable, with both L1 Chinese and Japanese participants failing to show a similar advantage for L2 speech produced in their L1 accents. In line with these results, (Munro et al., 2006) reported a similar effect, demonstrating no consistent benefit of L1 accent across participant groups with a slight advantage in intelligibility for native Japanese speakers listening to Japanese-accented speech, but not for native Cantonese speakers listening to Cantonese-accented speech. In addition to methodological inconsistencies, it should additionally be noted that most research on the effect of accent on L2 intelligibility predominantly consider bilinguals to be a homogeneous group. Not only can this notion problematic within groups, but in attempting to compare accent affects between groups, this can lead to conflicting results with no clear explanation. For example, in comparing Chinese, Japanese, Spanish and Standard American individuals, Major et al. (2002) may have overlooked substantial differences arising from the different bilingual experiences of these contrasting populations. Chinese and Japanese individuals are considerably less likely to experience consistent exposure to non-native accents than Spanish bilinguals. This limited experience with accent variability may therefore affect the comprehension of L2 when produced with a non-L2 accent. Such differences in bilingual experience have been proposed to underpin a great deal of variability and inconsistency in research into bilingualism (Bak, 2016), and, considering our understanding of the relationship between language experience and sensitivity to phonological cues, it may therefore be the case that L1 accent in the L2 differentially affects different bilingual populations.

This said, considered alongside research as discussed in the prior section, suggesting that language-specific phonetic information may play a role in both suppression and facilitation of parallel language access (Fricke et al., 2016; Ju & Luce, 2004), it may be possible that the presence of phonetic features of a listener’s L1 accent results in an increase in L1 activation in an L2 context. As such, reported inconsistencies in advantage by language-background could be due to a variable presence of L1 phonetic cues, and consequent variation in interference from the non-target lexicon. Exploring whether accent influences bilingual lexical access, resulting in effects on intelligibility, or potentially increased L1 activation, Lagrou, Hartsuiker and Duyck (2011) tested Dutch–English bilinguals in auditory lexical decision tasks conducted in both Dutch and English. In their first experiment, participants listened to English words produced by either a native English speaker (L2 Dutch) or a native Dutch speaker (L2 English).

Stimuli were either inter-lingual Dutch-English homophones (e.g., *lief* [sweet] – *leaf* /li:f/), control stimuli, fillers, or non-words. Whilst homophones were responded to consistently slower than control words, response times were slower overall for stimuli produced by a native Dutch speaker. Testing native English speakers using the same paradigm, the authors reported a similar effect of accent, with response times to non-native Dutch-accented targets longer in both participant groups. Acknowledging that English-accented target words had significantly longer target word durations due to the tendency for the speaker to stretch pronunciation, the authors proposed that the increase in response times could be attributed either to the increased opportunity for lexical activation prior to response afforded by longer sound file duration, or to genuine accent effects due to the mismatch between non-native production and stored lexical representations. In their third experiment, intended to disentangle the two prior hypotheses, Lagrou et al. (2011) re-ran the same paradigm in the participants' native language. When tested in the L1 Dutch, response times were significantly faster to L1 accented stimuli compared to English accented speech, suggesting that lexical access was facilitated by the match between non-accented productions and stored lexical representations. Importantly, the lack of an interaction between speech accent and the homophone effect suggested that sub-phonemic cues present in accent did not reduce parallel activation of the listener's languages, resulting in equal interference from non-target representations irrespective of the presence of native accent. Exploring this further, Lagrou, Hartsuiker and Duyck (2013) ran a follow-up experiment in which they investigated the role of three factors with the potential to influence language non-selective access, namely sentence context, semantic constraints, and native language of the speaker. Dutch-English bilinguals listened to English sentences produced by either a native Dutch speaker or a native English speaker and made a lexical decision on the last word of the sentence. Similarly to their 2011 study, target words were inter-lingual Dutch-English homophones, control stimuli, fillers, or non-words. Results revealed an inter-lingual homophone effect, supporting the notion that non-selective language access in bilinguals occurs in auditory word perception as well as in visual word recognition. In this second study, however, accent modulated the homophone interference effect, with participants responding faster to English-accented sentences than those produced in a Dutch accent.

Two potential explanations for the effect found in Lagrou et al. (2013) were offered. Either the effects reflected an increase in the salience of the participants' L1, increasing activation of the L1 homophone representation, or an overall decrease in intelligibility may have reduced response times for L1-accented L2 speech. Although the design of Lagrou et al. (2013) means that it is not possible to determine which of the interpretations best explains the results, the possibility that presence of the L1 accent in L2 speech may increase the salience of listeners' L1 representations remains an interesting prospect. Should it be the case that heightened activation of the contextually-inappropriate native language results from exposure to L1 accent, it would bear particular relevance for both current models of language activation, and on a more practical applied level, second-language pedagogy and examination strategies. Should L1 accent heighten activation of L1 representations, it could potentially follow that the establishment of L2 representations during foreign language learning may be impaired by interference from L1-accented speech. In particular, considering early reports of the interaction between proficiency and L1 accent on L2 comprehension (Stibbard & Lee, 2006), for low-proficiency or beginner L2 learners the presence of the L1 accent may reduce intelligibility, and subsequently influence the acquisition L1 representations.

Perhaps as critically, the influence of foreign accents on either L2 intelligibility or increased salience of L1 representations may have significant implications for the recent drive to move from the use of solely native-accented speech in L2 listening tests. This move, to reflect the diversity of listening contexts that L2 speakers may encounter, has resulted in the inclusion of regionally and non-native accented material. Despite this, some have highlighted concerns that a potential test advantage might result for non-native listeners who share the L1 with that of the speaker (Major et al., 2002). Whilst the notion of a shared L1 advantage appears to differ both by language background and proficiency, with little consistent influence on test results reported (Bent & Bradlow, 2003; Hayes-Harb, Smith, Bent, & Bradlow, 2008; Major et al., 2002; Munro et al., 2006; Stibbard & Lee, 2006) it nevertheless highlights a potentially legitimate concern. This gap in the current literature, and consequently our understanding, of the interaction between accent and language activation is addressed in studies 1, 2 and 4, with the aim of disentangling whether L1 accented L2 speech increases L1 salience, or decreases intelligibility.

2.3. Methodology

Research consistently demonstrates the non-selective activation of words linked semantically (Beauvillain & Grainger, 1987), overlapping in phonology (Marian & Spivey, 2003; Wu & Thierry, 2010), or overlapping orthographically (van Heuven, Dijkstra, & Grainger, 1998) between a bilingual's two languages. Such studies, which reliably demonstrate the influence of segmental overlap in parallel activation of L1 and L2 lexical candidates, have traditionally explored language activation using masked priming paradigms, or eye-tracking measures, often incorporating the use of L1 stimuli in a second language context.

A major drawback of this use of L1 stimuli, or of interlingual homophones or homographs in experiments investigating bilingual cross-language activation is the artificial dual-language context they can create. For example, in studies using interlingual homophones or homographs (Chen et al., 2017; Dijkstra et al., 1998; Lemhöfer & Dijkstra, 2004), words with distinct meanings in the L1 and L2, but interlingually overlapping orthography or phonology (e.g., key /ki/, English; *ci* /ki/ (dog), Welsh), are presented to participants. Modulations in response times or accuracy relative to control stimuli (orthographic or phonological forms featuring in only one of the languages) are interpreted as indicative of cross-linguistic interference of increased processing difficulty due to the activation of multiple word-forms. In masked priming paradigms, participants generally see a word in one language (e.g., *dog*), followed by a target word either in their same language (e.g., *puppy*), or their other language (e.g., *Hündchen*). In order to mask the prime, presentation duration is extremely short (a few tens of milliseconds), and is immediately followed by the presentation of a target. As such, the prime is not consciously perceptible, and the paradigm is thus assumed to test activation of the masked language in a single-language context. The relative speed and accuracy with which participants respond to the target word is used to gauge the degree of priming. Despite a large number of studies on bilingual language activation adopting such methodologies, there remain major limitations to both. Firstly, it is difficult to ascertain the degree to which the results obtained are indicative of effects of language co-activation or language mode. In a review of the methodological and conceptual issues in bilingualism research, Grosjean (1998) highlights the necessity of considering the language mode that experimental conditions elicit. Factors such as awareness of recruitment conditions in relation to the requirement of a bilingual background, alongside language of instruction can result in heighted activation of one or both of a bilingual's languages, markedly different from that experienced on a day-to-day basis in the natural environment. As such, a bilingual language mode may not be representative of natural operation. Beyond this, and perhaps of greater importance, the paradigm itself may result in increased language activation. A significant drawback of both methods is the artificial bilingual context created. Although cross-language homophone/homograph studies and masked priming experiments appear perceptually monolingual, both methods test the influence of L1 activation on L2 processing through the means of L1 exposure. For masked priming experiments, to postulate that L1 activation might occur within an L2 context subsequent to exposing participants to their L1 (albeit imperceptibly) creates a somewhat cyclical argument in which L1 activation results from L1 exposure. Similarly, whilst it can be said that in cross-linguistic homophone/homograph designs participants are tested in a single-language context, they are nonetheless exposed to orthographic or phonological forms from the other language, thus producing a similar exposure-activation cycle as in masked priming paradigms.

How then can we study language co-activation in a functionally monolingual context? To avoid effects of a bilingual context, a number of researchers have employed implicit priming paradigms (Thierry and Wu, 2007; Wu & Thierry, 2010). Intended to avoid artificial dual-language activation, the method enabled measurement of native-language priming effects in bilinguals tested in an all-L2 context. The paradigm, which forms the basis of all experiments encompassed within this thesis, is outlined in the following section.

2.3.1. Implicit Priming

Implicit priming is a paradigm used solely in conjunction with covert measures, as opposed to overt behavioural responses. The method involves the presentation of visual or auditory prime-target pairs in a fully monolingual context, whilst participants are instructed to make semantic-relatedness or category judgements primarily intended to maintain attention and ensure that linguistic stimuli are processed to a certain degree of depth, rather than superficially. Whilst prime-target pairs are presented in one language (e.g., English), translation to a bilingual's other language (e.g., Welsh) conceals an overlap between critical word pairs. For example, Figure 6 depicts an example of phoneme overlap between a prime and a target English word with no perceivable semantic, phonological or orthographic link, unless participants resort to accessing Welsh translation equivalents of the stimuli. Previous studies have consistently demonstrated a priming effect for phonology, but not orthography, in highly fluent Chinese-English bilinguals suggesting that under certain conditions, unconscious access to L1 translation equivalents occurs.

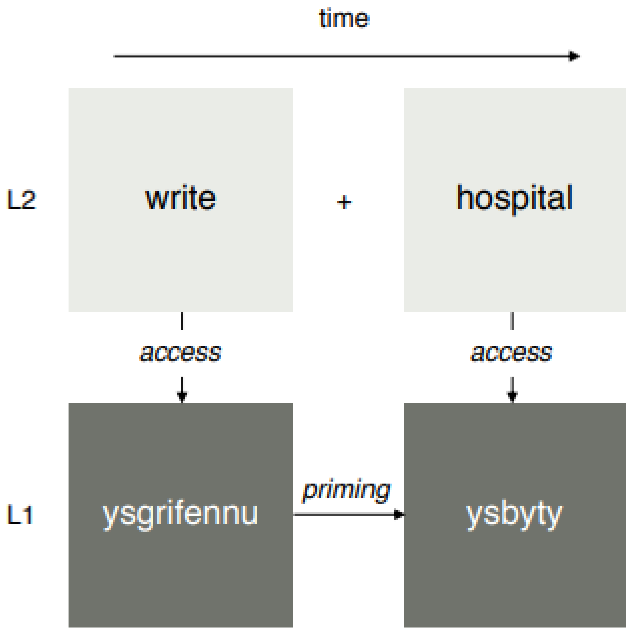

Figure 6. An example of an implicit priming paradigm for Welsh-English bilinguals. Priming occurs following access to L1 translation equivalents overlapping in initial phonology.

This effect has since been replicated in several studies, and across modalities (including sign language in bimodal bilinguals), with the effect detectable in ERP amplitude modulations in the absence of any behaviourally measurable response (Meade, Lee, Midgley, Holcomb, & Emmorey, 2018; Thierry & Wu, 2007; Wu & Thierry, 2010, 2012).In studies testing language activation through an implicit priming paradigm, ERPs offer the most sensitive measures of responses to stimuli, enabling the measurement of subtle, subconscious responses. Consequently, in addition to behavioural measures, ERPs are used throughout studies 1-4 of this thesis.

2.3.2. Event-related potentials

Event-related potentials (ERPs) are small changes in scalp-recorded voltages that are time-locked to the onset of specific stimuli. These voltage fluctuations represent neural activity elicited by cognitive operations following the event (generally the stimulus). The electrical potential generated by neural networks involved in stimulus processing originates from two main sources, action potentials and postsynaptic potentials (Luck, 2014). Whilst the timing, size and arrangement of axons mean that action potentials are generally undetectable on the scalp, ERPs are mostly the result of postsynaptic potentials, reflecting their summed activity when a number of cortical pyramidal neurons fire in synchrony (Peterson et al., 1995).

The temporal sensitivity of ERPs lends itself to language comprehension research, offering insight into the mechanisms that enable a listener to process input of considerable complexity at remarkable speeds (Mueller, 2005). Whilst a wealth of research into language activation mechanisms has employed behavioural measures such as reaction time (RT) and accuracy, the level of insight afforded by such measures is limited. Investigating language comprehension through the means of behavioural measures requires collection of an overt response. A behavioural response, such as reaction time, reflects not only variability in the targeted cognitive process, but additionally that of the multiple mechanisms that underlie the response process. As such, effects revealed in behavioural measures are difficult to attribute to a specific cognitive process, and less still the stage of processing at which the variability might occur (Luck, 2014). Conversely, ERPs enable continuous monitoring of the neurological processing of a particular group of stimuli. With a temporal resolution in the millisecond range, they provide fine-grained insight into stages of neural processing but they lack spatial resolution due to the myriad of potential internal generator configurations that might underlie a given pattern of surface activity (Luck, 2014). Unlike behavioural measures, ERPs provide an opportunity to monitor participants' covert responses, broadening our understanding of unconscious neurological processes. The fine temporal resolution of ERPs enables investigation of not only the time-course of language comprehension, but additionally exploration of the different phases of information processing involved within a such a task. Early ERPs (roughly the first 200 ms after stimulus onset) are considered mostly sensory or exogenous, as they are generally modulated by perceptual manipulations and the physical characteristics of the stimulus (Sur & Sinha, 2009). The P2 for example (a positive peak occurring between 175-250 ms), usually responds to simple stimulus features such as size, brightness, or visual repetition (Tim Curran & Dien, 2003). In contrast, later ERP components are influenced by more complex stimuli properties. The Phonological Mapping Negativity (230-350 ms), is influenced by context-derived phonological expectation. Similarly, the N400 (300-500 ms) indexes semantic relatedness and ease of integration (Kutas & Federmeier, 2011; Kutas, Neville, & Holcomb, 1987) and the P600 (peaking around 600 ms), is elicited by syntactic phenomena and re-analysis. As such, the latency of the ERP component roughly corresponds to the complexity of processing, allowing for the disentangling of both low-level and high-level effects.

2.3.2.1. ERPs and Language

The description of the following ERP components focusses on the use of four event-related potentials, namely P2, N250, PMN and N400 and their use in language research, predominantly within paradigms intended to explore the mechanisms and processes underpinning lexical access.

- P200

The P200 (also called P2) is a wave occurring between 150 – 275 ms post stimulus across anterior or posterior recording sites, first identified to be sensitive to the degree of attention paid to a target. Studies initially investigating ERP correlates of visual search and visual target properties have consistently found enhanced P200 response to target stimuli, when the latter are identifiable by colour (Hillyard & Münte, 1984), orientation, or size (Luck, 2014) and low probability of occurrence (Luck & Hillyard, 1994). Further research has examined the sensitivity of the P2 to old/new perceptual priming, and have generally reported a P200 increase with repetition (Curran & Dien, 2003; Misra & Holcomb, 2003; Rugg & Nieto-Vegas, 1999). Whilst a number of studies have confirmed these effects, certain limitations have been noted. For example, Misra and Holcomb (2003) presented participants with stimuli that involved either immediate or delayed word repetitions, and reported that only immediate repetition produced significant P200 differences, highlighting the fact that such effects can be short-lived. In a similar paradigm, Curran and Dien (2003) measured P200 responses to novel or repeated words in both the visual and auditory modalities, but found that only visually presented stimuli produced a P200 repetition effect. The modality-sensitive nature of the P200 effect has prompted suggestion that, as opposed to purely perceptual priming which might be anticipated to occur across modalities, the modulation may represent retrieval of specific information at an early, pre-semantic processing stage (Rugg, Doyle, & Wells, 1995; Rugg & Nieto-Vegas, 1999). In particular, the specific sensitivity has been interpreted to indicate that the P200 reflects ingrained, long-term, modality-specific memory representations (Almeida & Poeppel, 2013). Despite this, there is very limited evidence that the P200 might be sensitive to lexicality, based upon studies in which it has been demonstrated to be sensitive to word repetitions, an effect not apparent for pseudowords (Rugg et al., 1995; Almeida & Poeppel, 2014) and lexical frequency (Barnea & Breznitz, 1998; Curran, Tucker, Kutas, & Posner, 1993). Whilst current research provides a foundation of knowledge regarding the effect of certain manipulations on the P200, more work may be required in order to develop a more robust understanding of the component's functional sensitivity.

- N250

The N250 is a negative wave maximal at 250 ms, occurring as early as 110 ms post stimulus onset (Grainger et al., 2006; Grainger & Holcomb, 2009). The component is largest over midline electrodes, and can be seen across both anterior and posterior sites (Chauncey et al., 2008). The N250 displays sensitivity to masked repetition priming both for orthographic and phonological repetitions, and it has been primarily used to investigate the timeline of lexical access, in particular the discrete nature of the retrieval of orthographic and phonological representations in the time course of word processing (Grainger et al., 2006).

The N250 is distinguishable from the P2 in terms of its lack of sensitivity to perceptual features. Chauncey et al. (2008) investigated the influence of font type and size on the N250. Whilst repetition priming was demonstrated to influence the N250 amongst other, later components, there was no effect of font, suggesting that the N250 was not influenced by surface-level features (Chauncey et al., 2008). The findings suggest that the N250 indexes prelexical orthographic processing, as opposed to initial perceptual processing, although further research suggests the component is not limited in sensitivity to word processing in the visual modality. Disentangling orthographic repetition priming and that elicited by phonological form, Grainger et al. (2006) showed participants target words that were primed by pattern-masked pseudowords. The authors varied the degree of phonological overlap between prime and target, but matched words for orthographic overlap (e.g. bakon-BACON vs. bafon-BACON). Results demonstrated a clear distinction between orthographic and phonological priming, with the latter starting at around 225 ms.

Whilst at present there remains limited research to guide our understanding of the breadth of functional sensitivity of the N250, in the domain of language, the component is proposed to index information integration within a cognitive system engaged in processing letters into ordered combinations, in order to generate phonological representations (Grainger et al., 2006; Chauncey et al., 2008).

- Phonological Mapping Negativity

The phonological mapping negativity (PMN) is an early ERP component generally maximal at around 300 ms post stimulus onset. The PMN was originally observed as a differentiated component preceding the N400 by Connolly, Stewart, and Phillips in a 1990 study in which it was interpreted as representing a subprocess prior to contextual integration (Newman et al., 2003)[1].

The PMN has been proposed to reflect pre-lexical phonological processing (Connolly et al., 2001; Connolly & Phillips, 1994; Desroches et al., 2009), involving the mapping of speech signals onto phonological representations (Neman & Connolly, 2009). The PMN typically increases in amplitude when the expectation of particular phonological input is violated in paradigms using words (Newman & Connolly, 2009), sentences varying in cloze probability (Connolly & Phillips, 1994), and pictures (Desroches et al., 2008) in order to create phonological expectations. Research using such stimuli to

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[1] Originally called the phonological mismatch negativity, the PMN has been relabelled the phonological mapping negativity both to distinguish it from the mismatch negativity, and to better describe its behaviour due to its sensitivity not only to phonological mismatch, but fulfilled expectations.

elicit the component have predominantly reported PMN responses to auditory language (Connolly et al., 1995), however, more recently, evidence has emerged to suggests that the effect may also occur in visual modality (Desroches et al., 2009; Jones, Kuipers, & Thierry, 2016; Vaughan-Evans, Kuipers, Thierry, & Jones, 2014).

Although the PMN was originally reported over fronto-central regions, phonological priming effects over parietal regions similar to those exhibited by semantic congruency effects have been consistently reported (Desroches et al., 2009; Dumay et al., 2001; Malins et al., 2013; Newman & Connolly, 2009; Praamstra et al., 1994; Sučević, Savić, Popović, Styles, & Ković, 2015a). As such, the topography of the component is somewhat inconsistent, reflected in discrepancy in the labelling of centro-parietal phonological priming effects as either a parietal PMN, N200 or early N400 (van den Brink, Brown, & Hagoort, 2001; van den Brink & Hagoort, 2004; Van Petten, Coulson, Rubin, Plante, & Parks, 1999).

- N400

The N400 is the most commonly studied electrophysiological response in the context of lexical access (Almeida & Poeppel, 2014). In 1980, Kutas and Hillyard first published the report of an N400 modulation, an ERP effect linked to meaning processing. In a paradigm anticipated to produce a P300 response, they noted that sentences with anomalous endings (i.e., *I take coffee with cream and* ***dog***) elicited a large, parietally maximal negative wave. Since its discovery, over 1000 reported studies have used the N400 as a dependent measure, expanding our understanding of the component's functional sensitivity (Kutas & Federmeier, 2011). Although described as a negative peak, the N400 does not necessarily manifest as an absolute negativity, but is instead generally compared across conditions to determine relative negativity. Whilst the component typically peaks at 400 ms, it can span between 200 and 600 ms post-stimulus-onset (Kutas & Federmeier, 2011). Its breadth of sensitivity means that the component is generally characterised as a function of its timing, behaviour and morphology, with the term N400 used as a heuristic label for stimulus related brain activity that occurs in a pattern of sensitivity to manipulated variables 200–600 ms post-stimulus-onset (Kutas & Federmeier, 2011).

Within language research alone, the N400 has been shown sensitive to cloze probability and expectation, lexical priming involving manipulation of semantic, phonological, categorical, and associative relationships and repetition priming (Kutas & Federmeier, 2011). In general, in studies exploring single word comprehension, the N400 is reduced in amplitude by form-based or semantic relatedness between a target and the preceding word (Dumay et al., 2001; Holcomb, 1988; Holcomb & Neville, 1991; Kutas & Hillyard, 1980b; Praamstra et al., 1994; Praamstra & Stegeman, 1993; Radeau et al., 1998). An important distinction needs to be made between the concepts of prediction, most relevant in priming within sentential context, and that of association, key to understanding single-word priming effects. Research suggests that contextual information can be used by a listener in order to predict upcoming words (Federmeier, 2007). In speech comprehension, processing a word's meaning involves the comparison of incomplete acoustic information to context-derived predictions, and the prediction-driven semantic, orthotactic and phonological expectations (Kutas & Federmeier, 2000). As such, sentences are able to set a context which limits the cohort of potentially expected words. This context, known as cloze probability, is able to restrict the pool of eligible lexical candidates through context-based prediction. For example, the sentence *The sun rises in the morning and sets in the…* strongly primes completion with the word *evening*. Conversely, the sentence *the girl ate the…* is of far lower cloze probability, allowing for a range of phrase-final lexical candidates. In sentences of sufficiently high cloze-probability, the features of the anticipated target are pre-emptively activated. In single-word contexts, insufficient information weakens predictability, and instead priming is assumed to be the result of multimodal associations (Kutas & Federmeier, 2000).

The influence of both semantic and orthographic/phonological priming on N400 amplitude results in a component that offers insight into the process underpinning lexical processing. However, whether N400 reduction indexes facilitation of access to stored semantic representations, or whether it reflects processing difficulty, and the effort required to integrate the orthotactic and phonological properties of novel stimuli within a given context, remains subject to debate. Studies in support of the latter interpretation point to evidence of increased N400 amplitude in response to pseudo-words as compared to real words in lexical decision tasks (Attias & Pratt, 1992; Bentin, 1987; Deacon, Dynowska, Ritter, & Grose-Fifer, 2004; Rugg & Nagy, 1987; Soares, Collet, & Duclaux, 1991), arguing that a component sensitive to ease of lexico-semantic retrieval should show little effect when presented with pseudowords for which no stored representation exists (Debruille, 2007). In contrast, evidence of amplitude modulations correlating to word frequency and repetition (Petten & Kutas, 1991) have been interpreted to suggest the component may reflect how readily information associated with lexical forms is retrieved from memory (Kutas & Federmeier, 2000). As such, when participants are presented with words of higher frequency, or context is set by a preceding prime (Federmeier, 2007), the consequent N400 amplitude reduction indexes ease of integration. Evidence in support of such an interpretation includes N400 attenuation to categorically associated items (e.g., football, baseball), which are said to result in priming due to the development in the brain of a functional link between the higher-order features of a word, built up over years of experience (Kutas & Federmeier, 2000). Similarly, there is an important distinction between the N400 increase found in response to orthographically legal, pronounceable pseudowords compared to those which differ from unpronounceable non-words, which elicit little or no N400 activity (Bentin et al., 1985; Smith & Halgren, 1987). If the N400 purely represents the cognitive effort required to integrate words within a given context, all non-words irrespective of orthography and phonology should potentially elicit a large N400 response. Conversely, if the N400 indexes facilitation of access or integration, the amplitude increase in response to phonotactically/orthographically legal non-words may instead represent increased search effort. Evidence demonstrating this latter response offers potential insight into the time-course of word processing, suggesting that in the early stages orthography and phonology are processed prior to later retrieval of semantic information.

To summarise, the breadth of sensitivity of the N400 to manipulation of both lower-level perceptual and higher-level semantic factors has prompted a number of interpretations suggesting that the component may represent cognition at the intersection of these processes, i.e., semantic access. Kutas and Federmeier describe the N400 as “a temporal interval in which unimodal sensory analysis gives way to multimodal associations in a manner that makes use of – and has consequences for – long term memory” (2000: 639). As such, as the interchange between early, perceptual ERPs and semantic retrieval and integration, the N400’s 200 - 500 ms time window spans the convergence of these input streams (2000: 639). Because of this, the N400 is seen to be influenced by a combination of distributed neural representations and the clarity of the input to which it responds. For example, the word *cat*, visually presented, could be thought to activate ‘cap’, ‘sat’ and ‘cut’ due to activation of relevant stimulus features, whilst semantic representations associated with both the target stimuli (e.g., *dog, pet, animal*), and the feature-driven co-activated words will activate to varying degrees (Kutas & Federmeier, 2000). However, the same authors acknowledge that, assuming word recognition must precede semantic access, N400 effects found in response to both pseudowords and real words prior to their recognition point remain difficult to explain (Kutas & Federmeier, 2011). Whilst there appears to be greater support for the suggestion that the N400 does indeed index ease of access, there is general agreement that the N400 is, at least in part, driven by the degree of context-driven predictability of a target (Federmeier, 2007; Kutas, Van Petten, & Kluender, 2006; Lau, Holcomb, & Kuperberg, 2013).

2.3.2.2. ERP correlates of lexical access

It may be interesting at this stage to consider a potential inconsistency arising from the previously introduced indices, given a certain degree of overlap in functional significance, topography, and time windows alluded to in the prior sections. Whilst the models outlined in section 2.1 lay the foundations for an understanding of the trajectory of lexical access, an understanding of the exact temporal realisation of such processes is mostly derived from ERP studies exploring the functional sensitivities of a number of components. Despite this, these overlaps in sensitivity, topography or temporality blur the clear distinctions drawn between ERP components by research.

The PMN manifests as a predominantly fronto-central or centro-parietal ERP component influenced by phonological expectation and peaking at approximately 300 ms. Conversely, the N400 is a centro-parietal negativity peaking at approximately 400 ms, which displays sensitivity to context-driven prediction and potential ease of lexical access. If the two components present entirely distinct, independent processes, why do both ERP components demonstrate sensitivity to phonological priming?

The degree to which the PMN and N400 overlap, or coexist as functionally distinct components has been the subject of substantial debate. Whether the PMN alone is sensitive to phonological violations, whilst the N400 indexes purely semantic effects has been tested in a number of experiments. For example, in a double-dissociation study, Connolly and Philips (1994) tested participants in four conditions intended to distinguish effects of phonological expectancy from those of semantic priming by orthogonally manipulating semantic and phonological expectancy in high cloze-probability sentences. Target words were a semantic match-phoneme match (e.g., The piano was out of **tune**); semantic match-phonological mismatch (e.g., The pig wallowed in the **pen** [mud]); semantic mismatch-phoneme match (e.g., The gambler had a streak of bad **luggage** [luck] or semantic mismatch-phoneme mismatch (e.g., Joan fed her baby some warm **nose** [food]). The semantic mismatch-phoneme mismatch condition elicited a combined PMN – N400 response relative to the semantic match-phoneme match condition. However, in the critical conditions, the authors reported only an early negativity, interpreted as a PMN response, when participants were presented with a phoneme mismatch, whilst only they observed a classical but slightly later N400 modulation only in the semantic mismatch condition. The results were interpreted as indicative that the two components are functionally distinct, with the PMN sensitive to early lexical processing during which the onset of a word is compared to a phonological template, whilst the N400 represents semantic integration processes. However, this study had a number of shortcomings. Firstly, the largest PMN modulation was found in response to stimuli affording both a phoneme and semantic mismatch. Furthermore, in the phoneme match-semantic mismatch condition, the peak latency of the N400 was delayed by over 50 ms relative to that recorded in the phoneme mismatch semantic mismatch condition. Both the increase in PMN to the phonologically and semantically mismatching stimuli relative to pure phoneme-mismatches and the increased N400 latency for pure semantic violations suggests that the two components may not be functionally independent.

In a later phonological priming study intended to determine whether lexicality influences PMN amplitudes, Connolly et al. (2001) presented participants with word/nonword primes (e.g., *house/telk*) followed by a letter. Participants were instructed to think of a word/non-word that rhymed with the prime, but that began with the letter subsequently displayed. The authors reported a large PMN response to phonologically mismatching trials, but no effect of lexicality, concluding that the PMN was not influenced by semantics. But in a later paper, published in 2009, the authors highlighted the results of an MEG study by Kujala, Alho, Service, Ilmoniemi, and Connolly (2004) in which substantial but non-significant difference in PMN latencies were found in MEG data between words and nonwords “preventing any firm conclusions about the nature of the PMN based on this paradigm” (Newman & Connolly, 2009;4).

Following this, Newman et al. (2003) investigated phonological processing independently from lexical/semantic influences in a task in which participants were instructed to delete the initial consonant off a four-syllable prime word (e.g., *clap*, /k/). Subsequent to the presentation of a prime word, participants saw a target that either fitted with the prime following consonant deletion (e.g., *lap*) or represented one of three possible incorrect targets. Incorrect targets were broken down into those for which the wrong consonant (WC) was deleted (e.g., *cap*), an irrelevant word (IW) that differed entirely from the correct answer (e.g., *nose*) or featured consonant cluster deletion (CC), in which both initial consonants were deleted (e.g., *ap*). For the correct condition, PMN mean amplitude was significantly reduced, whilst it was significantly greater and undistinguishable across all incorrect conditions. Results were interpreted as evidence for PMN phonological sensitivity, and its functional distinction from the N400, particularly due to the fact that its amplitude was comparable for both word and non-words targets, suggesting a lack of influence of early lexical and semantic characteristics. Despite the interpretation offered, the authors went on to acknowledge the likelihood of P300 contamination having uniquely reduced PMN amplitude in the correct condition. As such, the results represent three conditions with reliable results, in which the PMN amplitude failed to differ significantly, despite the predictions of graduations in response by phonological violation (largest in IW condition, followed by WC and CC). Similarly, the interpretation of results as indicative of the independence of the PMN and N400 is incompletely supported. Firstly, the authors highlight PMN modulations in response to correct vs incorrect targets in the “absence of any semantic processing requirements” (2003: 646) as evidence against shared PMN/N400 semantic sensitivity, despite the aforementioned lack of reliability of the correct response due to early P300 contamination. Furthermore, despite emphasising that PMN modulations in the absence of task-borne semantic processing requirements support this distinction, the authors simultaneously go on to highlight the lack of sensitivity to word-non word contrasts as evidence that the PMN is unresponsive to lexicality. The lack of measurement of the N400 in the results weakens this argument, as it is not possible to determine whether task demands would have elicited N400 lexicality distinctions. Interestingly, Newman and Connolly (2009) later reported that the N400 was modulated by rhyme overlap, whilst the PMN did not distinguish between incorrect targets, citing the results of the study as evidence for the distinctiveness of the two components and their sensitivity to different sized units of phonological information. In Newman and Connolly (2009), a repeat of the 2003 experiment design, 13 participants were asked to delete the initial consonant off a four-syllable word. PMN modulations were measured between 260-320 ms and the N400 between 380-460 ms based upon visual inspection of waveforms. The authors reported a PMN response to matching/mismatching targets, and a lexicality effect on the N400-like response, concluding that the two components were functionally dissociated. However, upon visual inspection, a larger PMN to words as compared to nonwords was apparent over centroparietal sites, which the authors attributed to the onset of the N400.

Whilst evidence to support the specific PMN component reported by Connolly and Philips (1994) is conflicting, there remain consistent findings indicative that ERP activity between 200 - 400 ms reflects the activation and processing of phonological information (Desroches et al., 2008; Hagoort & Brown, 2000; van den Brink et al., 2001; Van Petten et al., 1999). A number of alternative interpretations for phonological sensitivities in this timeframe have been put forward. These interpretations vary from early N400 accounts (Dumay et al., 2001; Praamstra & Levelt, 1994; van Petten et al., 1999), separate components including the P250, P325 (Hargoot & Brown, 2000; Van den Brink et al., 2001; Grainger et al., 2006; Holcomb & Grainger, 2009) or variations upon the fronto-central visual PMN as originally reported (Desroches et al., 2009; Sučević et al., 2015). Furthermore, it remains unclear whether early modulations represent a mismatch between auditory input and lexical representations activated by context-derived phonological expectation (Connolly & Phillips, 1994; Newman & Connolly, 2009), early semantic integration based on partial and incomplete information about a perceived word (van Petten et al., 1999), or the comparison of lexical candidates activated by acoustic input with context-derived semantic expectation (Hargoot & Brown, 2000). For example, van den Brink et al. (2001) extended upon the design of Connolly and Phillips (1994) reporting biphasic ERP responses to semantically or phonologically incongruent target words. Semantically constrained Dutch sentences were completed with target words forming three conditions; a correct condition, featuring fully congruent highest cloze-probability words, an initially congruent condition, with sentences ending with words that shared the initial phonology of the correct target, and a fully-incongruent condition in which words different both phonologically and semantically from the correct target word. The authors proposed that the paradigm might serve to distinguish between reports of phonological processing influences on either a monophasic N400 effect (Van Petten et al., 1999), or the biphasic negative shift reported by Connolly and Phillips (1994; Hargoot & Brown, 2000). The authors reported a clearly distinct response at approximately 200 ms, followed by a second deflection at 400 ms. The early response was reported as larger for fully incongruent stimuli, with no significant difference between the fully congruent or initially congruent conditions. As such, the findings were purported as evidence against the interpretation given by Connolly and Phillips (1994) that the early negative deflection represents the match between auditory input and context-derived phonological expectation. Instead, the authors suggested that the component reflects the comparison of form-based-activated lexical representations to their semantic fit within a sentential context, consistent with that of Hagoort and Brown (2000). In contrast, the interpretation of effects reported by van Petten et al. (1999) and Praamstra and Levelt (1994) as an early deflection of the monophasic N400 appear supported by reports that the auditory N400 can generally be seen to occur earlier, and with a more frontal topography (for a review, see Kutas & Van Petten, 1994; Kutas et al., 2014). Indeed, such latency and topography are not unlike those reported in early PMN studies.

Considering the substantial variability in the interpretation of ERP modulations observed in the first 200 - 400 ms after word presentation, some authors have sought to draw parallels between the framework of lexical activation models and ERP effects. Figure 7 offers an approximate mapping of ERP modulation with the time-course of lexical processing within the Bi-modal Interactive Activation Model, as proposed by Grainger and Holcomb (2009).

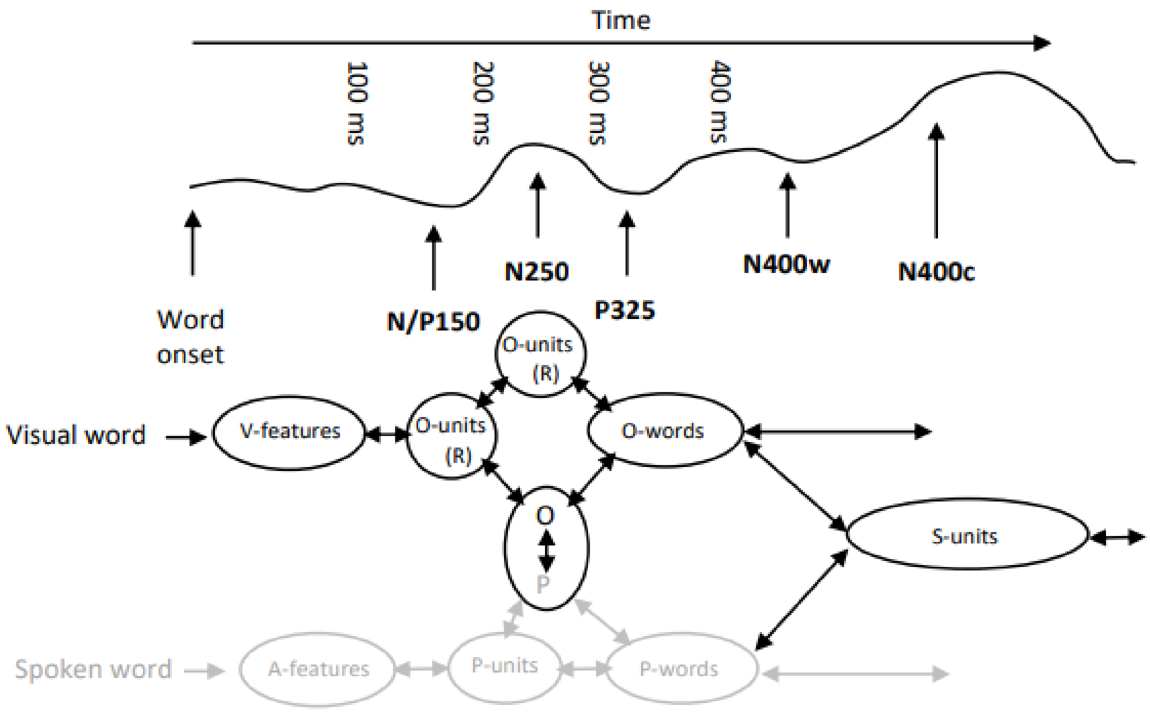

Figure 7. The time course of word recognition as adapted from Grainger and Holcomb (2009). 'R' refers to location-specific, retinotopic code, and W to location-invariant, word-centred code. A clear distinction is drawn between the representations involved in grapheme–phoneme or phoneme-grapheme translation (O⇔P) compared to the sublexical representations of spoken-word recognition (P-units). See Grainger and Holcomb (2009) for a more detailed overview of visual word recognition stages.

In the figure, four specific components are mapped, namely the N/P150, N250, P325, and N400 (broken down into two subcomponents, the N400w; sensitive to word and concept interaction processes, and the N400c; influenced by concept-to-concept processing). Of particular interest regarding the time-course of phonological representation activation is the period between 200-400ms, in which activation of phonological sublexical units is proposed to extend to that of lexical representations. Within this period, the authors highlight two components, the N250, and P325. The authors consider the N250 as reflecting the processing and integration of orthography subsequently used to generate phonological representations, and suggest that the component is additionally influenced by the mapping of orthography on to whole-word representations. The second component, the P325, was initially reported by Holcomb and Grainger (2006) as a relatively new component peaking between the N250 and N400, and sensitive to full word repetition within masked priming paradigms. In their 2006 study, the authors highlighted the lack of consistency in evidence of ERP responses pre-N400 to repetition priming in the literature (Holcomb, Reder, Misra, & Grainger, 2005; Misra & Holcomb, 2003; Schnyer, Allen, & Forster, 1997), suggesting that long stimulus-onset asynchronies (500+ ms) might influence the variable effects reported.

The authors suggested that with a stimulus-onset asynchrony (SOA) of 500 ms, lexical and sublexical priming effects on target processing may dissipate, leaving only the residual semantic influences seen to affect N400 amplitude. Instead, using an SOA of 50 ms, the authors reported modulation of the P325 to full-word repetition priming, proposing that the component is sensitive to the processing of whole-word phonological and orthographic representations.

2.3.3. ERPs: Mapping a time course of lexical processing

'What is essential whether linking a newly-discovered response with an older one or splitting a well-studied response into subcomponents is that the measure be reliably identifiable in data and its sensitivity to stimulus and task properties mapped out; only then can it be used to meaningfully answer questions about cognitive and neural function.'

Kutas and Federemeier (2011; 4)

Whilst ERPs offer insight into the sequence of cognitive processes underpinning word identification, the exact time-course of the mechanisms underlying lexical retrieval from approximately 50,000 possibilities in less than half a second continue to elude researchers in the field, despite being a subject particular interest within the field of cognitive science for at least four decades (Grainger & Holcomb, 2009). The degree of overlap between purportedly discrete components and subcomponents within this time window has meant that I have adopted a broader approach to ERP analysis. Focussing upon the activation of phonological representations, I have selected the 200-400 ms time window in the experiments presented in the current thesis, considering that it can be assumed that ERP amplitudes within this time window consistently respond to phonological priming. In contrast to a method in which specific components (e.g., PMN, N250, P325) are analysed, I have chosen to focus on the entire timeframe of phonological activation (200-400 ms), the *sensitivity of which to stimulus and task properties* is ubiquitous in the literature. It is noteworthy that in all of the studies presented here, an SOA of 250 ms or less was used, in line with the suggestion of Holcomb and Grainger (2006; Grainger & Holcomb, 2009) that longer SOAs may reduce priming resulting from phonological or orthographic form repetition. In addition, and somewhat critically, a large window of analysis for phonological priming is particularly adapted for the studies reported here given that phonological priming was always implicit and mediated across languages in contrast with the quasi totality of the studies reviewed above. As for the N400, which has been studies to a much greater extent, I have adhered to the classic 350 - 500 ms window, the classical and widely used time-window for the measurement of lexical-semantic priming.

Chapter 3

Accent

3.1. Study 1 – L1 accent in the second language facilitates unconscious access to first language phonological representations.

Abstract[2]

Behavioural and neurolinguistic studies have repeatedly shown that language access is non-selective in bilinguals. A notable exception comes from studies on orthographic specificity, showing that words containing language-specific letter combinations constrain lexical access. Here, we test the intuitive idea that accent can modulate cross-language activation in bilinguals. Highly fluent Welsh-English bilinguals made semantic relatedness judgements on English word pairs, unaware that some pairs concealed a phonological repetition via translation into Welsh. We found a strong modulating effect of accent, such that Welsh accented words prompted unconscious access to Welsh translation equivalents, whereas English accented primes failed to yield such an effect. Accent-dependent phonological priming was indexed by event-related brain potential modulations between 200 and 400 ms post stimulus onset, consistent with previous observations of implicit phonological priming. We conclude that L1 accent facilitates access to first language representations in bilinguals operating in their second language.

Keywords: Event-related potentials; word processing; implicit-priming; cross-language activation; speech processing; lexical access

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[2] Section 3.1 is under review in Language, Cognition and Neuroscience (see Appendix C)

3.1.1. **Introduction**

A listener processing a stream of speech must use multiple cues to access lexical representations at a pace compatible with that of the signal. Prominent theories of language perception suggest that the identification of each word encountered begins with the activation of numerous phonologically overlapping candidates, with retrieval of the correct item from the mental lexicon involving rejection of competing items (McClelland & Elman, 1986; Marslen-Wilson, 1990; Norris & McQueen, 2008). This process of lexical activation is further complicated in bilinguals, who face competition from representations in either of their languages. Consequently, over the last two decades a substantial amount research has focussed on whether bilingual word recognition involves retrieval from one integrated lexicon, in which both L1 and L2 representations are stored, or discrete systems for each language.

More recently, studies have shown that lexical access is largely language non-selective in fluent bilinguals, in both visual word recognition (Duyck, 2005; van Heuven & Dijkstra, 1998) and auditory word perception (Spivey & Marian, 1999; Ju & Luce, 2004; Thierry & Wu, 2007; Wu & Thierry 2010; Lagrou, Hartsuiker & Duyck, 2013), consistent with the notion of an integrated lexicon. Beyond the wealth of evidence obtained through behavioural investigation (e.g., Spivey & Marian, 1999; Duyck et al., 2007; Van Heuven et al., 1998), studies using event-related potentials have established that cross-language interference effects occur spontaneously and unconsciously. For instance, Thierry and Wu (2007; Wu & Thierry, 2010) found evidence for unconscious L1 activation in Chinese-English bilingual participants, as demonstrated by implicit L1 priming in a solely L2 context. In the 2007 study by Thierry and Wu, participants were presented with English prime words, which, via translation into Chinese, concealed an orthographic and phonological overlap with critical target words. The authors observed that character repetition resulted in an N400 reduction similarly to that elicited by semantically related targets, suggesting that participants had accessed L1 translation equivalents, in the absence of any behaviourally measurable effect. In a second experiment intended to provide further insight into the nature of the mental representation accessed, Wu and Thierry (2010) presented participants with a similar L2 semantic relatedness paradigm and separately tested orthographic and phonological priming through the L1. Results showed that whilst prime-target phonological overlap in Chinese produced significant N400 attenuation, orthographic overlap did not yield a significant priming effect. The authors concluded that Chinese-English bilinguals accessed the phonological –not the orthographic– representations of L1 words when functioning in their L2.

The factors that enable bilinguals to function within a single-language context despite unconscious L1 co-activation have been explored to a lesser degree. In a 2002 study, Rodriguez-Fornells et al. investigated the mechanisms by which bilinguals might prevent interference from a non-target language. Using ERPs and fMRI, they reported that lexical frequency of words in Catalan failed to modulated N400 amplitude when bilingual participants responded to Spanish target words whilst ignoring Catalan words. The authors interpreted the results as showing that, under certain conditions, semantic representations of words in the ignored language are inhibited. They proposed that such a language-specific pattern of response could originate at a sub-lexical level, involving an indirect phonological access route to the target language lexicon that avoids interference. A number of limitations of the methodology of this study have been highlighted (Grosjean & Li, 2008), in particular that graphemic cues afforded by the stimuli may have curtailed access to the non-target language. Subsequently, a number of other studies provided independent support for language-selective access constrained by sub-lexical orthographic cues. Casaponsa and Duñabeitia (2016), for instance, explored the influence of orthotactics in language priming tasks. Participants were presented with naturalistically learnt L2 words either containing language-specific bigram combinations (orthographically marked), or orthographic patterns acceptable in both languages (orthographically unmarked) in a modified Reicher–Wheeler paradigm and a masked translation priming experiment. In the Reicher-Wheeler paradigm, participants were presented with a forward mask (e.g., ####) followed by the referent word or nonword, then a backward mask alongside two letters, and asked to indicate which of the two letters appeared in the word. In the second experiment, the same participants made lexical decisions on Spanish targets preceded by their translations in Basque, which were either orthographically marked or unmarked. Results from the Reicher-Wheeler experiment showed that marked stimuli (both words and nonwords) yielded slower reaction times than unmarked stimuli, suggesting that letters from marked stimuli received less reinforcement from spread of activation at the lexical level than unmarked stimuli (common to Basque and Spanish). In the second experiment, participants showed significant translation masked priming effects only for words preceded by orthographically unmarked primes, demonstrating that unconscious sensitivity to statistical orthographic regularities can yield language-selective access.

Research on the role of sub-lexical features in mediating parallel language access in auditory word processing is relatively sparse. Current findings suggest an influence of sub-lexical phonetic cues on language non-selective access (Lagrou, Hartsuiker & Duyck, 2013) and invite further questions regarding the role of acoustic-phonetic information in lexical activation. In particular, since the 1960s studies have explored whether accent assists or hinders comprehension and intelligibility in bilinguals listening to their second language. Whilst early studies found a beneficial role of L1 accent (Brown, 1968; Wilcox, 1978; Flowerdew, 1994; Bent & Bradlow, 2003) and generally concluded that speech in a speaker's own accent may be easier to understand, others have suggested that mere familiarity with an accent is enough to aid comprehension (Pihko, 1997; Gass & Varonis, 1984).

Exploring whether accent could influence lexical access, Lagrou, Hartsuiker and Duyck (2011) tested Dutch–English bilinguals in auditory lexical decision tasks conducted in both Dutch and English. In an initial experiment, participants listened to English words produced by either a native English speaker (L2 Dutch) or a native Dutch speaker (L2 English). Target stimuli included items which were either inter-lingual Dutch-English homophones (e.g., lief [sweet] – leaf /li:f/), control stimuli, fillers, or non-words. Recognition of homophones was consistently slower than that of control words, but reaction times (RTs) were overall slower across target types for words produced by a native Dutch speaker. When testing native English speakers using the same paradigm, the effect of accent was similar, with non-native Dutch-accented target words eliciting longer reaction times. Noting that in the case of English-accented target words the speaker tended to stretch pronunciation, resulting in significantly longer target word durations, the authors acknowledge that the increase in reaction times could either be due to increased opportunity for lexical activation prior to response or to the mismatch between non-native production and stored lexical representations. In a third experiment, intended to disentangle the two prior hypotheses, Lagrou et al. (2011) re-ran the same paradigm in the participants' native language. When tested in the L1 Dutch, RTs were significantly faster to non-accented than English accented speech, suggesting that lexical access was facilitated by the match between non-accented productions and stored lexical representations.

Interestingly, a lack of interaction between accent and the homophone effect suggested that sub-phonemic cues present in accent do not reduce parallel activation of a listener's languages.

Following this, Lagrou, Hartsuiker and Duyck (2013) tested Dutch-English listeners to investigate the role of three potential factors in language non-selective access, namely sentence context, semantic constraints, and native language of the speaker. Dutch-English bilinguals listened to English sentences produced by either a native Dutch speaker or a native English speaker and made a lexical decision on the last word of the sentence. The inter-lingual homophone effect found, i.e., longer reaction times for inter-lingual homophones compared to control stimuli, supported the notion that, in bilinguals, non-selective language access occurs in auditory word perception as well as in visual word recognition. Furthermore, accent modulated the homophone interference effect, with participants responding faster to English-accented than Dutch-accented sentences. The authors concluded that further research is necessary to determine whether these effects reflect an increase in the salience of the participants' L1 leading to greater interference, or a decrease in overall intelligibility when L2 speech is L1 accented.

Studies investigating cross-language activation in bilinguals have typically revealed sensitivity to unconscious priming in a time window encompassing the N250 and P325 (Holcomb & Grainger, 2006; Grainger, Kiyonaga & Holcomb, 2006; Grainger & Holcomb, 2009), Phonological Mapping Negativity (PMN; Connolly & Philips, 1994; Desroches et al., 2009; Vaughan-Evans et al., 2014), and N400 range (Holcomb & Grainger, 2006; Thierry & Wu, 2007; Wu & Thierry, 2010). In the present study, we sought to determine whether the presence of sub-phonemic L1 accent cues would facilitate access to the inactive L1 lexicon in an L2 context, supporting the increased L1 salience account, or whether the accent effect is more attributable to intelligibility difficulties, with L2 accented speech providing a closer match to the listener's stored representations. Testing highly-fluent Welsh-English bilinguals in a paradigm intended to elicit unconscious L1 phonological priming effects similar to that observed by Wu and Thierry (2010), we investigated whether L2 (English) words produced with an L1 (Welsh) accent would elicit priming effects mediated by phonological overlap in the L1. To manipulate accent, primes were produced by both a monolingual English speaker with a SE accent, and a Welsh speaker (a non-native English speaker) with a regional accent typical of the Llyn Peninsular in North Wales. Whilst other studies (Lagrou, Hartsuiker & Duyck, 2011; 2013) have manipulated accent by selecting native speakers of a certain language, the bilingual context in Wales is quite unique. A notable issue therefore arises in testing Welsh-English bilinguals and manipulating accent to indicate native language (L1). Because the population in Wales consists of a large number of native speakers of English with Welsh accents, a Welsh accent in itself is not necessarily indicative of an L1 Welsh speaker. To address this, the Welsh speaker in the current study was selected from the Llyn Peninsular, an area that is notably Welsh-dominant. Thus, it would be atypical to find a native English speaker with an accent characteristic of the region.

In the present cross-modal priming experiment, Welsh-English bilingual participants made semantic relatedness decisions on English word pairs, some of which featured a word-initial phoneme overlap through translation into Welsh, e.g., interview (*cyfweliad*) – warm (*cynnes*). We hypothesised that L1 accent may facilitate access to the L1 in an all-in-L2 context, resulting in an increase in phonological priming for word pairs featuring L1 accented L2 primes, manifesting as a reduction of mean amplitude within the 200–400 ms range spanning the N250-PMN-P325 range for Welsh accented relative to English accented stimuli. We also hypothesised that decreased intelligibility might translate as a reduction of N400 modulation when participants made semantic relatedness judgments on L1 accented L2 words as compared to the same words produced with an L2 accent.

3.1.2. **Methods**

3.*1.2.1.* *Participants*

Twenty-one highly proficient Welsh-English bilinguals participated in the experiment. Two datasets were rejected due to poor electrophysiological data quality resulting in a final sample of 19 participants (12 female, 7 male, mean age = 24.8; SD = 8.9, one left-handed). All had normal or corrected-to-normal vision, no learning disabilities and self-reported normal hearing. All had started learning Welsh at or before the age of 3, spoke Welsh at home, and had studied through the medium of Welsh up to the age of 18. Whilst age of acquisition for English varied, it was on average significantly later than for Welsh (t(23) = -6.377, p = < 0.001) and all participants self-reported equal proficiency in Welsh and English or greater proficiency in Welsh (**see Table 1**). Participants all received Welsh-medium schooling up to the age of 12, with a majority taught through the medium of Welsh up to University and English taught formally as a second language from the age of six.

Table 1: Participant language background

Measure	Mean	SD
Age of Welsh acquisition	0.2	0.9
Age of English acquisition	3.8	2.29
Daily Welsh usage (%)	64	20
Daily English usage (%)	35	19

3.1.2.2. Materials

Auditory word primes were 39 familiar, mid-range frequency, three-syllabic words of English. Visual word targets were 234 familiar, mid-range frequency words of English varying in length from 2 – 4 syllables split into two lists of 117, in order to manipulate phonological overlap and semantic relatedness separately. The prime and target words were paired to form experimental conditions as follows: (1) Phonological overlap via Welsh translation (overlap condition) as in “interview – warm” (in Welsh: *cyfweliad – cynnes*); (2) Semantic relationship (related condition) as in “interview – ask” (in Welsh: *cyfweliad – gofyn*); (3) No overlap through Welsh (no overlap condition) using a stimulus from the same list as condition (1) as in “interview – wind” (in Welsh: *cyfweliad – gwynt*); and (4) No semantic relationship (unrelated condition) using a stimulus from the same list as condition (2) as in “interview – bush” (in Welsh: *cyfweliad – llwyn*). Critically, the target words of each pair were rotated across conditions (1) and (3) on the one hand and across conditions (2) and (4) on the other, meaning that all words featured as targets in the overlap condition were also featured as targets in the no overlap condition and similarly for semantically related and unrelated conditions. Furthermore, each auditory prime word was paired with three possible visual word targets, resulting in 117 (3 x 39) prime-target combinations per list.

Primes and targets were matched across conditions for lexical concreteness and frequency, with Welsh frequencies taken from Cronfa Electroneg o Gymraeg (CEG;

Ellis et al. 2001) and English frequencies from SUBTLEX (van Heuven, Mandera, Keuleers, & Brysbaert, 2014). Concreteness measures for English materials were calculated from the corpus published by Brysbaert et al. (2014), and, due to corpus unavailability, assumed to be similar for Welsh translations. The 39 auditory prime words were digitally recorded by two adult female speakers at a sampling rate of 48.8 kHz and resampled using Audacity to 44.1 kHz to ensure compatibility with E-Prime stimulus presentation software.

3.1.2.3. Procedure

Participants gave written informed consent to take part in the experiment that was approved by the School of Psychology, Bangor University ethics committee. Testing took place across two separate sessions, with a break of at least one day between the two. The two accents were separated by session and counterbalanced so that half of the participants heard Welsh-accented primes in the first session, and the other half in the second session. Within each session, participants engaged in 156 trials consisting of 39 trials from each of the 4 experimental conditions. For each auditory prime word, the target was one out of three possible visually presented words, with targets rotated between participants. In each trial, participants first saw a fixation cross for 100 ms on a 17” RCT monitor at a distance of 100 cm from the eyes, followed by an auditory prime, played over loudspeakers set around the monitor.

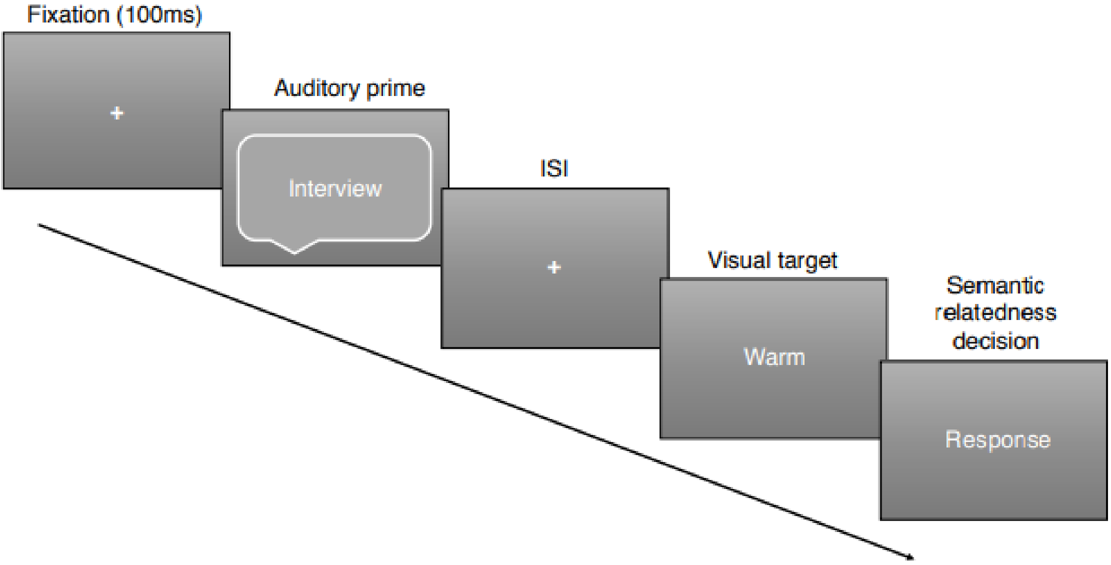

Figure 8 – Experimental procedure. 'Interview' translates as cyfweliad and 'warm' translates as cynnes in Welsh.

After the end of the auditory prime, a second fixation cross was displayed for a variable ISI of 160–240 ms before the visual target word was presented in black Times New Roman font, size 14 points on a light grey background (**see Fig. 8**). Participants were asked to indicate by button-press if prime and target pairs were related in meaning during a response window lasting a maximum of 2000 ms and response immediately triggered the next trial. Response-hand side was counterbalanced between participants. Participants performed a brief training period prior to commencing the full experiment to ensure they were familiarised with the procedure.

3.1.2.4. ERP recording and pre-processing

EEG data was recorded using a BioSemi system from 128 active Ag/AgCl electrodes with the passive common mode sense (CMS) electrode as reference and driven right leg (DRL) as ground. Electrodes were held in place on the scalp with an elastic cap. Prior to recording, EEG electrode impedances were reduced to below 5 kΩ, and noisy electrodes were replaced by means of spherical interpolation. Data was recorded at 2048 Hz, resampled to 1024 Hz prior to analysis and re-referenced offline to the global average reference. Six facial bipolar electrodes positioned on the outer canthi of each eye and in the inferior and superior areas of the left and right orbits provided bipolar recordings of the horizontal and vertical electrooculograms (EOG). Data was filtered offline using a 30 Hz (48 dB/oct) low-pass and 0.1 Hz (12 dB/oct) high-pass Butterworth Zero Phase shift band-pass filter. Filtered data was inspected prior to ocular correction, which was conducted using Independent Component Analysis (ICA), which was run on a separate block, recorded prior to the main testing block for each session the participant attended. Participants were instructed to blink and make repeated vertical and horizontal eye movements in order to acquire eye-movement data on which ICA was computed, using the AMICA procedure (Palmer, Makeig, Kreutz-Delgado, & Rao, 2008). Data was subsequently segmented into epochs ranging from −200 to 1000 ms, time-locked to the onset of the visual target word. Baseline correction was performed relative to pre-stimulus activity before grand-averages were computed in each of the experimental conditions. There were at least 30 trials per condition for each participant.

3.1.2.5. Data analysis

- Modelling of behavioural data

Accuracy was separately modelled as a function of two within-subjects factors, with one model for accent (Welsh, English) and phonological overlap (overlap, no overlap) and another model for accent (Welsh, English) and semantic relatedness (related, unrelated). We used generalized mixed-effects modelling (via the *glmer* with binomial link function in the lme4 v1.12 library; Bates, Maechler, Bolker, & Walker, 2014), with factors centred for the analyses to minimise collinearity. Random effects, including participant and item intercepts and slopes were modelled and systematically trimmed (interaction terms were removed) until the model converged (Barr, Levy, Scheepers, & Tily, 2013). Reaction times were log transformed to approximate a normal distribution, before being submitted to linear mixed effect modelling (using the *lmer* function in lme4) using the same iteration procedure as above.

- ERP analysis

Previous studies reporting effects of phonological expectancy in the phonological mapping negativity range (230-350 ms) or unconscious access to L1 phonology effects, report maximal sensitivity over centroparietal regions (Dumay et al., 2001; Praamstra et al., 1994; Hargoot & Brown, 2000; Newman & Connolly, 2009; Desroches et al., 2009; Malins et al., 2013; Sučević et al., 2015; Thierry & Wu, 2007; Wu & Thierry, 2010). To explore effects of phonological overlap, we thus analysed ERP amplitudes over a time window corresponding to the timeframe in which phonological priming is usually observed, i.e., between 200 and 400 ms at centroparietal electrode sites (Grainger, Kiyonaga & Holcomb, 2006; Connolly & Philips, 1994; Desroches et al., 2009). To test effects of semantic priming, we analysed ERP mean amplitudes in the classic N400 window (350-500 ms) over central regions (Kutas and Hillyard, 1980; Kutas and Federmeier, 2011; Thierry and Wu, 2007; 2010). Both analyses were conducted by means of two-by-two repeated measures analysis of variance (ANOVA). For the phonological priming analysis, the repeated measures ANOVA was conducted over 12 centroparietal electrodes (cf. Fig. 9a) with accent (Welsh, English) and overlap in L1 (overlap, no overlap) as factors. As regards the analysis of semantic relatedness effects, N400 mean amplitudes were analysed over 15 central electrodes (spanning frontocentral and centroparietal regions; cf. Fig. 9b) where the N400 is usually maximal with accent (English, Welsh) and relatedness (related, unrelated) as independent variables.

3.1.3. **Results**

3.1.3.1 Behavioural results

In the model testing the effects of phonological overlap on accuracy we found no main effect of either accent or phonological overlap and no interaction. In the second model testing semantic relatedness effects on accuracy, a main effect of relatedness emerged, such that participants were more accurate for unrelated than related pairs (b = 3.43, SE = <0.5863, z = -5.852, p = <0.001). There was no effect of accent and no interaction between accent and relatedness.

As regards reaction times, there was no main effect of either accent or phonological overlap and no interaction. In the model of semantic relatedness, however, there was a main effect of relatedness, such that participants responded faster to unrelated than related pairs (*b* = -0.03, *SE* = <0.007, *t* = -4.42, *p* = <0.001). There was no effect of accent and no interaction between accent and relatedness.

3.1.3.2 Electrophysiological results

The repeated measures ANOVA on ERP mean amplitudes in the phonological priming window failed to reveal a main effect of accent, F(1, 18) = 0.001, p = .974, η_p^2 = 0.000, nor an effect of overlap, F(1, 18) = 0.048, p = .829, η_p^2 = 0.003 (**Fig. 9a**). However, there was a significant interaction between accent and overlap, F(1, 18) = 5.13, p = 0.036, η_p^2 = 0.222, such that ERP amplitudes were modulated by phonological overlap in the Welsh accent condition, t(18) = -2.12, p = 0.048, but not in the English accent condition, t(18) = -1.53; p = 0.141.

In the 350-500 ms time window there was a significant main effect of semantic relatedness on mean ERP amplitudes, F(1, 18) = 18.32, p < 0.001, η_p^2 = 0.504, such that N400 amplitude was significantly more negative in the unrelated than the related condition, t(18) = -4.28, p < 0.001 (**Fig. 9b**). There was no effect of accent, F(1, 18) = 0.119, p < 0.734, η_p^2 = 0.007, and no interaction between accent and relatedness, F(1, 18) = 0.182, p = .674, η_p^2 = 0.010.

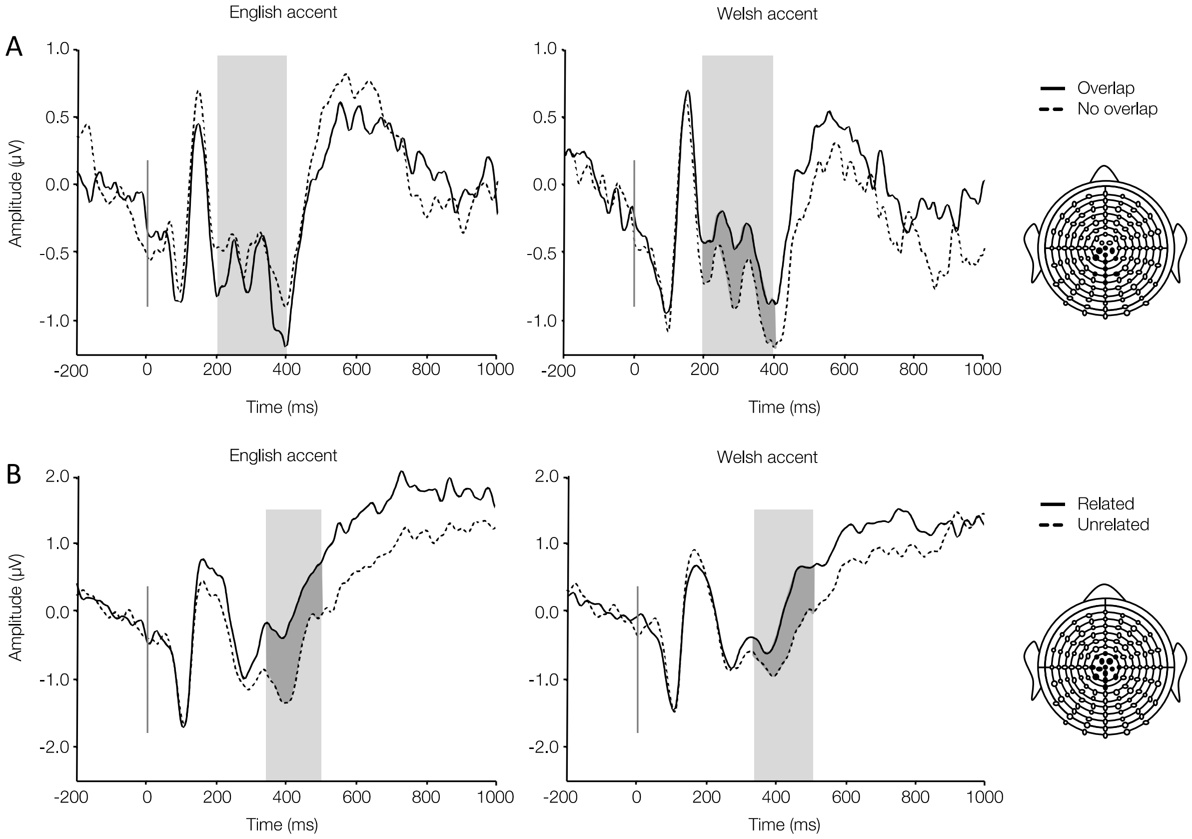

Figure 9. Event-related potentials elicited by target L2 words in the phonological overlap contrast and the semantic relatedness contrast. (A) Comparison of phonological overlap and control conditions for L2 accented primes (left) and L1 accented (right). (B) Comparison of semantically related and unrelated conditions for L2 accented primes (left) and L1 accented (right). Head maps show location of electrodes included in each of the two analyses.

3.1.4 Discussion

We manipulated speaker accent in an implicit phonological priming paradigm with Welsh-English bilingual participants involving spoken word primes and visual word targets. Beyond a classic semantic relatedness effect widely reported in the literature (Kutas & Hillyard, 1980b, 1980a; Thierry & Wu, 2007) we found a significant effect of L1 phonological overlap for spoken L2 word primes produced with a Welsh accent, but not for primes pronounced with an English accent. However, we found no significant modulation of semantic priming by accent. Whilst the former finding provides support for the existence of a modulating effect of accent on cross-language phonological activation, the latter result suggest that intelligibility is not critically affected by accent in fluent bilinguals.

Consistent with previous studies showing implicit access to L1 phonological representations in participants tested entirely in their L2 (Thierry & Wu, 2004; 2007; Wu & Thierry, 2010), we found a reduction of mean ERP amplitudes for semantically unrelated word-pairs concealing a phonological overlap via L1. To our knowledge, this is the first report of a modulatory effect of accent on cross-language activation. It is noteworthy, in addition, that the phonological priming effect found here occurred earlier than that reported previously, e.g., in Chinese-English bilinguals. Whilst there is general agreement that ERP modulations in the N400 window indexes lexical and post-lexical priming, earlier modulations are generally associated with sub-lexical priming, whether orthographic or phonological (Grainger & Holcomb, 2009). In masked priming experiments, ERP modulations in the N250 range have been shown to reflect sub-lexical access (Kiyonaga et al., 2007; Meade et al., 2018; Schoonbaert et al., 2011). In their review of lexical masked priming and ERPs, Grainger and Holcomb (2009) proposed that access to sub-lexical representations occurs approximately 250 ms post-stimulus onset, followed by whole-word representation processing at around 325 ms. Accordingly, we suggest that the effect observed in the current study reflects sub-lexical phonological priming. In Thierry and Wu's (2007) and Wu and Thierry's (2010) studies, priming *de facto* likely happened at the lexical level since overlap between primes and targets concerned a full Chinese character, rather than one or two initial phonemes as in the current study. In addition, in these previous studies, priming was intra-modal (visual or auditory) rather than cross-modal (here auditory-to-visual) and the Chinese-English bilinguals tested, despite being highly fluent, dealt with typologically distant languages and did not master them to the same extent as simultaneous Welsh-English bilinguals.

The early effect reported may be explained further by the specific bilingual population studied. Our Welsh-English bilinguals have lived in North-Wales, an area with a unique bilingual context in which Welsh is a minority language protected by revival programmes and spoken as a native language on an equal stand with English. Welsh monolingualism only occurs in elderly individuals living in relatively isolated in rural areas, or in young pre-school children before they become exposed to the strongly bilingual community beyond home. Thus, even though the native language of participants involved in this study was Welsh, proficiency levels in English were essentially native-like. It follows that access to Welsh translation equivalents of English words should be more efficient than that of Chinese translation equivalents of English words in late Chinese-English bilinguals. This interpretation is also consistent with findings in speech production as reported by Spalek, Hoshino, Wu, Damian, and Thierry (2014), who showed that German-English bilinguals unconsciously accessed German word forms as early as 300 ms post picture onset when asked to produce English adjective-noun phrases.

It must be noted that the topography of the priming effects found in the current study was centroparietal in contrast to N250 modulations found in masked priming experiments (Grainger & Holcomb, 2009; Grainger et al., 2006; Holcomb & Grainger, 2006; Van Hell & Kroll, 2013), which tend to be maximal over frontocentral regions. The N250 is thought to index the mapping of sub-lexical form to orthographic representations. Translation priming effects shown to modulate the N250 have been suggested to reflect either activation of translations via direct lexical links, or activation of form-level representations as a result of the semantic representation feedback (van Hell & Kroll, 2013). Instead, the topography of the modulation is closer that of the P325, a differential effect attributed to phonological overlap in masked priming experiments with a centroparietal distribution (Grainger & Holcomb, 2009; the N400; and that of phonological expectation effects consistently reported in phonological priming experiments (Dumay et al., 2001; Praamstra et al., 1994; Rugg, 1984a, Rugg, 1984b; Newman & Connolly, 2009; Desroches et al., 2009; Malins et al., 2013; Sučević et al., 2015). We speculate that the centroparietal distribution of the effect in the current study may relate to the cross-modal nature of the priming paradigm used. Indeed, only studies that have used a visual priming paradigm have reported PMN modulation over the frontocentral regions (Connolly & Philips, 1994).

Recall that our study aimed to shed light on the alternative between the increased L1 salience and reduced L2 intelligibility accounts put forward by Lagrou et al. (2011; 2013). In the latter studies, the authors observed longer RTs for L1-accented L2 speech, whilst L2 accented stimuli reduced (albeit did not eliminate) the inter-lingual homophone effects. A reduced intelligibility account would lead to the prediction of more demanding semantic processing of L1 accented L2 words. However, in our study, no such effect of accent on semantic processing was detectable, whether indexed by accuracy or RT in the semantic relatedness task or N400 modulations elicited by semantic relatedness. Instead, our results support the alternative interpretation that L1 accented L2 speech increases L1 salience given that L1 phonological priming was only found when L2 prime words were L1 accented. This said, we cannot conclude from the current results that reduced intelligibility may not be at play in the case of bilinguals with lower proficiency in their L2.

This being said, in our study L1 accented L2 speech failed to elicit any measurable phonological priming, whereas the interlingual homophone effect of Lagrou et al. (2013) was only reduced in magnitude by accent as opposed to being suppressed entirely. We contend that this difference relates primarily to the use of an implicit priming paradigm in our study, in which overt L1 language cues (e.g., homophones) are absent, lessening the likelihood of L1 activation. For instance, when the word ‘interview’–*cyfweliad* is used as a prime for the word ‘warm’–*cynnes*, no information regarding a potential phonological overlap between prime and target is afforded by the stimuli in the L2 (overlap uniquely concerns the L1). In contrast, when the word *lief*–‘sweet’ in Dutch in presented at the end of a sentence, the overlap with its interlingual homophone in English ‘leaf’ is obvious, likely heightening the activation level of native language representations, and increasing the intensity of cross-language priming effects.

The findings of the current study may have implications for second language acquisition. If L1 accent heightens activation of first language representations, as suggested by our results, the establishment of L2 representations during L2 learning may be adversely affected by L1 accent. Moreover, in lower proficiency bilinguals or L2 learners, we cannot rule out that L1 accented L2 speech may also reduce intelligibility. Nevertheless, it is important to stress that the population tested here is not representative of unbalanced bilinguals who have different levels of exposure to their two languages, and who are not required to switch between their languages on a frequent basis. In addition, it is noteworthy that Welsh accent in Wales is also a regional accent, i.e., it is possible to encounter native speakers of English with a Welsh accent who speak little or no Welsh. Future studies will determine how semantic access is affected by foreign-accented speech in relation to proficiency in the L2, and whether L1 accent in L2 learners can affect intelligibility. Furthermore, follow-up investigations in different communities will hopefully tease apart contributions of foreign and regional accents in cross-language activation.

3.1.5 Conclusion

In sum, for the first time, we show that lexical access to L1 representations is stronger in bilinguals listening to L2 words when speech is L1 accented. Since phonological priming did not occur when L2 words were heard in a canonical L2 accent, suggesting that accent can act as a sort of gating mechanism, regulating activation of a bilingual's language representations. Importantly, accent manipulation had no detrimental (or boosting) effect on semantic processing, suggesting that access to phonological representations and meaning are not regulated by a common mechanism. Future studies manipulating accent in unbalanced bilinguals will shed critical light on this matter, since access may be less selective in such bilinguals.

3.2 Study 2 - Polysemy, accent, and second language processing

3.2.1. Introduction

More than half of the world's population is thought to speak more than one language (Grosjean, 2010). Over the last two decades our understanding of bilingualism, and the brain's ability to accommodate multiple languages has developed substantially. It is now a fairly uncontested fact that when a bilingual uses one language, the other remains active (Spivey & Marian, 1999; Marian & Spivey, 2003; Wu & Thierry 2010). How this dual activation influences language perception, comprehension and production, and what this can tell us about the cognitive mechanisms and structures underlying language processing has been subject to considerable research.

Most native English speakers, upon reading word *Hund* will relate to the experience of equating the foreign, less familiar word to their native English equivalent *dog*. According to certain models of language activation, these translation connections to the native language (L1) underpin second language (L2) production and comprehension processes (Kroll & Stewart, 1994). The Revised Hierarchical Model (RHM; Kroll & Stewart, 1994), for example, proposes that such lexical-level links between the L2 and L1 result in direct conceptual representation connections. As such, when a native German learner of English hears the word *castle*, the L1 translational equivalent *Schloss* is, in turn, activated. The RHM, which was predominantly inspired by sequential language acquisition, proposes that L2 words are linked through lexical level conceptual connections to the L1. Lexical level links are initially considered to be stronger from the L2 to the L1, as L2 words are thought to be learnt through direct mapping onto their L1 equivalents. Over time, second language conceptual links are said to strengthen as proficiency increases (Hernandez et al., 2005; Kroll & Tokowicz, 2001). A number of aspects of the RHM have been called into question (Brysbaert & Duyck, 2010), in particular the model's concepts of discreet lexicons and language selective access, a notion disputed by a host of behavioural (Duyck et al., 2007; Lagrou, Hartsuiker & Duyck, 2013; Van Heuven et al., 1998), eye-tracking (Spivey & Marian, 1999; Ju & Luce, 2004), and EEG (Thierry & Wu, 2007; Wu & Thierry 2010) studies showing that lexical access is largely language non-selective, and providing a wealth of support for the notion of an integrated lexicon. The seminal results of Spivey and Marian (1999; Marian & Spivey, 2003) were among the first to demonstrate cross-linguistic language interference effects. In their 1999 study, late Russian-English bilinguals listened to L1 and L2 instructions to look at a particular target object while viewing a display with four objects. In certain trials, the name of the target object shared initial phonology with the target object in the participants' other language. For example, when hearing the instruction *Look at the fish*, the target object shares initial phonology with the Russian competitor *fishka* (Engl.: game piece). In the critical condition, interlingual distractor objects (e.g., a game piece) appeared on the screen. The authors reported increased eye movements to distractor items in the participants' other language, indicating cross-language interference.

Spivey & Marian's (1999) results are supported by a considerable number of behavioural studies using cross-language or masked priming paradigms to demonstrate parallel lexical activation (Beauvillain & Grainger, 1987; Dijkstra, Timmermans, & Schriefers, 2000; Duyck, Assche, Drieghe, & Hartsuiker, 2007; Lagrou et al., 2013; van Heuven & Dijkstra, 1998). Although these experiments consistently establish an influence of cross-language activation, both eye-tracking and behavioural studies conventionally make use of masked and cross-language priming paradigms. A major drawback of these methods is the dual-language environment they create. Cross language paradigms generally consist of the presentation of a target word in one language preceded by a prime word in the other language. Similarly, in cross-language masked priming paradigms usually involve exposure to a prime word in one language for a very short presentation duration, rendering the prime consciously imperceptible, before a target word in the other language is presented. As such, exposure to both languages potentially increases parallel language activation levels and possibly gives rise to artificial cross-language activation effects. Although this involves more explicit exposure to both the first (L1) and the second (L2) language for cross-language priming paradigms, the problem remains for masked priming paradigms. Although perceptually monolingual in nature, the influence of activation of the non-target language on target-language processing is tested through the means of dual language exposure. To postulate that native language activation occurs within a L2 context subsequent to exposing participants to their L1 (albeit imperceptibly) creates a somewhat cyclical argument in which language activation potentially results from artificial language activation through exposure.

To overcome the limitations of cross-language and masked priming paradigms, in a seminal paper Thierry and Wu (2007; see also Wu & Thierry, 2010) tested language activation using an all-in-L2 implicit priming paradigm to modulate unconscious event-related potentials (ERPs) effects. Beyond the sensitivity of behavioural measures such as reaction times and accuracy, ERPs offer the ability to measure participants' covert, unconscious responses to stimuli, potentially broadening our understanding of unconscious neurological processes underpinning lexical activation. Thierry and Wu (2007) presented Chinese-English bilinguals with English prime and target words. Unknown to the participants, in critical trials prime-target pairs concealed a character overlap via L1 translation. For example, whilst the words *train* and *ham* are unrelated in English, their Chinese translations *Huo Che* and *Huo Tui* share a character in their L1 translation. The authors reported that, in the absence of any significant behavioural effects, the presence of a character overlap in L1 translations resulted in attenuation of the N400, an ERP component assumed to reflect cognitive processing effort. The effect was interpreted as evidence of L1 form-based priming, indicative of unconscious L1 activation during L2 processing. Wu and Thierry (2010) further explored the nature of non-selective language access using homophones and homographs in Mandarin Chinese, demonstrating that unconscious L1 priming took place for word pairs overlapping in phonology, not orthography. Considered alongside consistent evidence from a myriad of behavioural and eye-tracking experiments, the notion that the activation of L1 and L2 representations is largely non-selective in bilinguals has prompted the incorporation of shared lexical and sub-lexical levels in a number of bilingual word processing models. The Bilingual Interactive Activation model (BIA+; Dijkstra & van Heuven 2002; Dijkstra & van Heuven, 1998; Grainger & Dijkstra, 1992) for example, is a visual word recognition model that implements a language-nonselective access process. The BIA+ incorporates three nodes (sublexical, lexical and semantic) for both visual and auditory language processing, linked via inhibitory and excitatory connections. Non-selective access involves initial activation of word candidates from different languages, with a shared semantic network. Similarly, the BLINCS model (Shook & Marian, 2013) postulates that a bilingual's two languages share phonological and semantic networks, whilst the phono-lexical and ortho-lexical networks are separate but integrated.

If lexical access involves non-selective retrieval from an integrated lexicon, how do bilinguals successfully function in a perceptibly monolingual mode without significant interference from non-target language activation? Such a question necessitates investigation into the range of lexical and sublexical information potentially used to mediate parallel language access. For visual word processing, evidence predominantly points to a constraining role of orthotactics, that is, the frequency and position of letter combinations in a given language. Orthotactics has been shown to play a role in both language detection and lexical access (Casaponsa et al., 2015; Kesteren et al., 2012; Vaid & Frenck-Mestre, 2002) in bilinguals. Van Kesteren et al. (2012) for instance, tested Norwegian-English bilinguals in three tasks: a Norwegian-English language decision task, an English lexical decision task, and a Norwegian lexical decision task. In the mixed lexical decision tasks, words from the non-target language were included, requiring a 'no' response. Some of these words featured language-specific letters (smør, English: hawk) or bigrams (dusj, English: veal). Results showed that both types of sublexical markers facilitated participants' responses, but language-specific letters resulted in greater facilitation than bigrams. Comparison between the results from the mixed lexical decision tasks and the language decision task demonstrated that decisions originated at the sublexical level of bigrams rather than lexical representations. More recently, Casaponsa et al. (2015) used ERPs to explore the influence of sub-lexical orthographic regularities on language detection. In a masked language-switching priming task, Spanish-Basque bilinguals and a Spanish monolingual control group were presented with Spanish word targets preceded by unrelated Spanish or Basque words. Basque prime words were either orthographically marked or unmarked, meaning that they were either orthographically illegal or legal in Spanish, respectively. For example, the bigram "sk" in the Basque word *neska* - (Engl.: girl), is illegal in Spanish. Conversely, the Basque word *mutil* (Engl.: boy) complies with Spanish orthotactics. Mean amplitude modulations in the N250 and N400 ranges in response to target words were used to index switch costs associated with an unconscious language switch. Results showed that marked Basque primes resulted in a language switch in both the monolingual and bilingual groups, as indexed by an increase in N250 and N400 amplitudes, whilst effects for unmarked primes were found in the bilingual group only. The results suggest that the orthographic regularity is an important feature that informs language detection in bilingual readers.

As regards the auditory domain, the features that inform language detection and mediate non-target language activation in bilinguals have been explored to a lesser degree. Perhaps the most obvious feature, and one of particular focus of studies since the 1960s, has been accent. Early studies predominantly explored the effect of accent on speech intelligibility and comprehension in bilingual listeners, reporting a beneficial effect of L1 accent (Brown, 1968; Wilcox, 1978; Flowerdew, 1994; Bent & Bradlow, 2003). More recently, however, research has explored the influence of accent on language non-selective access (Lagrou et al., 2011; Lagrou et al., 2013; Lewendon et al., *under review)*, with results inviting further questions regarding the role of such acoustic-phonetic cues in mediating lexical activation. Lewendon et al. (*under review*) tested highly-fluent Welsh-English bilinguals in an implicit priming paradigm intended to elicit unconscious L1 phonological priming effects similar to those observed by Wu and Thierry (2010). In order to investigate whether accent might mediate L1 activation Welsh-English bilingual participants were asked to make semantic relatedness decisions on English word pairs, some of which, once translated into the L1, featured a word-initial phoneme overlap. For instance, despite being semantically unrelated, the word pair *interview* (Welsh: cyfweliad) – *warm* (Welsh: cynnes) features a phonological overlap through translation into Welsh. Results revealed that priming effects resulting from L1 phonological overlap only occurred for L2 words produced with an L1 accent, and thus that L1 accent facilitates activation of L1 phonological representations of L2 words.

In the current study, we intended to explore the influence of phonological cues on non-target language activation at a semantic level. Models such as BLINCS feature a semantic network shared between languages. Shook and Marian (2013) however noted that a fully integrated semantic network is challenged by previous evidence showing influence of cultural information on semantic representations (Ameel, Storms, Malt & Sloman, 2005; Dong, Gui & MacWhinney, 2005) and recommended further research into the degree to which semantic representations are shared. The suggestion that the semantic network might be integrated across languages of bilinguals is particularly relevant when one considers the prior example. Upon hearing the L2 word *castle*, we can assume from current evidence that the German listener not only activates a cohort of phonologically, orthographically, and semantically overlapping competitors, but additionally the native translation *Schloss*. Whilst this unconscious activation of translation equivalents has been shown to preferentially concern phonological representations in Chinese-English bilinguals (Wu & Thierry, 2010), the extent of this activation at the semantic level is currently unknown. Activation of the word *Schloss* may entail additional difficulties for the German listener because it is a polysemous word, generally used to refer to a castle, but with the additional, distinct meaning of *lock*. Assuming an integrated semantic system, this would mean that a German listener hearing the word *castle* should activate the word *Schloss*, and, followed by its related semantic and conceptual associations, *lock*.

Exploring this theory, Elston-Güttler and Williams (2008) studied the effect of L1 polysemy on L2 semantic interpretation. The authors presented German-English bilinguals and native English participants with English sentences ending in target words that were either semantically acceptable or incongruent completions. In the critical condition, targets were polysemous words in German, realised as independent words in English (e.g., the German word *Blase* translates to English as *bubble* or *blister*). In this condition, the unexpected meaning of a polysemous German word completed a sentence in English, e.g., *His shoes were uncomfortable due to a bubble*. Participants were asked to indicate whether the target words formed an acceptable completion to each sentence, and response times and accuracy were compared for the critical conditions to a control condition in which neither sense of the L1 translation were congruent (e.g., *She was very hungry because of a bubble*). In comparison to the native English participant group, German-English bilinguals made significantly more errors and had longer response times to polysemous words in comparison to the control condition. The results suggest that highly-fluent bilinguals activate L1 conceptual information from L2 words due to lexical-level translation links. Despite this, the authors note that due to the nature of the anomaly detection task, it is possible that participants' reaction time and accuracy increases were contaminated by explicit knowledge of the polysemous nature of the L2 translations. As such, it remains difficult to determine whether the reported effect is due to contamination of the responses due to the decision task employed, or whether without explicit knowledge of the manipulation and the polysemous nature of the target words interference from L1 representations would still have occurred. Furthermore, behavioural measures such as reaction times and accuracy are unable to provide information about implicit, automatic processes. Whilst electrophysiological methods, in particular the N400, have been demonstrated to reveal implicit activation of native language representations, this is often in the absence of behavioural effects (Thierry & Wu, 2007; Wu & Thierry, 2010). As such, it may be the case that without the explicit awareness of the manipulation due to the nature of the task, behavioural responses would be unaffected. However, this in itself would not necessarily indicate a lack of implicit access to native language representations.

In the present study we tested German-English bilinguals in a paradigm intended to reveal whether (a) alternative semantic representations of polysemous words are activated in bilinguals processing the L2, and (b) whether accent can modulate implicit activation of L1 semantic representations. Participants heard sentences in L2 English, followed by a visual word target. Based on prior evidence of heightened activation of native language representations when the L2 is produced with an L1 accent (Lewendon et al*., under review*), sentences were recorded in both a standard German and English accent to determine whether accent modulates activation of L1 semantic representations. As in Elston-Güttler and Williams (2008), in the critical condition the L2 targets word translated to the incorrect meaning of a polysemous German word, e.g., *She added some flowers to improve the look of the* ***ostrich***, where *ostrich,* once translated to the German *Strauß*, has the alternate meaning of *bouquet*. Based on a lack of effect of relatedness between the two meanings of a polysemous word for native speakers in prior research, we chose a mixture polysemous words with more and less closely related meanings. To engage participant's attention and ensure semantic processing, participants were asked to make decisions regarding pictures displayed after a random subset of sentences, indicating whether or not pictures were thematically related to the preceding sentence. We hypothesised that for critical trials, the existence of an alternative meaning in German of the English word would allow semantic priming to occur, despite the sentence ending being incongruous in English. Furthermore, we expected that a German accent would heighten activation of semantically congruent German representations of otherwise unrelated English target words, resulting in easier semantic integration of the target word. We predicted that such effects would manifest as a main effect of experimental condition driven by a reduction of mean amplitude within the N400 window (350–500 ms) in the 'acceptable-through-L1-polysemy' condition, and that such a reduction would be even more pronounced when L2 speech was heard with a German as compared to an English accent. In the latter case, we thus expected to find an accent by condition interaction in the N400 range.

3.2.2. Methods

3.2.2.1. Participants

Twenty-two highly proficient German-English bilinguals participated in the experiment. Two datasets were rejected due to participants reporting explicit knowledge of the manipulation upon debriefing. A further dataset was excluded due to a low comprehension score, resulting in a final sample of 19 participants (13 female, mean age = 26.6; *sd*= 4.9). All participants were right handed, had normal or corrected-to-normal vision, no learning disabilities and self-reported normal hearing. All were native German speakers for whom German was the first language. Age of acquisition for English was on average 9.6 (*sd*=5.2). Participants were tested for comprehension via a questionnaire in which they provided translated definitions of all target words. Participants with an overall comprehension of less than 70% were excluded from the final analysis (n=1). There was no significant difference in comprehension scores between the four experimental conditions.

Table 2: Participant language background

Measure	Mean	SD
Age of German acquisition	0	0
Age of English acquisition	9.6	5.2
Daily German usage (%)	75	17
Daily English usage (%)	19	14
Daily usage (other) (%)	11	9

3.2.2.2. Materials

Thirty-five auditory sentence onsets were paired with 70 polysemous written target words and distributed across four experimental conditions. Target words were familiar English words corresponding to 35 German translation equivalents, for example, *bouquet* (as in a bunch of flowers) and *ostrich* (as in the large bird) corresponding to the German word *Strauß*. The 35 auditory sentences were repeated four times, whilst the target words appeared twice in the experiment so as to form four experimental conditions as follows: (1) expected condition (henceforth expected condition), as in "*She added some flowers to improve the look of the* ***bouquet"***; (2) acceptable-through-L1-polysemy condition (henceforth polysemous condition) as in "*She added some flowers to improve the look of the* ***ostrich****";* (3) unexpected condition (henceforth control condition), in which the target word was anomalous in either language as in "*She added some flowers to improve the look of the* ***racket"***; and (4) acceptable condition (henceforth filler condition), a relatively lower cloze-probability related condition, as in "*She added some flowers to improve the look of the* ***lawn"***. The latter condition was included to ensure a balanced design in terms of expectancy (50% related / 50 unrelated) and to equate stimulus exposure across the experimental session. Counterbalancing was achieved by redistributing stimuli used in conditions (1) and (2) across conditions (3) and (4), such that all target words presented in the expected and polysemous conditions also featured as targets in the control and filler conditions. The inclusion of the filler condition (4) ensured that all target words were seen a total of 4 times, twice as a congruent L2 sentence completion, and twice an L2 incongruent completion. Each auditory sentence was recorded in both an English and German accent, such that participants were exposed to all 140 stimulus pairings twice.

English target words were matched within language across conditions for lexical concreteness, frequency and length (**see Table 3**). German translations were matched across condition for frequency, with concreteness assumed to be similar to that of the English values. Word length for German translations was not compared as the translations were not presented to participants. Log transformed frequencies for English words were taken from SUBTLEX-UK (van Heuven, Mandera, Keuleers, & Brysbaert, 2014), and concreteness measures from the *Concreteness ratings for 40 thousand generally known English word lemmas* corpus published by Brysbaert, Warriner, and Kuperman (2014). German frequencies were calculated on log-transformed values from SUBTLEX-DE (Brysbaert et al., 2011). Norming was run on the three conditions of interest (participants = 36), with a significant different in the goodness-of-fit for words in the expected condition relative to the control and polysemous conditions ($p < 0.001$). There was no significant difference between the polysemous and control conditions (see Appendices F and G).

Table 3: Mean frequency, concreteness and word length for each condition with standard deviation.

Condition	**Frequency (English)**		**Concreteness (English)**		**Length (English)**		**Frequency (German)**	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Expected	4.19	0.69	4.48	0.54	5.82	2.03	2.53	0.40
Polysemous	4.07	0.59	4.38	0.72	5.25	2.16	2.53	0.40
Control	4.02	0.59	4.27	0.75	5.62	2.28	2.49	0.28

The 35 auditory sentences were digitally recorded by two adult female speakers, one a native German speaker and another an English speaker, at a sampling rate of 48.8 kHz and resampled using Audacity to 44.1 kHz to ensure compatibility with E-Prime stimulus presentation software.

3.2.2.3. Procedure

Participants gave written informed consent to take part in the experiment. The experiment was covered by the data protection plan approved by the data protection office at Humboldt-Universität zu Berlin and the Deutsche Gesellschaft für Sprachwissenschaft. Testing took place in a single session, with the two accents counterbalanced so that half of the participants first heard German-accented sentences, whilst the other half heard English accented sentences first. During the testing session, participants listened to 140 trials in each accent, consisting of the same 35 trials from each of the 4 experimental conditions in both a German and English accent. In each trial, participants first saw a fixation cross for 100 ms on a 16” RCT monitor at a distance of 100 cm from the eyes. The fixation cross remained on the screen whilst participants listened to the auditory sentence, which was played over loudspeakers set around the monitor. After the end of the sentence, the fixation remained on the screen for a variable ISI of 160–240 ms before the visual target word was presented in black Arial font, size 16 points on a light grey background. Pictures were presented pseudo-randomly (after approximately every 1 in 5 sentences) and participants were asked to indicate whether the picture was related or unrelated in content to the previous sentence and/or target word. Response was indicated by button-press during a response window lasting a maximum of 3000 ms, and the response immediately triggered the next trial. Response-hand side was counterbalanced between participants. Participants performed a brief training period prior to commencing the full experiment to ensure they were familiarised with the procedure.

3.2.2.4. ERP recording and pre-processing

EEG data was recorded using a 38 channel ActiCHamp system referenced online to the left mastoid. Impedance was reduced for all EEG electrodes to below 5 kΩ prior to data acquisition. Data was recorded at 1000 Hz and re-sampled to 250 Hz prior to analysis. Six facial bipolar electrodes positioned on the outer canthi of each eye and in the inferior and superior areas of the left and right orbits providing bipolar recordings of the horizontal and vertical electrooculograms (EOG). Data was re-referenced offline to the algebraic mean of the left and right mastoids and filtered using a 30 Hz (24 dB/oct) low-pass and 0.1 Hz (12 dB/oct) high-pass Butterworth Zero Phase shift band-pass filter. Eye movements were corrected by Independent Component Analysis (ICA) using the AMICA procedure (Palmer et al., 2008). Data was segmented into epochs of −200 to 1000 ms, time-locked to the onset of the visual target word and baseline correction was performed relative to pre-stimulus activity. Grand-averages were computed for the three experimental conditions, with at least 30 trials per condition for each participant.

3.2.2.5. ERP data analysis

To determine whether incongruent English (L2) target words with correct translations via L1 polysemy were processed differently to entirely anomalous target words when preceded by L1-accented speech, mean ERP amplitudes were analysed in the classic N400 window (300-500 ms; Kutas & Hillyard, 1980; Kutas & Federmeier, 2000; Dumay et al., 2001; Federmeier, 2007) over central scalp regions to test for expectancy effects and the significance of an accent by condition interaction. A repeated-measures analysis of variance (ANOVA) with accent (English, German) and condition (correct, anomalous and polysemous) as independent variables was conducted on mean N400 amplitudes collected at electrodes of maximum sensitivity with the 32 electrode array (C3, Cz, C4, CP1, CP2).

3.2.3. Results

Overall accuracy in response to picture targets was 89%, with no participant scoring less than 70%. There was no main effect of accent on N400 amplitude ($F(1,18) = 0.12$, $p = 0.727$, $\eta_p^2 = 0.007$), but a significant effect of condition ($F(2,36) = 4.37$, $p = 0.020$, $\eta_p^2 = 0.187$), such that ERP mean amplitudes were significantly more negative between 300 – 500 ms in the control relative to the expected condition ($t(18) = 2.067$, $p = 0.046$) and in the polysemous as compared to the expected condition ($t(18) = 2.864$, $p = 0.007$). Critically, we found no significant difference between the control and the polysemous conditions ($t(18) = -0.796$, $p = 0.431$), nor an interaction between accent and condition ($F(2,36) = 2.19$, $p = 0.651$, $\eta_p^2 = 0.022$).

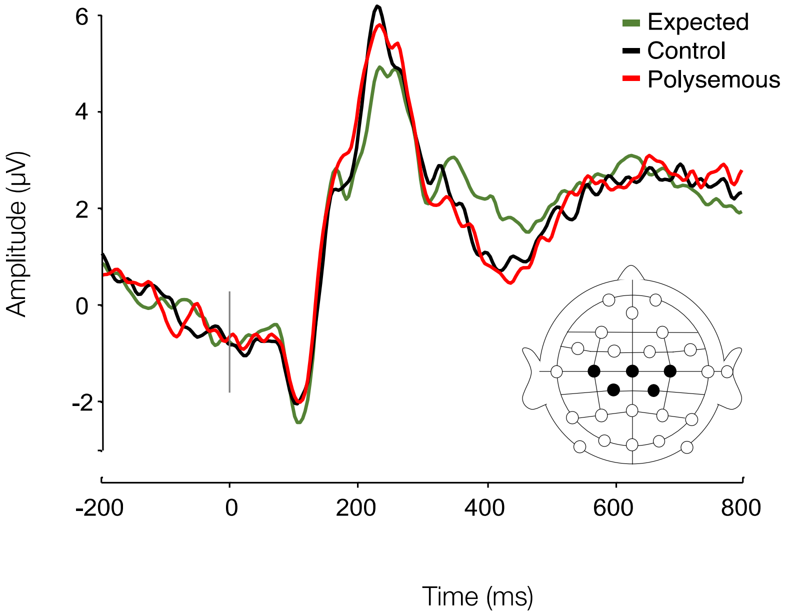

Figure 10: ERP mean amplitudes elicited by final sentence words in the expected, polysemous and control conditions.

3.2.4. Discussion

Here, we tested German-English bilinguals to determine whether the alternative meaning of polysemous words is accessed when bilinguals implicitly activate translation equivalents in the L1 of the L2 words they encounter, and whether accent modulates such cross-language activation. We found a main effect of condition, but no interaction between condition and accent. Whilst ERP mean amplitude for expected final words differed from the polysemous and control conditions, eliciting a classic N400 response (Kutas & Federmeier, 2011), mean ERP amplitude for the polysemous completion was indistinguishable from those elicited in the fully incongruent (control) condition. Thus, in the conditions of this study, processing of L2 words was not influenced by the semantic acceptability of L1 translations, indicating that unconscious L1 activation may not have spread to alternative meanings of the words in the L1. Furthermore, L1 activation was not different in nature when speech featured an L1 accent.

Our results are inconsistent with those obtained by Elston-Güttler and Williams (2008), who showed an interference effect of L1 polysemy on L2 word processing and proposed three potential processing routes operating in parallel. First, they suggested that a lexical-level link would result in the activation of German translation equivalents (e.g., *castle* activates *Schloss*). The word *Schloss* would directly activate the word *lock*, and consequently interference in recognising the anomaly would arise from the phrase *The knights stormed into the* ***lock***. In this route, the interference in perception of the anomaly was proposed to occur due to the translation connection at the lexical level. Second, the word *castle* would also directly activate the word *Schloss* via the same lexical level translation connections. However, this second route differs in the following activation of associated concepts in German (e.g., *key*, *safe*, *lock*, *door*). In the third route, which Elston-Güttler and Williams attribute to Jiang (2000, 2002), the word *castle* activates associated concepts such as *key*, *safe*, *lock*, *door* directly due to the inheritance of semantic specifications during L2 word learning. To distinguish between routes 1, 2 and 3, the authors divided polysemous words into highly related (e.g., *bag* and *pocket* for *Tasche*) and moderately related (e.g., *snake* and *queue* for *Schlange*) ones. They proposed that for route 1, relatedness should bear no effect on the degree of activation of lexical-level translation links. Conversely, for routes 2 and 3, the presence of a word such as *bag*, in a context which is more relevant to *pocket*, e.g., *On his shoulders he carried a large leather* ***pocket***, was predicted to result in heightened cross-language activation due the number of shared relevant features. In their study, Elston-Güttler and Williams (2008) attributed the interference effects found (longer accuracy and greater error rate) in response to incorrect translation of polysemous German words in route 2, based on significantly greater effect of polysemy for highly related than for moderately related words.

However, the study of Elston-Güttler and Williams (2008) has limitations that need to be considered. Firstly, the error rates and reaction times for highly related polysemous target words relative to the control condition were significant for both native English speakers and German-English bilinguals. Secondly, it remains possible, as acknowledged by the authors, that the results depended on German-English participants' explicit knowledge of the polysemous nature of L1 translations. In light of the significant effects observed for highly related items for native English speakers as well as native German speakers, their lack of knowledge of German, resulting in an absence of German translation-level connections means that the effect cannot solely have arisen from the critical manipulation of German polysemy. Instead, it is likely that the effect may have arisen from the relevant conceptual features shared by the L1 words in English. As such, hearing the phrase *In winter a heavy warm coat is practical to* ***carry***, participants may have found it more difficult to determine whether the word was incongruent relative to the correct completion *wear*. Compared to the moderately related condition, e.g., *Mary's back hurt so the massage expert began to* ***grate***, there is a clear distinction in the goodness-of-fit of the highly related targets as compared to the moderately related targets. Furthermore, for German-English bilingual participants, the potentially explicit access to correct translations via L1 lexical-level translation connections would unnaturally increase the level of L1 interference, resulting in further delayed RT and increased error rates. Finally, it is possible that for German participants the processing of an anomalous L2 target word sharing a number of conceptual features with the correct L2 completion may have resulted in increased RT and errors relative to native English participants due to slower overall processing. Indeed, in Elston-Gütler and Williams' study, reaction times and error rates were greater for German-English than English participants across all conditions. As such, the processing of an anomalous target word conceptually related to the correct completion may have resulted in greater cognitive workload for the non-native speakers than for natives. Here we chose to avoid focussing participants' attention on the expectancy of the final word and focussed instead on a picture relatedness task, meaning that reaction times and error rates were not directly reflective of polysemous word processing.

Furthermore, in the current study, we deliberately chose polysemous items that did not feature an obvious link between their two meanings e.g., *Schloss* – 'castle' / 'lock' as opposed to *Tasche* – 'pocket' / 'bag'. In contrast to Elston-Gütler and Williams (2008), we rejected datasets of any participants who upon debriefing reported awareness of the manipulation. We thus maximised the likelihood of any effect of L1 translation links being entirely due to implicit L1 access. Whilst the results suggest that without explicit awareness bilinguals do not show signs of access to L1 conceptual representations in an all-in-L2 context, our study also has important limitations to consider. To enable the use of the expected version of the polysemous target word in the correct condition (e.g., *The knights stormed into the **castle***) and the alternative translation equivalent in the acceptable-through-L1-polysemy condition (e.g., *The knights stormed into the **lock***), the two different meanings of the polysemous words were assigned to only one of these two conditions. Furthermore, to prevent P3 contamination in the expected condition, we rotated all target words across an additional two conditions, one correct and one fully anomalous, thus ensuring that half of the stimuli were acceptable and half were not. Due to stimulus constraints, this meant that for each condition in the experiment, target words differed. Whilst the use of different target words, although controlled for a number of lexical variables such as frequency, length, and goodness-of-fit across conditions, introduces a source of variance since the items were different across conditions, such a limitation should not have precluded an interaction between accent and experimental condition to arise.

It is important to note that despite the absence of a polysemy by accent interaction we found a classic N400 response, with mean ERP amplitudes significantly more negative in response to unexpected words, as compared to expected sentence endings. This effect suggests that the experiment was successful in eliciting participant responses to the visual target words following auditory sentence comprehension, and that the participants remained attentive throughout. However, there remain three main reasons why we may not have found the anticipated condition by accent interaction in the current study. Firstly, in approximately 50% of the cases, expected target words corresponded to the most common translation of the corresponding polysemous word in German. This may have reduced the likelihood of participants accessing the alternative meaning of the words in L1. This consideration might also have implications for other studies in the field. Lexical frequency is well-known to impact word recognition and retrieval (Alario et al., 2002; Norris & McQueen, 2008; Taft & Hambly, 1986). As such, it should be anticipated that, during the course of parallel activation, German-English bilinguals would likely activate the more common meaning of an L1 translation equivalent. Limited power meant that the analysis of the solely more common polysemous targets was not possible. Consequently, it may be the case that the lack of effect for polysemous target words may be due to reduced access to the more uncommon translation equivalent.

Secondly, it may be the case that accent does not facilitate (or impair) access to L1 semantic representations. As such, the use of different stimuli in each condition therefore becomes a clear issue. Without accent as a significant factor, enabling comparison between identical polysemous conditions, we are instead limited to comparisons between the polysemous condition and the fully unrelated control condition. Although each condition was controlled for frequency, concreteness and length, the difference in target words as mentioned above adds an inevitable source of variance in ERP responses. Without an interaction between accent and polysemy, it is therefore not possible to definitively attribute any main effect of polysemy to the activation of L1 polysemous representations, as opposed to variation in target word responses.

Finally. it may be the case that the lack of a polysemous effect sheds light on the processes underpinning word recognition. Upon the identification of a word, any competing lexical candidates are fully inhibited. As such, the alternative L1 meaning of anomalous L2 words, albeit correct, may not influence semantic processing. This in itself would be an interesting finding, demonstrating support for models of language that are able to account for a degree of inhibition of non-target language representations. For example, the BIA+ model of bilingual word recognition features a language node which allows for contextual information to influence the correct reading of an interlingual homograph (Thomas & van Heuven, 2005; Dijkstra & Van Heuven, 1998). The model proposes that despite bottom-up activation of both word-node representations of a homograph, competition between word nodes results in inhibition, such that both representations of the homograph remain below the recognition threshold. It may be the case that for the German-English bilingual participants, contextual information sufficiently inhibits the full activation of the alternate meaning of the polysemous translation, restricting the spread of activation to the correct translation equivalent.

In the present study it is not possible to differentiate between these two interpretations. Whilst the current study partly contradicts Elston-Güttler and Williams' results, with no significant difference between polysemous and unrelated control target words, we are unable to determine whether alternative meanings of L2 words in the L1 are actually activated at a semantic level and whether this process takes place online. Future research combining ERP and behavioural measures should investigate the effects of L1 polysemy in an L2 experiment, in which the explicit awareness of participants is manipulated.

Chapter 4

Lexical stress

4.1. Study 3 - Does suprasegmental stress gate bilingual cross-language lexical access?

4.1.1. Introduction

In many languages, stress can fundamentally alter the perception of a word. Its realisation, whilst varying substantially both across and within languages, is often indicated by changes to syllables on a segmental level, such as vowel reduction, e.g., *‘conflict* vs *con’flict*. Alternatively, stress can be realised via suprasegmental changes in fundamental frequency, duration and amplitude of the stressed syllable, e.g. *‘insult* vs *in’sult* (Cutler et al., 1986). In languages with lexical stress, words typically have one syllable which is most prominent (primary stressed), although secondary, or non-primary stress sometimes occurs in the case of longer words. While stress is variable, and has to be learnt for individual lexical items in languages such as English or Dutch, stress in other languages such as Welsh or Hungarian is not contrastive, but instead conforms to strict rules, often appearing consistently on certain syllables.

English and Welsh are therefore two languages with contrasting stress systems. As a language with variable stress, primary stress in English generally conforms to certain rules, but may appear on any syllable within a given word. Within English speech, lexically contrastive stress can serve as a distinction between words. For example, stress can be used to differentiate the verb and noun forms of related words e.g., *‘record* vs *re’cord*, or distinguish between the otherwise unrelated concepts *‘in,sight* vs *in’cite*. Whilst these minimal pairs are infrequent, stress additionally plays a substantial role in the language’s derivational morphonology, the process by which new, but related forms of words are construed through affixation (e.g., *‘complex* vs *com’plexity*). Lexical stress in English is marked through cues on both the segmental and suprasegment level. Segmentally, vowel reduction is a common indicator of an unstressed syllable, with schwa [ə] as the most common reduced vowel sound. Schwa production is localised in the mid-central space, which is generally underutilized in English (Byers & Yavas, 2017; Flemming, 2009), and results in changes to the segmental properties of the word, resulting in the difference in the initial vowel sound between the words *‘conflict* (/ˈkɒn/) and *con’flict* (/kən/). On the suprasegmental level F0 (Fry, 1958) and duration (Fry, 1955) have been suggested to be the two main stress cues, with mixed results as to the role of amplitude (Turk & Sawuch, 1996, cited in Culter, 2005). Generally, it is considered to be the combination of these features, as opposed to a single acoustic cue, that indicates lexical stress (Lieberman, 1960).

In contrast to the variable stress patterns of English, Welsh lexical stress is highly regular, occurring consistently on the penultimate syllable. Incidences of irregular stress placement are generally uncommon, with exceptions only found in English loanwords (Mennen et al., 2015). A relative paucity of research means that the intricacies regarding the realisation and perception of stress in Welsh are less well understood than that of English, and consequently Welsh lexical stress realisation remains subject to some debate. In perhaps the most comprehensive investigation into stress in modern Welsh, Williams (1983) provides an overview of the acoustic correlates and realisation of Welsh lexical stress and concludes that its defining feature is its rhythm, noting that stress is often indicated by syllable duration such as the shortening of a stressed vowel, and the lengthening of a post-stress consonant. Whilst this consistent pattern in duration is supported by later studies into Welsh lexical stress (Webb, 2011; Mennen et al., 2015), it is important to note that some of these studies have significant limitations. In the case of Williams' 1989 research, the perception of syllable duration in Welsh words was recorded from a small sample of 1 native Welsh and 2 native English listeners, limiting the power of the results. Likewise, Webb's later study on stress production, in which native English monolinguals and Welsh-English bilinguals produced word pairs in English and Welsh that have a similar initial syllable and post-stress consonant phoneme (e.g. English: *Panel*; Welsh: *Panad*), compared syllable duration measurements only across, but not within words. Whilst the results do suggest that the duration of the post-stress syllable is an important cue to Welsh stress, the lack of duration comparisons between the stressed vowel and post-stress consonant within words, as opposed to between English and Welsh targets limits the insight offered by the findings. In terms of the role of F0 in Welsh lexical stress, findings are more mixed. Whilst some studies have suggested that the stressed syllable is generally lower in pitch (Bosch, 1996, Jones, 1949), others propose that there is a direct link between Welsh stress realisation and pitch-prominence (Williams, 1983). These discrepancies may be explained by later research by Mennen et al. (2015), who found that F0 differences between stressed and unstressed syllables in Welsh were smaller than in English. Furthermore, investigating the influence of linguistic experience on the acoustic correlates of Welsh stress, Mennen et al. reported that greater English exposure resulted in increased convergence for F0 patterns to that of English, but had no effect on stress duration cues, suggesting that duration may be a more robust cue to stress in Welsh. Despite the linguistic context in Wales, in which Welsh coexists alongside English, the results of Mennen et al. (2015) suggest that stress realisation in Welsh has not entirely converged to resemble that of English.

The distinction between lexical stress realisation in English and Welsh may prove important in terms of the role of suprasegmental information in auditory word comprehension (Slowiaczek, 1990; Cooper et al., 2002; Van Donselaar et al., 2005; Jesse et al., 2017). Studies investigating how stress influences lexical access and recognition suggest that for speakers of variable stress languages, stress cues can have both an inhibitory and a faciliatory effect. Incorrect stress, for example, can create intelligibility or interpretation issues. Field (2005), for instance, showed that misplaced stress reduces speech intelligibility by comparing comprehension of disyllabic English words produced naturally or with an anomalous, shifted stress. Jesse et al. (2017) explored the use of suprasegmental information by English listeners during speech processing using eye-tracking. Participants heard spoken instructions (e.g., “Click on the word *admiral*”), whilst viewing a screen displaying four written referents. Of the four displayed words, two formed a critical pair that, whilst segmentally identical in their first two syllables, differed segmentally in featuring either 1st or 2nd syllable lexical stress (e.g., ˈ*admiral*–ˌ*admi*ˈ*ration*). Results showed that prior to becoming segmentally distinguishable beyond the second syllable, target words were fixated on to a greater degree than competitors, suggesting that stress information was indeed used by participants. This finding reinforced prior evidence for a facilitatory role of stress in lexical recognition both from eye-tracking (Reinsch et al., 2010) and behavioural studies (Jesse & McQueen, 2014; van Donselaar et al., 2005).

Exploring whether reliance on suprasegmental cues might differ for native and non-native listeners, Cooper et al. (2002) tested English monolinguals and Dutch-English bilinguals on four cross-modal priming and two forced-choice identification experiments. In the cross-modal priming paradigm, both native and non-native speakers identified the visual target word significantly faster when it was preceded by a monosyllabic or disyllabic stress-matching fragment prime (e.g., *mus-*

from *music* versus *museum*). Native English listeners responded similarly to stress-mismatching disyllabic primes and control primes, whilst mismatching monosyllabic primes resulted in partial facilitation. In contrast, non-native Dutch speakers experienced partial facilitation for both mismatching monosyllabic and disyllabic primes. In the forced-identification experiment, Dutch participants significantly outperformed Native English participants when asked to assign a monosyllabic fragment (e.g., mus-) to one of two words differing in stress (e.g., *music* or *museum*). Whilst cross-modal priming effects could be explained based on the relative strength of segmental and suprasegmental information, results from the forced-identification experiment likely derive from linguistic experience and native stress contrasts. In Dutch, vowel reduction and segmental contrast are uncommon, potentially heightening reliance, and consequently sensitivity to suprasegmental stress contrasts. Conversely, in English there is a paucity of segmentally ambiguous but suprasegmentally distinguished words. With vowel reduction a key cue to English stress placement, English speakers may not rely strongly on suprasegmental stress cues. Thus, Dutch participants could outperform their English native peers by applying their native-language skills in suprasegmental processing to English.

Speakers of languages without contrastive lexical stress (e.g., French, Hungarian, Welsh) are often reported to experience difficulty in discriminating between stress patterns of languages with variable stress (Dupoux et al., 1997; Dupoux et al., 2001). This difficulty has been attributed to language acquisition in infancy. Peperkamp (2004) argues stress deafness varies based on the degree to which the native language stress system is based on phonological rules (such as syllabic structure) or morphological rules. Native speakers of languages with phonologically dictated stress systems are thought to acquire their stress systems pre-lexically, that is, prior to the establishment of the lexicon. Furthermore, an awareness developed during this period of the absence of contrastive stress in the native language is thought to reduce sensitivity to stress contrasts, resulting in stress deafness in adulthood. Whilst speakers of stress-variable languages are able to use suprasegmental stress cues to assist in the process of word recognition, it is suggested that native speakers of fixed-stress languages may instead understand stress on the basis of pre-lexical templates (Honbolygó et al., 2004; Honbolygó & Csépe, 2013; Kóbor et al., 2018).

How then might this be relevant in bilingual cross-language activation? In Study 1, we demonstrate that L1 accent cues facilitate access to native language representations in Welsh-English bilinguals. This work builds upon a substantial body of literature showing that lexical access is generally non-selective in fluent bilinguals (van Heuven & Dijkstra, 1998; Duyck, 2005; Spivey & Marian, 1999; Ju & Luce, 2004; Thierry & Wu, 2007; Wu & Thierry 2010; Lagrou, Hartsuiker & Duyck, 2013), and demonstrates a potential role of accent in modulating such cross-language access (Lagrou, Hartsuiker & Duyck, 2011; 2013). In the present study, we isolate lexical stress, a feature that contributes towards L1 accent, and alter it to explore cross-language activation. Specifically, we asked whether Welsh-approximate stress cues, when present in the L2, heighten L1 activation. Penultimate stress in Welsh is produced predominantly through the shortening of the stressed vowel, and the lengthening of a post-stress consonant, and potentially the lowering of the stressed syllable pitch. As such, the realisation of Welsh penultimate stress aligns closely with that of final syllable stress in English (**see Table 4**). If, therefore, Welsh-English bilinguals understand stress on the basis of pre-lexical templates, the presence of Welsh-approximate stress in the L2 may heighten native language activation.

To explore this, we tested a bilingual and English monolingual participant group in a priming paradigm in which they heard semantically related and unrelated word pairs consisting of auditory primes followed by visual word targets. We manipulated auditory word primes so that stress was placed on either the 1st, the 2nd or the 3rd syllable. Given the prime words selected, first syllable stress was always correct, corresponding to natural productions in English, and second and third-syllable stress were anomalous.

Table 4. Effects of Welsh penultimate stress and English third syllable stress on final syllable realisation. *Insufficient research on intensity in Welsh lexical stress.

Feature	**English**	**Welsh**
Pitch	Higher pitch	Higher pitch relative to prior syllable
Intensity	Greater intensity	*
Duration	Increased duration	Increased duration

To test L1 activation, in an implicit phonological priming manipulation (overlap condition) word pairs featured initial phonological overlap via translation into Welsh (i.e. *criminal* – *beach*; in Welsh: ***tr**oseddwr* – ***tr**aeth*; Fig.6). Phonological processing and expectancy has consistently been demonstrated to influence ERPs within the range of the phonological mapping negativity (Connolly & Philips, 1994; Newman & Connolly, 2008; Desroches et al., 2009; Sučević et al., 2015), N250 - P325 (Holcomb & Grainger, 2006; Grainger, Kiyonaga & Holcomb, 2006; Grainer & Holcomb, 2009; Hargoot & Brown, 2000) and early N400 (Dumay et al., 2001; Praamstra et al., 1994; Thierry & Wu, 2007; Wu & Thierry, 2010) over centroparietal regions. We hypothesised that for Welsh-English bilinguals, lexical stress resembling that of their native language would heighten L1 activation, resulting in increased implicit phonological priming. We predicted for the bilingual participant group this would manifest as a reduction of mean ERP amplitudes within the 200–400 ms range at centroparietal electrode sites for the phonological overlap condition when primes featured third-syllable (Welsh-approximate) stress. In line with previous literature on cross-language implicit phonological priming (Thierry & Wu, 2007; Wu & Thierry, 2010) alongside considerable evidence for stress deafness in speakers of fixed-stress languages (Dupoux et al., 2008; Peperkamp, 2004), we predicted no effect of stress or overlap on behavioural measures.

4.1.2. Materials and Methods

4.1.2.1. Participants

Forty-two participants took part in the experiment, 22 native English speakers and 20 Welsh-English bilinguals. Of the 42 participants, 3 datasets were excluded due to participants disclosing specific learning difficulties or neurological conditions subsequent to testing. Thus, the final sample consisted of 20 native English and 19 Welsh-English bilingual participants, of which 13 in the English group and 15 in the Welsh group were female. Participants were aged between 18-37 (English mean age 20.71, sd=2.93; Welsh mean age 23.6, sd=6.01), and all had normal or corrected-to-normal vision and self-reported normal hearing.

Table 5: Participant language background

Welsh-English bilinguals

Measure	Mean	SD
Age of Welsh acquisition	0	0
Age of English acquisition	3.26	2.68
Daily Welsh usage (%)	67	22
Daily English usage (%)	32	22

English monolinguals

Measure	Mean	SD
Age of English acquisition	0	0
Daily English usage (%)	96	7
Daily usage (other) (%)	1.3	3.18

All participants self-reported being right-handed, and both groups completed a language-history questionnaire regarding their language use and proficiency (**see Table 5**).

4.1.2.2. Materials

For each condition, 41 trisyllabic stress-initial English words were selected[3]. Targets words were 123 mid-range frequency English words, with the same list repeated across prime lists (**see Table 6**). Both prime and target words were selected from SUBTLEX (van Heuven, Mandera, Keuleers, & Brysbaert, 2014) and Cronfa Electroneg o Gymraeg (CEG; Ellis et al. 2001).

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[3] Note that for the conditions (1) and (2), all English trisyllabic word primes translated to trisyllabic Welsh words with penultimate stress.

Table 6: Prime – target rotation

Overlap

Prime	**Rotation 1**	**Rotation 2**	**Rotation 3**
		Target	
ʻinterview (cyfweliad)	warm (cynnes)	knife (cyllell)	slept (cysgodd)
ʻinterview (cyfweliad)	knife (cyllell)	slept (cysgodd)	warm (cynnes)
ʻinterview (cyfweliad)	slept (cysgodd)	warm (cynnes)	knife (cyllell)

Related & filler

Prime	**Rotation 1**	**Rotation 2**	**Rotation 3**
		Target	
ʻinterview	warm	**knife**	slept
ʻinterview	**knife**	slept	warm
ʻinterview	slept	warm	**knife**

Prime-target pairs formed three conditions: (1) an overlap condition, in which semantically unrelated words shared phonological overlap via Welsh translation (e.g., *universe – army* (in Welsh: ***by****dysawd*– ***by****ddin*); (2) a no overlap condition (e.g., *decorate – army* (in Welsh: *addurno – byddin*); and (3) a semantic related condition consisting of both related words (e.g., *uniform – army* (in Welsh: *gwysg – byddin*) and unrelated filler items. Overlap and no-overlap pairs consisted of 123 prime-target pairs. Of the 123 trials forming the semantic relatedness and filler list, 36 were semantically related and 87 were filler pairs. Related pairs thus constituted approximately 10% of the overall materials, intended to maintain participant attention and ensure that words were processed fully to the semantic level. For the critical conditions (conditions 1 and 2), log transformed frequencies for both English primes and their Welsh translations were calculated and controlled within language across conditions. Mean frequency of primes was as follows: overlap English = 3.03 (*sd* = 1.07), overlap Welsh = 1.52 (*sd* = 0.56); no overlap English = 3.12 (*sd* = 1.21), no overlap Welsh = 1.54 (*sd* = 0.55). Concreteness measures were calculated from the Brysbaert et al. (2014) corpus (overlap = 4.11, *sd* = 0.68; no overlap =3.85, *sd* = 0.71) and, due to corpus unavailability, assumed to be similar for Welsh translations.

For each condition primes were digitally recorded by a native English speaker, creating three contrasting recordings of each word with stress produced on the first, second or third syllable (e.g., *'universe*; *u'niverse*; *uni'verse*), resulting in a final total of 123 primes. In each condition, the three target words per prime were rotated between participants, so that a third of each participant group heard a different prime stress production with a different target (**see Table 6**). The native English speaker was instructed to practise stress manipulations by increasing the pitch, duration and loudness of the stressed syllable, whilst producing the same vowels every time. Inspection of each recording was conducted syllable-by-syllable to ensure that no vowel reduction could be overtly perceived. Sound files were recorded at a sampling rate of 48.8 kHz and resampled using Audacity to 44.1 kHz to ensure compatibility with E-Prime stimulus presentation software. For both conditions, auditory primes were paired with 3 possible visual word targets.

4.1.3. Procedure

During the testing session participants were presented with a total of 369 trials, consisting of 123 word pairs from each condition. Prior to testing, participants gave written informed consent approved by the School of Psychology, Bangor University ethics committee. In each trial, participants first saw a fixation cross for 100 ms on a 17" CRT monitor at a distance of 100 cm from the eyes. The fixation cross remained displayed whilst the auditory prime was played over loudspeakers set around the monitor. Immediately following the sound file, a fixation cross was displayed for a variable interstimulus interval (ISI) of between 160-240 ms (at 20 ms intervals randomly selected), which was followed by the visual word target presented in Arial, black, size 16 points on a light grey background. Participants were asked to indicate by button-press if prime and target pairs were related in meaning during a response time-window of 3000 ms. Participants' response immediately triggered the next trial, and response-hand was counter-balanced across participants. Presentation order was pseudorandomized such that no two stress recordings of a prime appeared in the same experimental block. Participants performed a brief training period prior to commencing the full experiment to ensure they were familiarised with the procedure, and training trials were not included in the analyses.

4.1.4. Data analysis

4.1.4.1. Modelling of behavioural data

Reaction time (RT) data was analysed by means of a of linear mixed effect modelling (*lmer* function in lme4) following log transformation to achieve a normal distribution. Accuracy data was submitted to generalized mixed-effects modelling (via *glmer* with a binomial link function in the lme4 v1.12 library; (Bates et al., 2014), after fixed factors were centred to minimise collinearity. For both reaction time and accuracy models, fixed effects including prime and participant intercepts and slopes were modelled and systematically trimmed until the models converged (Barr et al., 2013), and fixed and random effects and interactions were removed if they did not significantly contribute to model fit.

4.1.4.2. ERP recording and pre-processing

Electroencephalogram activity was continuously recorded from 32 Ag/AgCl electrodes according to the extended 10/20 convention at a rate of 1 kHz, referenced online to the left mastoid electrode. Impedances for all electrodes were kept below 5 kΩ. Data was filtered off-line using a 30 Hz (48 dB/oct) low-pass and 0.1 Hz (12 dB/oct) high-pass Butterworth Zero Phase shift band-pass filter and re-referenced offline to the algebraic mean of the left and right mastoids. Four facial bipolar electrodes positioned on the outer canthi of each eye and in the inferior and superior areas of the right orbit provided recordings of the horizontal and vertical electrooculograms (EOG). Eye blink artefacts were corrected mathematically based on the algorithm developed by Gratton, Coles and Donchin (1983). For each of the three stress manipulations, participants had a minimum of 60 valid epochs (average= 79.9, *sd*= 2.72). For the non-critical semantically related trials there were a minimum of 20 epochs per participant (average= 33.3, *sd*= 3.02). Data was segmented into epochs ranging from −200 to 1000 ms tied to the onset of the visual target word. Baseline correction was performed relative to the -200 ms pre-stimulus activity.

4.1.4.3. ERP analysis

For the overlap manipulation, we conducted a mixed repeated measures analysis of variance (ANOVA) of ERP amplitudes between 200 – 400 ms from a linear derivation of 6 centroparietal electrodes (Cz, C3, C4, Cpz, Cp3 & Cp4) with prime stress (1st, 2nd or 3rd syllable) and overlap (overlap, no overlap) as within subject variables, and native language (English or Welsh) as a between subject factor. The timing and topography of our window of interest was selected consistent with ERP evidence demonstrating influences on phonological processing and expectancy within this epoch, encompassing the phonological mapping negativity (Connolly & Phillips, 1994; Newman & Connolly, 2009; Desroches & Joanisse 2008; Sučević et al., 2015), N250 - P325 (Holcomb & Grainger, 2006; Grainger, Kiyonaga & Holcomb, 2006; Grainger & Holcomb, 2009; Hagoort & Brown; 2000) and early N400 (Thierry & Wu, 2007; Wu & Thierry, 2010; Dumay, 2001; Praamstra, Meyer & Levelt, 1994). Furthermore, to ensure primes and targets were processed fully at the semantic level, we conducted a repeated measures ANOVA with relatedness (related or unrelated) as the within subject independent variable, and native language (English or Welsh) as the between subject factor. Analysis was conducted on mean ERP amplitudes over centroparietal electrodes in the 350 – 500 ms time window during which the N400 is maximal (Kutas & Federmeier, 2011).

4.1.5. Results

4.1.5.1. Behavioural results

RTs were modelled for language group (Welsh, English), prime stress (syllable 1, 2 or 3) and L1 overlap (overlap, no overlap), centred to minimise collinearity. There was a significant main effect of stress ($b = 0.008$, $SE = 0.002$, t = -3.39, $p < 0.001$), such that reaction times to targets preceded by 2nd syllable primes ($b = 0.024$, $SE = 0.006$, $z = 3.81$, $p < 0.001$) and 3rd syllable primes ($b = 0.021$, $SE = 0.006$, $z = 3.38$, $p = 0.002$) were significantly faster than natural 1st syllable stress primes. There was no significant difference between 2nd and 3rd syllable prime stress ($b = 0.002$, $SE = 0.006$, $z = -0.42$, $p = 0.904$). Furthermore, the model revealed a significant overlap by group interaction ($b = 0.00$, $SE = 0.002$, t = -2.18, $p = 0.02$). For the English group, reaction times for overlapping word pairs was significantly slower than for non-overlapping word pairs (b = -0.014, SE = 0.003, t = 3.707, $p < 0.001$), whilst for the Welsh participants there was no significant effect of overlap (b = -0.003, SE = 0.005, t = 0.536, $p = 0.593$).

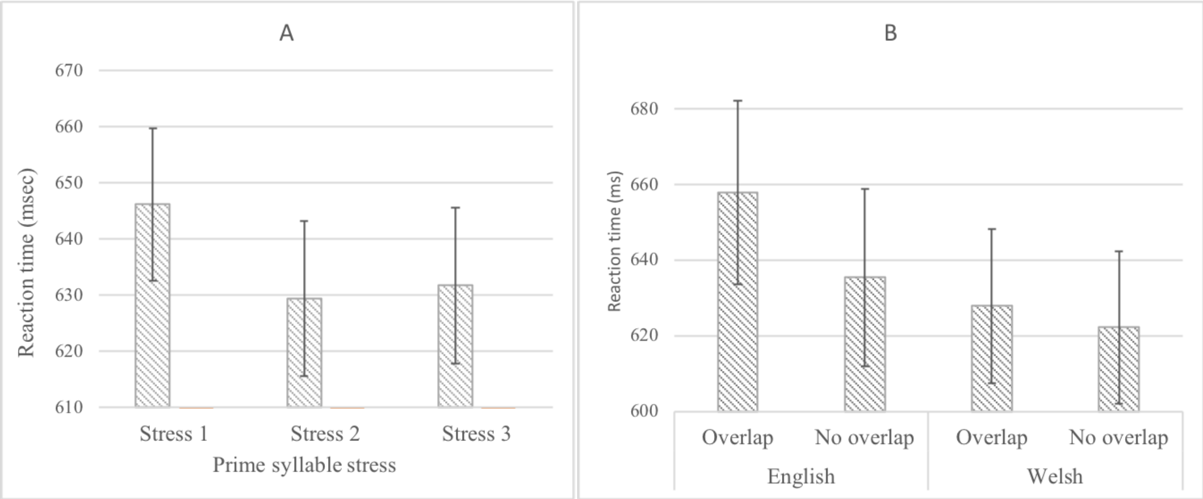

Figure 11. Reaction time data (A) by prime syllable stress, and (B) by Welsh phonological overlap. Error bars indicate standard error of the mean.

For accuracy data, analysis via general linear mixed effect models was not possible, as there were insufficient related trials due to the condition constituting only 10% of overall materials. There was a ceiling effect in the accuracy data, as seen in Figure 12. Due to the ceiling effect, accuracy varied by condition and accent between 95% to 96%. As such, any possible statistically significant differences would not be meaningful.

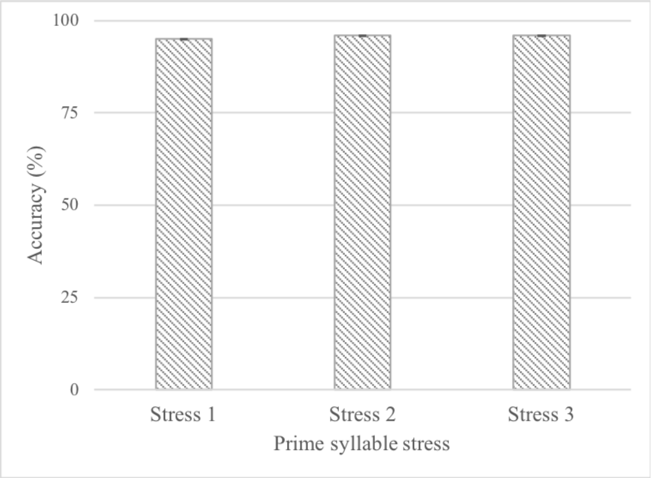

Figure 12. Accuracy by prime syllable stress. Error bars indicate standard error of the mean.

4.1.5.2. ERP results

To ensure that our experiment design worked and elicited a classic N400 response, we ran a repeated measures ANOVA with relatedness (related or unrelated) as the within subject independent variable, and native language (English or Welsh) as the between subject factor to investigate whether there was a significant effect of semantic relatedness on mean ERP amplitudes (**Fig. 13A**). We analysed mean ERP amplitudes between 350 – 500 ms (the N400 time window), which revealed a significant effect of relatedness ($t(37) = 7.99$, $p < 0.001$), such that amplitudes were significantly more negative in the unrelated than the related condition. There was no interaction between group and relatedness ($p > 0.05$).

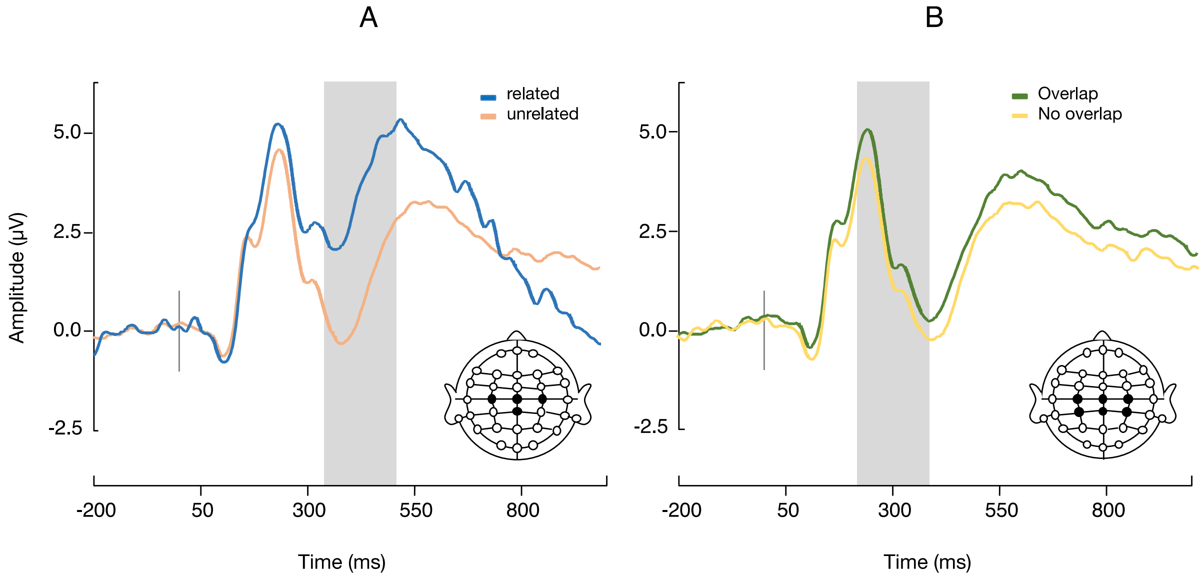

Figure 13 – ERP mean amplitudes for both English monolingual and Welsh-English bilingual participant groups for related vs unrelated prime-target pairs (A), and responses for both groups to word pairs featuring phonological overlap via Welsh translation and no phonological overlap (B).

Furthermore, to determine whether prime stress affected unconscious native language activation, we ran a repeated measures mixed ANOVA on ERP responses to visual word targets with prime stress (1st, 2nd, 3rd) and overlap (overlap, no overlap) as the within subject factors, and group (English, Welsh) as a between subject factor (**Fig. 13B**). There was a significant main effect of overlap between 200 – 400 ms ($F(1, 37) = 16.355$, $p < 0.001$, $\eta_p^2 = 0.307$), such that mean ERP amplitudes for the phonological overlap condition were significantly reduced relative to the no overlap condition. There was no significant main effect of stress ($F(2, 74) = 2.361$, $p = 0.101$, $\eta_p^2 = 0.060$) or language group ($F(2, 74) = 1.594$, $p = 0.210$, $\eta_p^2 = 0.041$). Furthermore, there was no interaction between overlap and language group (F(1, 37) = 0.550, p = 0.463, η_p^2 = 0. 015), stress and overlap (F(2, 74) = 1.594, p = 0.210, η_p^2 = 0. 041), or all three factors (F(2, 74) = 0.703, p = 0.499, η_p^2 = 0. 019).

4.1.6. Discussion

Here, we asked whether, for speakers of fixed-stress languages, the presence of L1-approximate stress increases activation of native language representations. We tested native English and Welsh-English bilingual participants in a semantic priming paradigm in which they heard related and unrelated word pairs consisting of auditory primes followed by visual word targets, and manipulated prime production so that the auditory words featured stress placed on either the 1st, 2nd or 3rd syllable. In critical pairs, prime-target pairs featured word-initial phonological overlap via translation to Welsh. Analysis of reaction times showed that responses to word pairs featuring a prime with anomalous stress (2nd or 3rd syllable) were significantly faster than for naturally stressed primes. Furthermore, there was an interaction between language group and overlap, such that English participants responded to overlapping word pairs significantly slower than to non-overlapping word pairs. In the ERP data we found no interaction between language group and overlap, nor an interaction between language group, overlap and stress. There was, however, a significant main effect of overlap on ERP mean amplitudes to target words between 200 – 400 ms, such that for both participant groups ERPs in response in the overlap condition was significantly reduced relative to the no overlap condition.

Thus, in the present study we found no predicted interaction between language group, overlap and stress in ERP amplitudes. Furthermore, there was no interaction between language group and overlap, in contrast with prior research (Thierry & Wu, 2007; Wu & Thierry, 2010). The main effect of overlap for both participant groups was unexpected, and may reflect a significant shortcoming of this study. The presence of differences in responses to the two conditions for native English speakers suggests that the key manipulation in this study (i.e., Welsh translation overlap) is likely to have been influenced by uncontrolled variation between the two conditions that is intrinsic to English words used. Indeed, in this study two sets of different prime-target word pairs were used in the overlap and no-overlap conditions. Whilst we controlled for lexical frequency and concreteness, this may have been insufficient to equate the two condition in terms of lexical properties. Furthermore, the inability to control for lexical concreteness in Welsh leaves open the possibility that spurious difference might have been present in terms of concreteness between conditions in the Welsh translations. As such, it is not possible to determine whether the absence of a language group by overlap interaction represents a lack of access to L1 representations for the bilingual group. We also found an interaction between language group and overlap in response accuracy, with no difference between overlapping and non-overlapping word pairs for Welsh participants, but English participants responding significantly slower to overlapping pairs. However, considering the limitations of the design, in combination with significant overlap in SE by condition, it would be purely speculative to consider whether this ease of response to overlapping pairs for Welsh participants represents different processing by groups due to potential interference generated by L1 overlap interference for Welsh participants. As such, the discussion hereon in will focus solely on results regarding the processing of stress in the two participant groups with contrasting native language stress systems.

In the ERP data, we found no main effect of stress between 200 – 400 ms for either participant group. However, for both English and Welsh participants, reaction times showed that responses to word pairs featuring a prime with anomalous stress (2nd or 3rd syllable) were significantly faster than for naturally stressed primes. This finding is interesting when one considers the language background of English participants. Whilst native speakers of fixed-stress languages, such as Welsh, often have difficulties processing lexical stress, the English participants should, as native speakers of a variable stress language, have experienced some degree of interference in lexical processing resulting from anomalous stress. It would appear, however, that the presence of incorrect stress did not inhibit responses to either the native language, for the monolingual English group, or to the second language for Welsh bilinguals. Instead, for both English and Welsh participants, reaction times showed that responses to word pairs featuring a prime with anomalous stress (2nd or 3rd syllable) were significantly faster than for naturally stressed primes, a finding that is not initially easy to explain. However, it may be that the difference in response times is in part be attributable to the manner of prime production. It is possible that for primes with 1st syllable stress the increased duration of the 1st syllable resulted in the uniqueness point of recognition being reached later, relative to 2nd and 3rd syllable stress primes. As such, the prime word may have been recognised quicker in the case of 2nd and 3rd syllable stress. But it is unexpected that participants process words quicker based upon anomalously stressed initial syllable(s). It may be the case that two different processes are at play in the two participant groups. As stress-deaf individuals, Welsh participants may have struggled to discriminate between correct and incorrect stress, lacking the sensitivities necessary to identify the lexical stress patterns of a non-native language. It follows that the aforementioned effect of syllable duration, in combination with a lack of sensitivity to stress, may have led them to reach the uniqueness point earlier for words with stress on the latter syllables. For native English speakers, on the other hand, it is known that suprasegmental stress patterns of a word influence lexical recognition to an extent (Jesse & McQueen, 2014; van Donselaar et al., 2005; Reinsch et al, 2010). However, it is possible that conscious awareness of the stress manipulations meant that participants were able to disregard lexical stress as a cue in word recognition, thus resulting in a similar effect of syllable duration, and speeded responses to words with 2nd and 3rd syllable stress.

Regarding accuracy data, both participant groups were significantly less accurate in response to target words preceded by 3rd syllable stress primes relative to naturally stressed primes. However, considered in light of the effect being driven by a 1% difference, this is unlikely to represent a meaningful difference in processing.

It is important to consider that there are a number of limitations to the current study. Firstly, the inclusion of semantically related pairs as 10% of overall items means that our ability to determine the influence of prime stress on the semantic integration of the target in the present study is limited, with insufficient power to test for an interaction between semantic relatedness and stress. As such, it was not possible to determine whether the presence of anomalous stress affected semantic processing of the prime word, that is, potentially disrupting semantic priming. In the present study we were unable to explore whether stress interacts with implicit activation of L1 phonological representations due to differences in response to the Welsh overlapping condition relative to the no overlap condition for the English and Welsh participant groups.

To address these limitations, we ran a follow-up study consisting of two experiments in which we incorporated a semantic priming paradigm (Experiment 1), and an implicit phonological priming paradigm as in the present study (Experiment 2). In Experiment 1 we sought to test whether anomalous stress had a measurable effect on semantic priming, which would provide evidence for an influence of stress on intelligibility in native speakers of a fixed stress language. In Experiment 2, we investigated the effect of L1 stress patterns on native language activation, testing whether Welsh-approximate (third syllable) stress produced in the second language (English), would result in heightened activation of translation equivalents, and greater implicit priming due to the presence of phonological overlap via L1 translation. Critically, this time, primes were repeated between the overlap and no overlap conditions to exclude spurious lexical property differences. We further hypothesised that the approximate of Welsh-typical stress patterns might be independently influenced by speaker accent, and thus also manipulated accent, by having prime words produced by a native English speaker and a native Welsh speaker. We ensured that for each of the two experiments, prime and target words were the same, with pairings changed between conditions so as to form semantically related and unrelated conditions in Experiment 1, and an L1 overlap and no-overlap condition in Experiment 2.

4.2. Study 4 - Electrophysiological differentiation of the effects of stress and accent on lexical integration in highly fluent bilinguals

Abstract[4]

Individuals who acquire a second language (L2) after infancy often retain features of their native language (L1) accent. Cross-language priming studies have shown negative effects of L1 accent on L2 comprehension, but the role of specific speech features, such as lexical stress, is mostly unknown. Here, we investigate whether lexical stress and accent differently modulate semantic processing and cross-language lexical activation in Welsh-English bilinguals, given that English and Welsh differ substantially in terms of stress realisation. In an L2 cross-modal priming paradigm, we manipulated the stress pattern and accent of spoken primes, whilst participants made semantic relatedness judgments on visual word targets. Event-related brain potentials revealed a main effect of stress on target integration, such that stimuli with stress patterns compatible with either the L1 or L2 required less processing effort than stimuli with stress incompatible with both Welsh and English. An independent cross-language phonological overlap manipulation also revealed an expected interaction between accent and L1 access. Interestingly, stress failed to modulate either semantic priming effects or covert access to L1 phonological representations. Our results are consistent with the concept of language-specific stress templates, and suggest that accent and lexical stress affect speech comprehension mechanisms differentially.

Keywords: Lexical stress; bilingualism; Event-related brain potentials; word comprehension; implicit priming; speech processing; lexical access.

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[4] Section 4.2 is under review in the *Brain Sciences* special issue *Cognitive Neuroscience of Cross-Language Interaction in Bilinguals* (see Appendix K)

4.2.1. Introduction

Bilinguals are often detectable by their native accent. Even a highly fluent, native-like speaker of a second language (L2) will often produce L2 speech with a number of native (L1) phonological and prosodic features (Long, 1990; Major, 2009; Thompson, 1991). Foreign accent in L2 speech is thought to result from interaction between the segmental and suprasegmental characteristics of the native and second languages (Best et al., 2001). The influence that this presence of native features has on second language processing has been the subject of research since the 1960s (Bent & Bradlow, 2003; Brown, 1968; Lagrou et al., 2011, 2013; Wilcox, 1978). Whilst earlier studies often report a beneficial role of L1 accent on L2 processing, suggesting that either speech in a speaker's own or a familiar accent may be easier to understand (Bent & Bradlow, 2003; Brown, 1968; Flowerdew, 1994; Gass & Varonis, 1984; Pihko, 1997; Wilcox, 1978), later studies report interference effects (Hayes-Harb et al., 2008; Lagrou et al., 2011, 2013; Stibbard & Lee, 2006). Lagrou, Hartsuiker and Duyck (2013) investigated the influence of L1 accent, alongside sentence context and semantic constraints, on language non-selective access. Dutch-English bilinguals made lexical decisions for the last word of English sentences produced by a native speaker of English or Dutch. A main effect of interference was found for interlingual homophones (e.g., lief "sweet" – leaf) with response times significantly longer relative to control stimuli. Furthermore, the homophone interference effect was modulated by accent, such that L1 Dutch-accented English sentences were responded to more slowly than English-accented English sentences. Whilst the interaction between accent and homophone interference suggests that native accent modulates language non-selective access, a main effect of accent, with faster responses to the English speaker than the Dutch speaker, lead the authors to suggest that future research should investigate whether L1 accent increases L1 salience, or results in an overall decrease in intelligibility.

Whilst the results of Lagrou et al. (2013) suggest that L1 accent in second language comprehension can influence lexical access in bilinguals, foreign accent is a 'complex of interlingual or idiosyncratic phonological, prosodic and paralinguistic systems' (Jenner, 1976: 167). The realisation of L2 intonation and prosody, for example, has been shown to be particularly influenced by corresponding properties of the L1 (de Mareüil & Vieru-Dimulescu, 2006; Jilka, 2000; Munro, 1995). Another feature that contributes towards accent is lexical stress, the perceptual prominence and accentuation of a syllable in a word. Lexical stress varies in its realisation both between and within languages. In stress-variable languages it can fundamentally alter the perception of words. For example, in certain languages, lexical stress can mark the difference between the phonology of words which are otherwise segmentally identical (e.g., in English, *insight* vs *incite*). In contrast, lexical stress is fixed in other languages, occurring consistently on specific syllable *loci*. Speakers of languages without contrastive lexical stress (e.g., French, Hungarian, Welsh) often experience 'stress deafness' - a difficulty in discriminating between stress patterns of languages with variable stress (Dupoux et al., 1997; Dupoux & Peperkamp, 2001). Despite this, results suggest that age of acquisition and degree of exposure to a language with variable stress increases sensitivity (Dupoux et al., 2010; Dupoux et al., 2008; Peperkamp & Dupoux, 2002). Furthermore, whilst stress deaf individuals struggle to consciously identify and discriminate between stress patterns, a host of EEG experiments have shown brain sensitivity to stress, and particularly to violations of native fixed stress patterns (Domahs et al., 2013; Domahs et al., 2012; Honbolygó & Csépe, 2013; Honbolygó, Csépe, & Ragó, 2004). For speakers of languages with non-contrastive stress, it is thought that stress may not be encoded in the phonological representation of words in their mental lexicon (Peperkamp, 2004), as during language acquisition infants are able to infer whether stress is lexically contrastive prior to the establishment of the lexicon (Peperkamp & Dupoux, 2002). Instead, this sensitivity to native fixed stress patterns has been proposed to reflect pre-lexical stress templates (Honbolygó & Csépe, 2013).

Consistent with the fact that L1 accent transfers from the first language to the second, L1 stress patterns have been shown to influence the production and comprehension of L2 lexical stress (Archibald, 1997; Erdmann, 1973; Chakraborty & Goffman, 2010; Schwab & Llisterri, 2011). Furthermore, although Lagrou, Hartsuiker and Duyck (2011; 2013) suggest that L1 accent may decrease intelligibility of L2 speech, or increase L1 activation, accent entails a host of segmental characteristics (e.g., realization of phonemes) and suprasegmental features (e.g., prosody, including intonation, timing and stress) (Jilka, 2000; Munro, 2001). The question thus arises to what extent individual suprasegmental features contribute to these effects. The existence of different lexical stress systems across languages provides an opportunity to explore the effects of L1 suprasegmental features on L2 processing.

Two languages with such contrasting stress systems are English and Welsh. English lexical stress is variable and, despite generally conforming to certain rules, may occur on any syllable within a given word. Stress is indicated for the most part through vowel reduction (e.g., the difference between the vowel sounds in the first syllables of the noun *conflict* and the verb *conflict*), or a combination of suprasegmental features including an increase in pitch, duration and amplitude of the stressed syllable (Cutler, 2005; Fry, 1955, 1958; Lieberman, 1960). In contrast, lexical stress in Welsh is highly regular, consistently occurring on the penultimate syllable. Although irregular stress does occur, this is an uncommon exception predominantly found in English loanwords (Mennen et al., 2015). In comparison to English, the relative paucity of research on Welsh lexical stress means that the intricacies of its realisation and perception are less well understood, and consequently remain subject to some debate. Although the current understanding of Welsh lexical stress is incomplete, it appears to be realised on the basis of two key characteristics: shorter duration and lower pitch of the stressed penultimate syllable relative to the unstressed ultima. Thus, contrary to that of the majority of European languages (Cooper, 2015), in which the stressed syllable is generally characterised by higher pitch, and greater duration, loudness and salience of the vowel, Welsh stress features both phonetic and phonological prominence of the final unstressed syllable relative to the stressed penult (Williams, 1983). Despite the unusual linguistic context in Wales, in which Welsh, whilst increasingly spoken as a native language, coexists alongside English with Welsh monolingualism existing solely in some pre-school children, evidence suggests that stress realisation in Welsh has not entirely converged to resemble that of English (Mennen et al., 2015).

In the present study, we manipulated lexical stress and native speaker accent in a cross-modal priming paradigm (Fig. 1) to investigate how lexical stress and accent differentially affect lexical access. Highly-fluent Welsh-English bilingual participants were asked to make semantic relatedness judgments on English word pairs, with trisyllabic auditory primes manipulated so as to feature stress on the 1st, the 2nd (penult) or the 3rd (ultima) syllable. For all target stimuli, first syllable stress was consistently correct, corresponding to natural productions in English. Although second and third syllable stress were anomalous in English, the phonetic and phonological prominence of third syllable English stress best approximated Welsh penultimate stress, which is operationalized through increased duration and high pitch on the following (ultima) syllable. Critically, Welsh translation equivalents of the primes were also trisyllabic words.

To differentiate between the effects of lexical stress as an isolated feature of the L1 (lexical stress) with that of accent as a whole, we manipulated speaker accent in a cross-factorial design. All primes in the 3 stress conditions were therefore produced by an L1 English speaker on the one hand, and an L1 Welsh speaker on the other. The English speaker selected was a monolingual with a SE accent, whilst the Welsh speaker was a non-native English speaker, with a regional accent typical of the Llyn Peninsular in North Wales. The Welsh speaker was selected from this area as it is a notably Welsh-dominant area. Consequently, whilst the population in Wales consists of a large number of native speakers of English with Welsh accents, it would be atypical to find a native English speaker with an accent characteristic of that of this region. The presence of L1 accent in L2 speech is thought to result in an increase in cross-language activation and reduced L2 intelligibility (Lagrou et al., 2011; 2013)]. Therefore, the inclusion of an accent manipulation, with stimuli produced by a native Welsh and native English speaker, served to both to enable comparison between the effects of L1-approximate lexical stress with that of accent on L2 intelligibility, and of L1 accent vs. stress as an isolated feature on L1 activation. Furthermore, due to variability in stress realization across the two languages, it was thought that the native English speaker would be unlikely to produce the language-specific features of lexical stress in Welsh. While the stress manipulation altered the position of stress within the word, the accent (speaker) manipulation altered the phonetic realization of stress, thus enabling us to determine whether specific differences in the phonetic parameters of stress differed in their effects on language processing. In two experiments we tested the effects of L1 accent and lexical stress patterns on L2 semantic priming (Experiment 1) and implicit phonological priming through the L1 (Experiment 2). The two experiments were run together with each experiment serving as filler items for the other.

Experiment 1 tested the effects of lexical stress and native speaker accent on semantic integration. If, as native speakers of a fixed stress language, Welsh-English bilinguals process stress based on language-specific, pre-lexical stress templates (Honbolygó & Csépe, 2013), L2-anomalous stress should be processed with relative ease (i.e. causing minimal interference to semantical processing) when congruent with the L1. Thus, semantic processing of prime words with 3rd syllable stress should prove easier than

2nd syllable stress, since the latter fits neither the correct stress pattern of the English primes nor that of Welsh. We consequently predicted that the stress manipulation would interact with relatedness, resulting in an increase in N400 amplitude for 2nd syllable stress primes relative to 3rd syllable stress in the case of related pairs (since unrelated pairs have no reason to show priming effects). Alternatively, if stress templates are encoded within the lexical entry, naturally stressed primes should induce greater semantic priming relative to incorrectly stressed primes irrespective of goodness of fit with L1 Welsh, and thus, both 2nd and 3rd syllable stress should incur the same increase in N400 amplitudes. In both cases, we predict that ERP priming effects would occur in the classic N400 time window spanning 350 – 500 ms (Kutas & Federmeier, 2011).

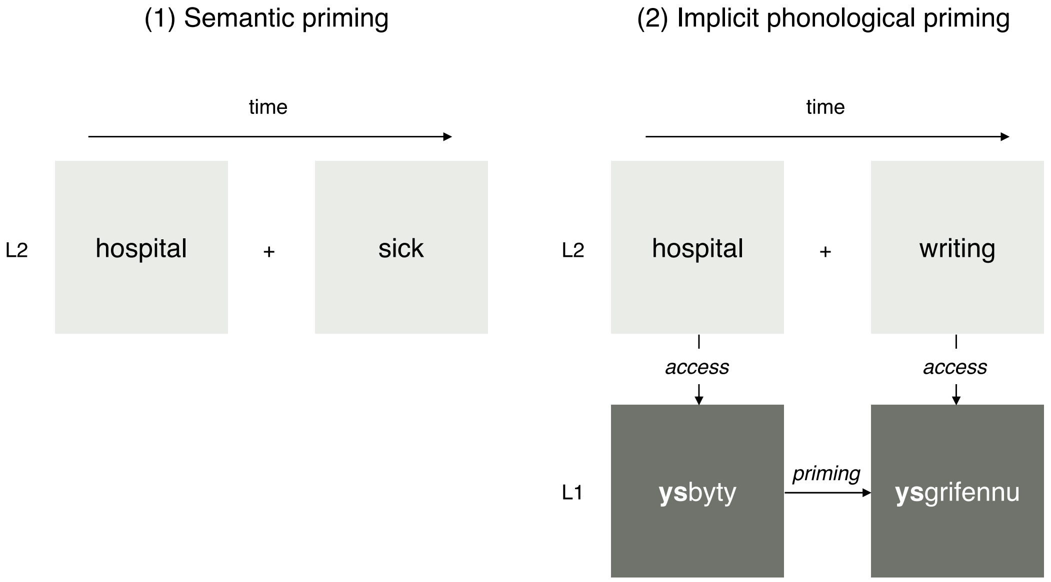


Figure 14 – (1) Semantic priming paradigm (Experiment 1) and (2) implicit phonological priming paradigm (Experiment 2). In both experiments, participants hear an L2 prime word, which is followed by a visual word target. For the implicit priming paradigm, unconscious access to L1 translations with word-initial phonological overlap results in implicit priming between otherwise unrelated L2 word pairs.

For both hypotheses, we predicted that reaction times and accuracy would be along the same lines as predictions for ERP results, such that, on the one hand, 2nd syllable prime stress would result in longer reaction times and lower accuracy, or alternatively, this would be true of both 2nd and 3rd syllable stress primes. Finally, if accent were to reduce intelligibility of the prime as hypothesized by Lagrou et al. (2011; 2013), we would also expect an interaction between accent and semantic relatedness.

Experiment 2 tested whether stress and accent differentially affect unconscious access to L1 phonological representations. Prior research has shown that phonological overlap through L1 results in a priming effect, attributed to unconscious native language activation (Thierry & Wu, 2007; Wu & Thierry, 2010). To test whether accent and stress influence L1 activation in an L2 context, we manipulated phonological overlap in the L1 translation equivalent of L2 English primes and targets, such that certain word pairs featured a word-initial phoneme overlap if translated into Welsh, e.g., hospital ('**ys**byty') – writing ('**ys**grifennu') (**see Fig. 14**). Note that all word pairs in this section of the experiment were semantically unrelated (see Methods). We hypothesised that (i) L1 accent would heighten activation of L1 phonological representations, resulting in an increase in implicit phonological priming, and (ii), if Welsh-approximate stress were to increase L1 activation, that 3rd syllable stress (compatible with Welsh) would result in increased phonological priming irrespective of accent. We predict that such priming effects would manifest as a reduction of ERP mean amplitudes between 200 – 400 ms over centroparietal electrode sites for word pairs with phonological overlap in the L1 (i) with Welsh-accented primes and (ii) with third syllable stress primes. Our time window of interest, and the topography selected was in accordance with prior research demonstrating that phonological processing and expectancy influences ERPs within the range of the phonological mapping negativity (Connolly & Phillips, 1994; Newman & Connolly, 2009), N250 - P325 (Holcomb & Grainger, 2006; Grainger et al., 2006; Grainger & Holcomb, 2009; Hagoot & Brown, 2000) and early N400 (Thierry & Wu, 2007; Wu & Thierry, 2010; Dumay et al., 2001; Praamstra et al., 1994) over centroparietal regions. Consistent with prior studies of implicit phonological priming (Thierry & Wu, 2007; Wu & Thierry, 2010), we predicted no effect of either accent, stress or overlap on behavioural measures.

4.2.2. Materials and Methods

4.2.2.1. Participants

Twenty-one Welsh-English bilinguals with normal or corrected-to-normal vision, no learning disabilities, and self-reported normal hearing participated in the experiment. Two datasets were rejected due to poor electrophysiological data quality resulting in a final sample of 19 participants (12 female, 7 male, mean age = 24.8; SD = 8.9). All participants gave written informed consent before taking part in the experiment (approved by the School of Psychology, Bangor University ethics committee, approval no. 2017-16168). All participants began learning Welsh prior to the age of three at home, and had studied through the medium of Welsh up to the age of 12. Age of acquisition for English varied, although only participants who had learnt English either as a second language through formal school tuition, or subsequent to Welsh in a bilingual home were included. For participants who had learnt English formally as a second language at school, tuition did not begin prior to the age of six. All participants except one were right-handed. Table 7 shows participants' language background for the L1 (Welsh) and L2 (English).

Table 7. Participants' language background

Measure	Mean	SD
Age of Welsh acquisition	0.2	0.9
Age of English acquisition	3.8	2.29
Daily Welsh usage (%)	64.5	20.2
Daily English usage (%)	35.2	19.5

4.2.2.2. Materials

Auditory word primes were 39 trisyllabic English words digitally recorded in English by both a female native English speaker and a female native Welsh speaker at a sampling rate of 48.8 kHz and resampled using Audacity to 44.1 kHz to ensure compatibility with E-Prime stimulus presentation software. For each recording, the prime was produced with stress on the first, second or third syllable in both a Welsh and an English accent, creating six contrasting recordings for each prime word (see Table 8). During prime recording, the speakers were initially instructed to practise stress manipulations by changing pitch, duration and loudness of each syllable, whilst producing the same vowels in each case. Inspection of recordings was conducted syllable-by-syllable to ensure no vowel reduction could be auditorily perceived.

Visual word targets were two lists of 117 words of English varying in length from 2 – 4 syllables. Whilst the same auditory primes were used in both the semantic relatedness and phonological overlap conditions, two discrete target lists were used in order to manipulate phonological overlap and semantic relatedness separately. Prime and target words were paired to form experimental conditions as follows: (1) Semantic relationship (related condition), as in *hospital – sick* (in Welsh: *ysbyty - gwael*); (2) No semantic relationship (unrelated condition) using target stimuli from the same list as condition (1), as in *hospital – publish* (in Welsh: *ysbyty – cyhoeddi*), (3) Phonological overlap via Welsh translation (overlap condition), as in *hospital – writing* (in Welsh: *ysbyty – ysgrifennu*); and (4) No overlap through Welsh (no overlap condition) using target stimuli from the same list as condition (3), as in *hospital – rock* (in Welsh: *ysbyty – craig*). In the critical manipulation for Experiment 1 (related condition vs. unrelated), the prime and target were either semantically related or unrelated. For all semantically unrelated conditions (2 - 4), there were no listed associations between prime and target pairs in either the Edinburgh Associative Thesaurus (Lapalme, 2017) or the University of South Florida Free Association Norms (Nelson et al., 1998) (mean = 0, SD = 0), whilst the semantic relationship condition (1) featured a greater degree of associations (mean = 3.0, SD = 8.9). In the critical manipulation for Experiment 2 (overlap condition vs. no overlap condition), the L1 translations of prime and target words overlapped or did not overlap in their initial onset phonemes. The phonological overlap was selected consistent both with the prediction of the Cohort Model (Marslen-Wilson, 1984; Marslen-Wilson & Tyler, 1980), namely that word candidate activation occurs within the first 150 - 200 ms of auditory input (roughly corresponding to the first 1-2 phonemes of a word), and with prior research demonstrating ease of processing for L2 words sharing initial consonants with L1 translations equivalents (Vaughan-Evans et al., 2014).

Each auditory prime word was paired with three possible visual word targets in order to display a different target for each of the three stress recordings, resulting in 117 (3 x 39) prime-target combinations per list. To minimise effects of familiarity, lexical frequency, word length, and concreteness, all words were familiar and had mid-range lexical frequency. Primes and targets were matched across conditions for lexical concreteness and frequency. Frequency measures for English materials were calculated from SUBTLEX (van Heuven et al., 2014) (mean = 4.64, *SD* = 0.70). An analogous corpus is not available for Welsh, so frequency measures for Welsh materials were calculated from Cronfa Electroneg o Gymraeg (CEG; Ellis, O'Dochartaigh, Hicks, Morgan, & Laporte, 2001)) (mean = 1.97, *SD* = 0.65). Concreteness measures for English materials were calculated from the *Concreteness ratings for 40 thousand generally known English word lemmas* corpus (Brysbaert et al., 2014) (mean = 3.55, *SD* = 1.02), and, due to corpus unavailability, assumed to be similar for Welsh translations.

Table 8: Phonetic parameters for each stress condition by accent. Tables A1 and B1 Specify values for duration, intensity and F0 by syllable. Tables A2 and B2 specify the syllable by stress interaction for each measure, followed by posthoc comparisons by syllable.

A1. English accent

	1st syllable			**2nd syllable**			**3rd syllable**		
Stressed syllable	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
Duration	0.199	0.173	0.156	0.158	0.232	0.164	0.340	0.354	0.425
SD	0.061	0.058	0.060	0.050	0.056	0.054	0.117	0.115	0.107
Intensity	76.8	73.5	73.6	73.3	75.5	73.4	70.7	72.5	74.6
SD	1.69	2.46	2.39	2.33	1.87	2.34	2.10	2.61	1.85
F0 (mean)	226.8	189.8	187.2	184.0	202.3	187.2	158.3	157.4	171.5
SD	17.9	25.7	16.7	12.2	16.5	16.5	5.4	10.5	8.3

A2. Analysis (English)

Duration (ANOVA: F = 84.186, p < 0.001)			
	1st syllable	**2nd syllable**	**3rd syllable**
Stress 1 – stress 2	**p < 0.001**	**p < 0.001**	p = 0.301
Stress 1 – stress 3	**p < 0.001**	p = 1.000	**p < 0.001**
Stress 2 – stress 3	p = 0.102	**p < 0.001**	**p < 0.001**
Intensity (ANOVA: F = 84.404, p < 0.001)			
Stress 1 – stress 2	**p < 0.001**	**p < 0.001**	**p < 0.001**
Stress 1 – stress 3	**p < 0.001**	P = 0.094	p = 1.000
Stress 2 – stress 3	**p < 0.001**	**p < 0.001**	**P = 0.034**
Pitch (ANOVA: F = 81.870, p < 0.001)			
Stress 1 – stress 2	**p < 0.001**	**p < 0.001**	p = 1.000
Stress 1 – stress 3	**p < 0.001**	p = 1.000	**p < 0.001**
Stress 2 – stress 3	p = 1.000	**p < 0.001**	**p < 0.001**

B1. Welsh accent

	1st syllable			2nd syllable			3rd syllable		
Stressed syllable	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
Duration	0.190	0.173	0.144	0.132	0.220	0.132	0.314	0.330	0.369
SD	0.053	0.060	0.044	0.044	0.060	0.041	0.093	0.094	0.098
Intensity	72.3	71.9	71.5	69.6	72.6	70.6	73.3	71.6	73.4
SD	2.13	2.40	2.75	1.88	1.73	2.05	1.67	1.82	2.19
F0 (mean)	229.1	208.3	203.5	109.8	220.7	192.6	240.7	205.7	198.3
SD	42.4	42.2	42.3	25.1	49.0	47.5	55.8	65.9	78.2

B2. Analysis (Welsh)

Duration (ANOVA: F = 75.9, p < 0.001)			
	1st syllable	**2nd syllable**	**3rd syllable**
Stress 1 – stress 2	p = 0.447	**p < 0.001**	p = 0.373
Stress 1 – stress 3	**p < 0.001**	p = 1.000	**p < 0.001**
Stress 2 – stress 3	**p < 0.001**	**p < 0.001**	**p < 0.001**
Intensity (ANOVA: F = 26.614, p < 0.001)			
Stress 1 – stress 2	**p < 0.001**	p < 0.714	p = 405
Stress 1 – stress 3	p = 0.405	p = 1.000	**p < 0.001**
Stress 2 – stress 3	**p < 0.001**	p = 0.254	**p < 0.001**
Pitch (ANOVA: F = 5.842, p < 0.001)			
Stress 1 – stress 2	p = 0.197	p = 1.000	**p < 0.001**
Stress 1 – stress 3	**p = 0.024**	p = 0.754	**p < 0.001**
Stress 2 – stress 3	p = 1.000	**p = 0.007**	p = 1.000

Furthermore, 1st, 2nd and 3rd syllable versions of each prime were presented with a different target within participant. Critically, target words were rotated across conditions (1) and (2) on the one hand and across conditions (3) and (4) on the other, meaning that all targets featured in the semantically related condition also featured in the unrelated condition and all targets in the phonological overlap condition also featured as targets in the no overlap condition.

4.2.2.3. Procedure

Participants were tested in two separate sessions separated by at least a day. Half of the participants were exposed to the Welsh-accented stimuli during their first session, whilst the other half heard English-accented stimuli first. Each testing session consisted of 468 trials, 234 forming the semantic relatedness paradigm and the remaining 234 forming the implicit phonological priming paradigm. A trial began with a fixation cross presented for the duration of 100 ms on a 17” CRT monitor at a distance of 100 cm from the participant's eyes. The fixation cross was followed by an auditory prime, which was played over loudspeakers set around the monitor. Following the auditory prime, a second fixation cross was displayed for a variable ISI of 160–240 ms. This was followed by the visual target word, which was presented in black Times New Roman font, size 14 points on a light grey background. Participants were instructed to indicate whether prime and target pairs were semantically related via a button-press within a 2000 ms response window, and response-hand side was counterbalanced between participants. Participants' response immediately triggered the next trial. Prior to commencing the full experiment, participants underwent a brief training period to ensure they were familiar with the procedure.

4.2.3. Data analysis

4.2.3.1. ERP recording and pre-processing

EEG data were recorded at 2048 Hz using a BioSemi system with 128 active Ag/AgCl electrodes with the passive common mode sense (CMS) electrode as reference and driven right leg (DRL) as ground. Prior to recording, a cap was fitted to secure the EEG electrodes in place, and electrode impedances were reduced to < 5 kΩ. Six further facial bipolar electrodes positioned on the outer canthi of each eye and in the inferior and superior areas of the left and right orbits provided bipolar recordings of the horizontal and vertical electrooculograms (EOG). Participants were instructed to blink and make repeated vertical and horizontal eye movements during an EEG recording prior to the main experiments in order to acquire eye-movement data for subsequent correction. Data was resampled to 1024 Hz prior to analysis, re-referenced offline to the global average reference and filtered offline using a 30 Hz (48 dB/oct) low-pass and 0.1 Hz (12 dB/oct) high-pass Butterworth Zero Phase shift band-pass filter. Noisy electrodes were replaced on an individual basis by means of spherical interpolation. Ocular correction was conducted using Independent Component Analysis (ICA) following visual inspection of the data using the AMICA procedure (Palmer et al., 2008). Data was then segmented into epochs ranging from –200 to 1000 ms relative to the onset of the visual target word, and baseline correction was performed relative to 200 ms pre-stimulus activity.

4.2.3.2. *Modelling of behavioural data*

For both experiments, reaction time data (RT) was log transformed so as to be normally distributed and submitted to a linear mixed effect model (*lmer* function in lme4). Fixed effects were centred to minimise collinearity, and random effects, including prime and participant intercepts and slopes were modelled and systematically trimmed such that interactions were removed until the model converged (Barr et al., 2013). Subsequently, fixed and random effects and interactions that did not significantly contribute to model fit were systematically removed from the initial model. Accuracy data was submitted to generalized mixed-effects modelling (via *glmer* with a binomial link function in the lme4 v1.12 library (Bates et al., 2014), after centring fixed factors to minimise collinearity. As in the reaction time analysis, random effects including participant and item intercepts and slopes were modelled and systematically trimmed until the model converged, and fixed and random effects and interactions that did not significantly contribute to model fit were systematically removed.

4.2.3.3. *ERP analysis*

In Experiment 1, mean ERP amplitudes were analysed in an epoch corresponding to the classic N400 window (350-500 ms) in which semantic priming is most observable over the central scalp regions (Kutas & Federmeier, 2011) to determine whether prime stress influenced semantic integration processes. In Experiment 2, mean ERP amplitudes were analysed between 200 – 400 ms, consistent with prior research demonstrating that phonological processing and expectancy influences ERPs within the range of the phonological mapping negativity (Connolly & Phillips, 1994; Desroches, Newman, & Joanisse, 2008; Newman & Connolly, 2009; Sučević et al., 2015), N250 - P325 (Grainger & Holcomb, 2009; Grainger et al., 2006; Hagoort & Brown, 2000; Holcomb & Grainger, 2006) and early N400 (Nicolas Dumay et al., 2001; Praamstra et al., 1994; Thierry & Wu, 2007; Wu & Thierry, 2010) over centroparietal regions.

ERP data was analysed by means of two repeated-measures analysis of variance (ANOVA), one for semantic relatedness (Experiment 1) and one for cross-language phonological priming (Experiment 2). In the case of the semantic relatedness manipulation, mean amplitudes for all time windows were analysed over 14 central electrodes where the N400 is usually maximal with accent (English, Welsh), prime stress (syllable 1, 2 or 3), and relatedness (related, unrelated) as independent variables. For the phonological priming analysis, the repeated measures ANOVA was conducted over 12 centroparietal electrodes with accent (Welsh, English), overlap in L1 (overlap, no overlap), and prime stress (syllable 1, 2 or 3) as factors.

4.2.4. Results

4.2.4.1. Experiment 1: Semantic priming

- Behavioural results

RTs were modelled as a function of the three within-subject factors, accent (Welsh, English), prime stress (syllable 1, 2 or 3) and semantic relatedness (related, unrelated). Accent and stress fixed effects did not significantly contribute to model fit and were removed. Results revealed a main effect of semantic relatedness, with unrelated pairs responded to significantly faster than related pairs (b = -0.029, SE = <0.009, t = -3.22, p = 0.002). Accuracy data was submitted to generalized mixed-effects modelling, but the model failed to converge with all fixed effects included. Instead, data was analysed separately by accent. For Welsh-accented word pairs stress fixed effects did not significantly contribute to model fit and was removed from the model. There was a significant effect of relatedness (b = 1.376, SE = 0.287, z = 4.78, p = <0.001), such that responses to unrelated stimuli were significantly more accurate than to related stimuli (**see Fig. 15A)**. For the English-accented analysis, the final model failed to converge and the random effects structure was consequently simplified until convergence was achieved. Simplification of the random effects structure did not affect the results of the model. The results revealed no effect of stress (b = 0.057, SE = 0.051, z = 1.12, p = 0.259) but a significant main effect of relatedness (b = 1.574, SE = 0.269, z = 5.84, p <0.001), such that accuracy for unrelated word pairs was again significantly higher than for related pairs, and a significant relatedness by stress interaction (b = 0.138, SE = <0.051, z = 2.70, p = 0.006). Post hoc tests found no effects of stress on accuracy for either unrelated (b = 0.115, SE = 0.160, z = 0.72, p = 0.471) or related stimuli (b =

0.080, SE = 0.047, z = -1.70, p = 0.080), although the latter just failed to reach significance.

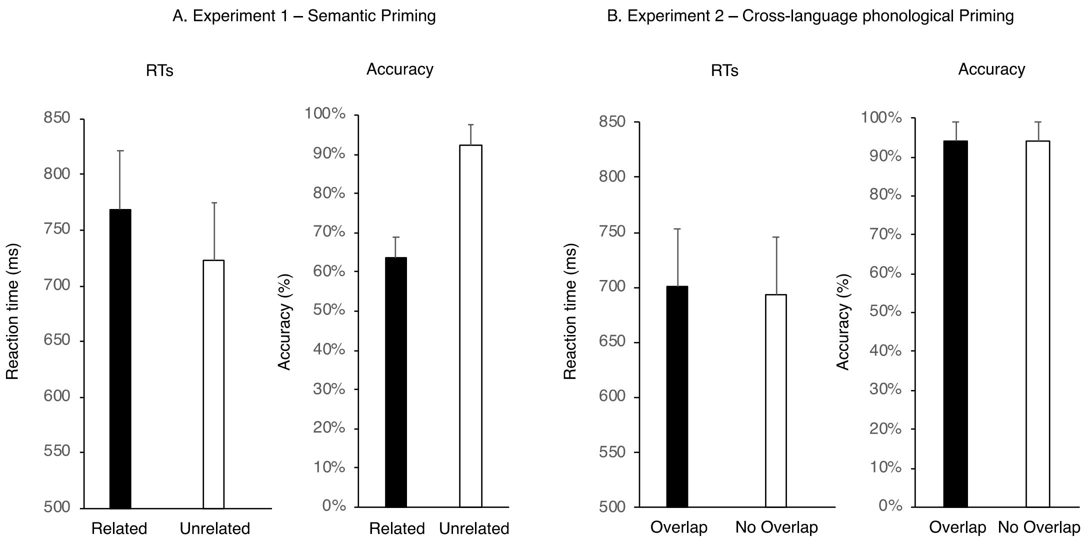
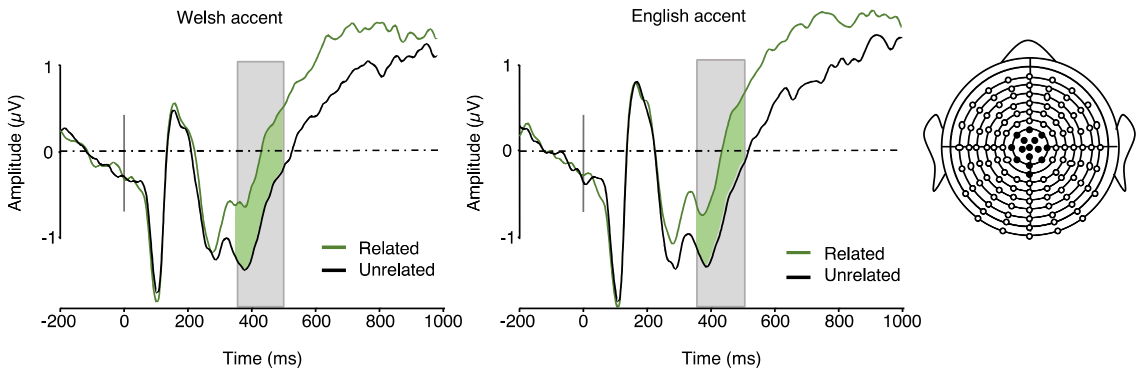


Figure 15 – Summary of the behavioural results in Experiment 1 and 2. A. Experiment 1, semantic priming. B. Experiment 2, Cross-language phonological priming. RTs: reactions times; error bars depict standard error of the mean.

- Electrophysiological results

A repeated measures ANOVA on ERP mean amplitudes in the 350-500 ms time window revealed a significant N400 decrease by semantic relatedness, but no significant effect of stress or accent. Specifically, there was a main effect of relatedness (F(1, 18) = 19.80, p < 0.001, ηp2 = 0.524) such that N400 amplitude was significantly more negative in the unrelated than the related condition for all stress and accent conditions (**see Fig. 16**). There was no significant main effect of accent (F(1, 18) = 0.64, p = 0.802, ηp2 = 0.004), but the main effect of stress was marginal (F(2, 36) = 2.84, p = 0.07, ηp2 = 0.137). Explorative post hoc comparisons of the three stress conditions showed that 2nd syllable stress elicited greater ERP amplitudes than 1st syllable stress (t(18) = 2.35, p = 0.023). There was no interaction between relatedness and accent (**Fig. 16A**; F(1, 18) = 0. 16, p = 0.691, ηp2 = 0.009); relatedness and stress (**Fig. 16B**; F(2, 36) = 0.10, p = 0.901, ηp2 = 0.006); or accent and stress (F(2, 36) = 0.54, p = 0.582, ηp2 = 0.030) and the three-way interaction was also not significant (F(2, 36) = 0.24, p = 0.781, ηp2 = 0.014).

A. Semantic relatedness by accent



B. Semantic relatedness by prime stress

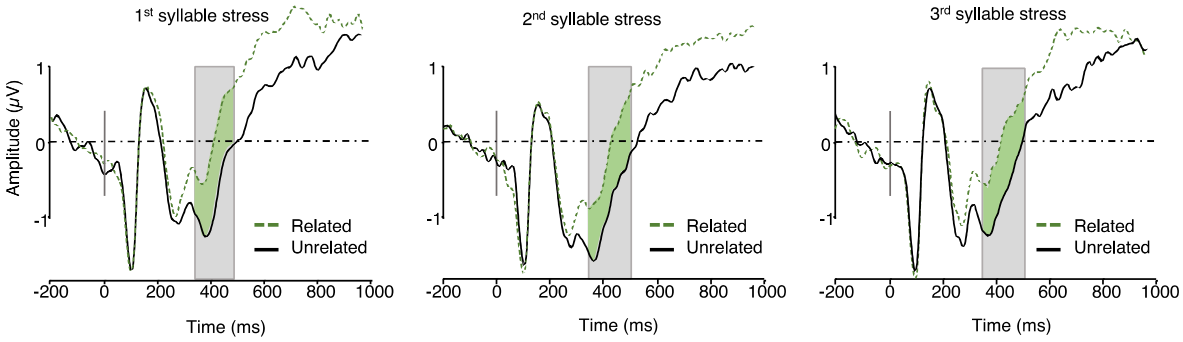


Figure 16. ERP plots from Experiment 1 (semantic priming) plotted for each of the two accents and each of the three stress conditions. (A) semantic relatedness effect by accent (no interaction). (B) semantic relatedness by stress (no interaction).

4.2.4.2. Experiment 2: Cross-language phonological priming

- Behavioural results

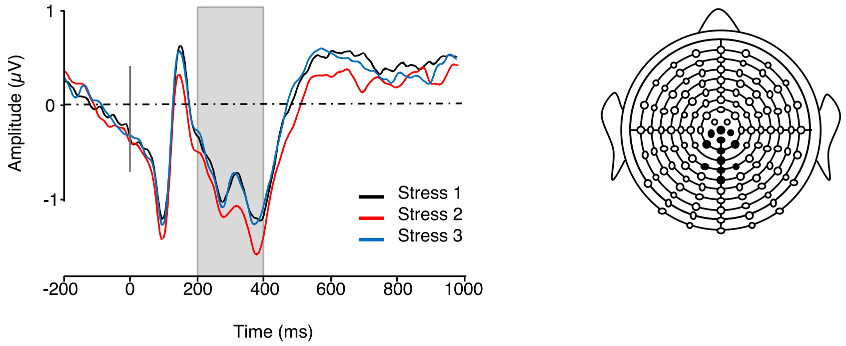
RTs were modelled for accent (Welsh, English), prime stress (syllable 1, 2 or 3) and L1 overlap (overlap, no overlap), centred to minimise collinearity. Accent, stress and overlap fixed effects did not significantly contribute to model fit and were removed. Therefore, as predicted, accent, stress and lexical overlap had no effect on RTs.

Accuracy data was submitted to generalized mixed-effects modelling and accent, prime stress and overlap were again centred to minimise collinearity. Random effects were modelled and systematically trimmed but the model failed to converge when all fixed effects were included. Data was analysed similarly to Experiment 1, modelled separately by accent. For Welsh-accented word pairs, the fixed effect of overlap did not significantly contribute to model fit and was removed. There was a significant main effect of stress (b = 0.239, SE = 0.076, z = 3.019, p = 0.002). Post hoc tests showed that accuracy in the 2nd syllable stress condition (Mean = 92%, SE = 5%) was significantly higher than that of the natural 1st syllable stress condition (Mean = 91%, SE = 5%, b = 0.431, SE = 0.180, z = -2.40, p = 0.043) and this was also true when comparing 3rd to 1st syllable stress (Mean = 93%, SE = 5%, b = 0.543, SE = 0.185, z = -2.94, p = 0.009). There was no significant difference between 2nd or 3rd syllable stress (b = 0.111, SE = 0.198, z = -0.56, p = 0.839). There was no effect of accent, stress or overlap for English accented word pairs, with the three fixed effects not significantly contributing to model fit and removed from the model.

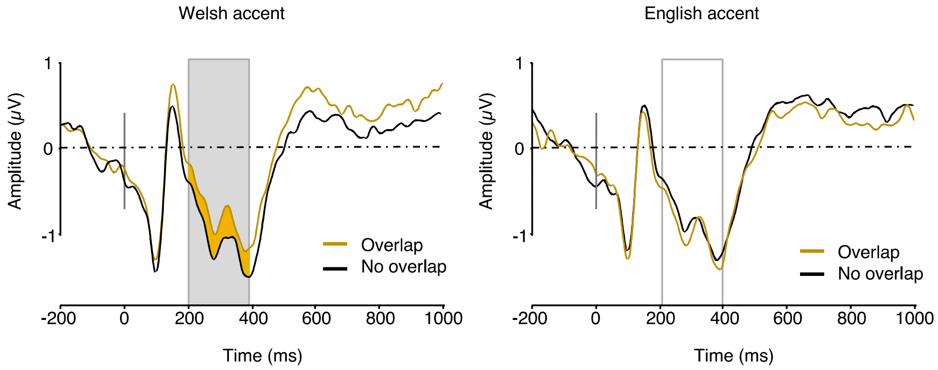
- Electrophysiological results

The repeated measures ANOVA conducted on ERP amplitudes in the 200-400 ms window revealed a significant main effect of stress (**Fig. 17A**, F(2, 36) = 5.56, p = 0.008, ηp2 = 0.236,). Post hoc analyses showed that ERP mean amplitudes were significantly more negative for target words preceded by 2nd syllable stress as compared to natural 1st syllable stress primes (t(18) = 2.93, p = 0.006) and 3rd syllable stress (t(18) = -2.83, p = 0.007). There was no significant difference between target words preceded by 1st syllable stress primes relative to 3rd syllable stress primes (t(18) = 0.09, p = 0.92). We also found a significant interaction between phonological overlap and accent (F(1, 18) = 5.95, p = 0.025, ηp2 = 0.249, Fig. 17B).

A. Stress main effect



B. Native phonological overlap by accent



C. Native phonological overlap by prime stress

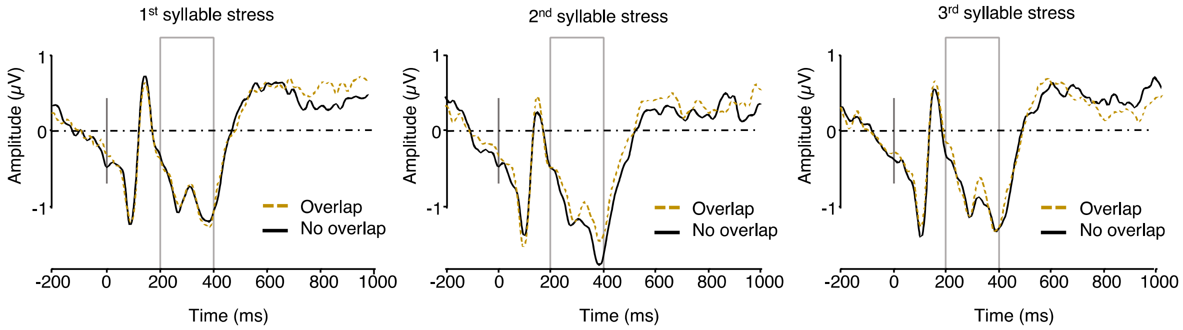


Figure 17. ERP plots obtained in Experiment 2 (cross-language phonological priming). (A) main effect of stress across both related and unrelated trials. (B) Phonological overlap by accent interaction (C) Phonological overlap by stress (no interaction).

Mean ERP amplitudes for overlapping pairs were significantly less negative than for non-overlapping pairs (t(18) = 2.35, p = 0.02) when primes were produced in a Welsh accent, but no such difference was found when primes were produced in an English accent (t(18) = 0.92, p = 0.36). Importantly, there was no interaction between phonological overlap and stress (F(2, 36) = 2.02, p = 0.693, ηp2 = 0.020, Fig. 17B). No other main effect or interaction was significant.

4.2.5. Discussion

In the current study, we investigated whether lexical stress and accent differently modulate semantic processing (Experiment 1) and cross-language lexical activation (Experiment 2) in highly proficient Welsh-English bilinguals. In Experiment 1, unrelated word pairs were responded to significantly faster, and with greater accuracy than related pairs. ERP results revealed a classic effect of relatedness on N400 amplitude and a marginal main effect of stress driven by 2nd syllable stress primes. Notably, there was no effect of accent in Experiment 1 and no interaction between accent and stress. As expected, in Experiment 2 there was no effect of accent, stress, or lexical overlap on RTs, but surprisingly responses to targets following Welsh-accented primes featuring 2nd or 3rd syllable stress were more accurate than responses to 1st syllable stress. In the ERP data we found an implicit priming effect, with significantly less negative mean amplitudes for stimuli overlapping through L1, but only when primes were produced in a Welsh accent. Finally, we found a significant main effect of stress, with ERP amplitudes for 2nd syllable stress primes significantly more negative than 1st or 3rd syllable stress primes.

4.2.5.1. Experiment 1

Accuracy results for Experiment 1 represent classic semantic priming effects, in that unrelated word were generally responded to with higher accuracy than related words (Wu et al., 2012). In contrast, reaction time results were unexpected, with faster responses to unrelated words than related words contrasting with that classically reported in semantic priming paradigms (Martin & Thierry, 2008; Neely, 1976). We speculate that the reduced RTs in response to related word pairs may relate to two characteristics of the experimental design: (i) Prime words were repeated 12 times, albeit with three different stress patterns and in two different accents. This may have led participants to generate incorrect expectations about any given prime (e.g., having heard a prime paired with a related target once, another iteration of the same prime word may have led to expecting an unrelated target). (ii) Given the design of the study, only 25% of word pairs were semantically related, making related pairs overall infrequent and less expected. In contrast, N400 modulation showed expected semantic priming effects, thought to index the spread of activation through the conceptual system (Kutas & Federmeier, 2011). Behavioural results and N400 effects were thus not perfectly aligned as has been shown repeatedly in ERP studies of semantic processing in which behavioural data were recorded (Thierry & Wu, 2007; Wu et al., 2012). This result is consistent with the view that the N400 is mostly insensitive to explicit task requirements or conscious evaluation of the stimuli (Kutas & Federmeier, 2011).

In Experiment 1 we hypothesized that, as speakers of a fixed stress language, Welsh-English bilinguals may process stress based on language-specific, pre-lexical stress templates. This should have resulted in increased N400 amplitude in the 2nd syllable stress condition as compared to both the 1st syllable stress condition (natural stress), and the 3rd syllable stress condition, given that the latter best approximates Welsh stress pattern. Instead of the anticipated stress by relatedness interaction, our results showed a marginal main effect of stress driven by 2nd syllable stress primes. Although marginal, and thus any interpretation should be tentative, the effect suggests that 2nd syllable stress interfered with the processing of visual word targets, irrespective of semantic relatedness or accent. Therefore, contrary to primes stressed incorrectly on the 2nd syllable, words produced with incorrect stress patterns compatible L1 (Welsh, 3rd syllable stress) may not have repercussion for the processing of visual word targets. This may resemble a kind of stress priming effect which will require further validation in the future.

Beyond this, we sought to differentiate between the effects of lexical stress (as an isolated feature) and speaker accent to test the proposals put forward by Lagrou et al. (2011; 2013), that L1 accent, when present in the L2, results either in heightened salience of the L1 or overall reduced intelligibility. In Experiment 1, we found no effect of accent on reaction times, accuracy or, critically, N400 mean amplitudes. Neither did we find any interaction between accent and semantic relatedness. This suggests that native accent in a second language context does not measurably affect intelligibility, since such an effect should have resulted in a modulation of the N400 effect across accent conditions.

4.2.5.2. Experiment 2

In Experiment 2, we found a main effect of stress on accuracy for Welsh-accented primes. This effect is not easy to interpret, because: (i) it was very small in size (maximally 2% accuracy difference); (ii) the full model testing the accent by stress interaction failed to converge and thus we cannot assume that there is an interaction between the two factors; and (iii) we must keep in mind that in Experiment 2, all prime-target word pairs were unrelated in the context of a semantic relatedness judgement task. For the latter reasons, we refrain from over-interpreting this result.

As predicted, however, in the ERP data we found an interaction between speaker accent and L1 phonological overlap on mean ERP amplitudes between 200 and 400 ms post target onset. For Welsh-accented primes, ERP amplitude was significantly less negative when prime and target words phonologically overlapped though L1 Welsh translations relative to the no overlap condition. We interpret this result as evidence of heightened L1 salience when primes were heard with a native accent, consistent with the latter of the two proposals put forward by Lagrou et al. (2011; 2013). Where Experiment 1 results failed to provide evidence in favour of reduced intelligibility of L2 speech produced with a non-native speaker, the latter result points toward increased L1 salience.

Furthermore, ERP results of Experiment 2 unexpectedly revealed a main effect of stress, manifesting as greater negativity in the 200 – 400 ms time-window for 2nd syllable stressed primes relative to 1st and 3rd syllable. Strikingly, this pattern is consistent with the main prediction we made for Experiment 1, namely that Welsh-English bilinguals would struggle processing stress patterns that are anomalous both with regard to the L1 and the L2. It may be considered surprising that 3rd syllable stress appeared easier to process than 2nd syllable stress, given the paucity of its occurrence in trisyllabic English words (Clopper, 2002). However, given that 3rd syllable stress was processed by participants in a manner similar to natural stress, we propose two interpretations for this observation:

Firstly, for speakers of fixed-stress languages, pre-lexical stress templates, developed in early L1 acquisition, may remain active in L2 processing. English (the L2 language in this experiment) is a variable stress language. Although studies report a varying role of stress in word recognition in English(Cooper et al., 2002; Jesse, Poellmann, & Kong, 2017; Slowiaczek, 1990; van Donselaar et al., 2005), lexical stress does appear to be at least partially encoded in lexical entries. As second language English speakers, however, Welsh-English bilinguals are thought to process stress in the L2 on the basis of pre-lexical L1 stress templates. When speakers of phonologically-fixed stress languages (stress that is based on phonological rules such as syllabic structure or vocalic peaks, as opposed to morphology) learn their language in infancy, it is thought they are able to establish whether their language features contrastive stress prior to the establishment of a lexicon, that is, pre-lexically (Peperkamp & Dupoux, 2002). Furthermore, this process of figuring out how stress matters seems to influence the degree to which stress is encoded as a feature within the lexicon (Dupoux et al., 1997; Levelt, Roelofs, & Meyer, 1999; Peperkamp & Dupoux, 2002). Sequential bilinguals learning a second language with variable stress, thus may lack the strategies that enable them to lexically encode suprasegmental features, or an inability to discriminate between stress patterns of variable-stress languages. It is therefore possible that our results break new ground by showing that highly fluent bilinguals understand stress in the second language on the basis of established native-language representations such as these fixed stress templates. If Peperkamp (2004) and Dupoux (Dupoux & Peperkamp, 2001) are correct, in the case of Welsh-English bilinguals, the insensitivity to lexical stress developed in infancy would mean that they are unable to incorporate stress information into the lexical entries of subsequently acquired L2 words.

Alternatively, the reason why responses to natural and 3rd syllable stress did not differ may relate to the fact that English is a language with both primary and secondary stress. Primary stress refers to the strongest emphasis of a syllable within a given word, and secondary stress corresponds to syllables which are stressed albeit to a lesser extent than the primary stressed syllable. When hearing primes with 3rd syllable stress, participants may have processed the word up to the end of the second syllable, whilst assuming secondary stress on the 1st syllable. Consequently, they would have reached the uniqueness point of recognition prior to perceiving the anomalous 3rd syllable. If so, it is possible that the correct word may have been selected even when primes were incorrectly pronounced with 3rd syllable stress. The data collected in the present study cannot tease apart these two interpretations, and future experiments involving stress manipulations in bilinguals will hopefully resolve this question.

Finally, the Experiment 2 sought to determine the degree to which stress and accent differentially affect parallel language activation in bilinguals. Remarkably, we found that stress did not interact with L1 phonological overlap and, by itself, failed to modulate cross-language activation. In contrast, the L1 accent by overlap interaction supported prior suggestions that native accent may heighten L1 salience in an L2 context (Lagrou et al., 2011, 2013). The lack of interaction between stress and accent points to independence between these characteristics of language regarding their respective contribution to cross-language activation and lexical processing in highly fluent bilinguals. Whilst native accent heightens the activation of the non-target native language, native-like lexical stress patterns appear to have no such effect. Instead L2 stress patterns congruent with those of the native language appear to be processed with relative ease, an effect possibly deriving from pervasive L1-generated, pre-lexical stress templates.

Chapter 5

Discussion

5.1. General discussion

Here, we ran four studies to investigate how accent and stress influence unconscious native language activation in bilinguals, and furthermore, the extent to which this activation spreads. Below, the four studies are discussed in reference to the main themes of this thesis, namely accent and stress.

5.1.1. Accent

In Chapter three we explored how, for bilinguals, the presence of L1 accent might influence unconscious L1 activation. The chapter addresses two main questions: Does the presence of a L1 accent in 2nd language speech heighten activation of L1 representations, and influence implicit cross-language activation of native-language semantics? In Study 1, we tested highly-fluent Welsh-English bilinguals in an experiment in which they made semantic relatedness judgements on English word pairs consisting of an auditory prime and a visual target. Participants were unaware that certain word pairs concealed a phonological repetition via translation into Welsh (e.g., "hospital – write" (in Welsh: ***ys****byty* – ***ys****grifennu*). In this study, we found a strong modulating effect of accent on mean ERP amplitude between 200 - 400 ms. This effect was interpreted as Welsh accent prompting unconscious access to Welsh translation equivalents, whilst English accent failed to yield such an effect.

This findings of Study 1 contributes novel insight into our understanding of bilingual language access in three ways. Firstly, and most obviously, the effect shows that accent has the ability to modulate the degree to which native language representations are active during second language speech comprehension. Such a result builds upon a body of literature suggesting that the influence of L1 accent in the L2 might be one of reduced intelligibility, or heightened L1 salience. Our data teases apart these two interpretations, finding no measurable effect of accent on reaction times, accuracy, or ERP correlates of semantic processing (as measured by N400 mean amplitude). As such, our findings suggest that the presence of accent does not modulate access to semantic representations in the given experiment, but does result in an increase in L1 salience. This finding has implications for models of bilingual language activation, in that suprasegmental features such as accent may be an important cue during lexical activation. Whilst current models of language activation do not explicitly account for the role of accent, some models do feature mechanisms which might be able to incorporate such an effect. For example, in TRACE, the role of context is incorporated into the process of word recognition. However, it is unclear as to whether accent itself would be incorporated under this umbrella, or whether context is limited to sentence level input. Similarly, BIMOLA features a top-down language information level, which serves an inhibitory role in lexical recognition. It may be the case that contextual features such as speaker accent are used by this feature in order to restrict the lexical search.

Secondly, it is interesting to note that the absence of L1 phonological priming for English-accented word pairs contrasts with prior research on unconscious native language activation (Thierry & Wu, 2007; Wu & Thierry, 2010). Whilst previous work has demonstrated implicit L1 priming effects for visual word, and cross-modality (auditory-visual) priming paradigms, neither study manipulated accent in order to elicit this effect. In our paper, we discuss this contrasting result in relation to participant language background and fluency. In the case of the Welsh-English bilingual participants in Study 1, Welsh monolingualism is a rarity, only occurring in elderly individuals living in relatively isolated rural areas, or in young pre-school children prior to exposure to the strongly bilingual community in which they live. Furthermore, although the native language of participants involved in Study 1 was Welsh, their proficiency in English was essentially native-like. In contrast, the Chinese-English bilinguals in Thierry and Wu (2007; Wu & Thierry, 2010) had for the most part only recently moved to an English-speaking country, having been raised in China. All were considerably less fluent in English than the Welsh-English participants of Study 1. When compared to these prior studies, our findings therefore highlight the potentially different processes underpinning second language processing in these two bilingual groups. In lower proficiency bilinguals, with less experience in a bilingual environment that necessitates regular code switching and suppression of the contextually inappropriate language, L1 activation appears to underpin second language processing. In contrast, for highly proficient bilinguals who have considerable experience selecting the correct language in a given context, and supressing the non-target language, L1 activation appears not to occur to the same degree, necessitating additional cues, such as speaker accent, to heighten L1 access. However, in the absence of research testing the effect of accent on implicit L1 priming in lower proficiency bilinguals, it is possible that these additional language cues heighten L1 access across proficiency levels. Finally, the results, in conjunction with those of study 4, potentially contribute to the current understanding of the ERP correlates of phonological processing, an question discussed further in section 5.5 below.

Whilst the results of Study 1 contribute to prior literature on native language sound-form priming within an L2 context, in Study 2, we sought to explore how accent influences a different form of unconscious native language activation. In a paradigm intended to reveal whether implicit activation occurs for L1 semantic representations, as for L1 phonological form, we presented German-English participants with English (L2) sentences recorded in both an English and a German accent, followed by a visual word target. In the critical condition the L2 targets word translated to the incorrect meaning of a polysemous German, e.g., *She added some flowers to improve the look of the* **ostrich**, where ostrich, once translated to the German 'Strauß', has the alternate meaning of bouquet. We expected that (i) the activation of a semantically congruent L1 representations would ease semantic integration of the L2 incongruent target word, and (ii) that, as in Study 1, L1 accent would facilitate access to L1 representations in an all-in-L2 context. Such a finding would not only contribute to our understanding of the role of accent in bilingual lexical access, but also test the accuracy of bilingual language models, such as BLINCS, that posit joint conceptual and semantic representations across languages.

We found no interaction between accent and polysemy. Furthermore, whilst there was a main effect of condition, there was no difference in responses to the polysemous and control conditions, with N400 mean amplitudes for fully incongruent words not significantly different to words which would complete the sentence correctly through access to the alternate meaning of the polysemous translation in L1. However, a number of limitations in the design of study 2 apply. Firstly, the use of different target words each condition, despite being controlled for frequency, length and goodness-of-fit, means that our findings are less robust than if the same targets been used in all conditions. The initial rationale behind the decision not to have the same target words in all experimental conditions was the targeting of an accent by condition interaction. As such, if anomalous L2 targets with correct translations via access to their alternate L1 polysemous meaning were processed with relative ease when sentence were heard in a German accent, differences could not be attributed to specific lexical properties of critical words.

Furthermore, due to oversight during stimuli creation, approximately 50% of the polysemous target condition featured the more common translation of the polysemous word. This limitation should also be taken into consideration in the interpretation of the prior results. For example, in the previous experiment by Elston-Güttler and Williams (2008), response time and accuracy was measured for the two groups (native English and native German) to English sentences ending in either anomalous or correct terminal words. As in our study, the German translation of the English terminal word was polysemous, with a second meaning that was compatible with the English sentence. Relative to native speakers of English, advanced German learners made more errors and responded slower to words in this condition, relative to a control condition. However, it should be noted that in each condition of the latter study, both versions of the polysemous word were used. Thus, the stimuli raised the same issue as in our study, i.e., that fact that 50% of incorrect sentence completions in the critical condition featured the more common meaning of the word. As such, the use of the more common meaning in approximately half the critical trials may have cancelled or substantially reduced any potential effect of activation of German semantic representations on processing. Lexical frequency has a significant effect in word recognition (Alario et al., 2010; Taft & Hambly, 1986; Norris & McQueen, 2008), and consequently, it should be anticipated that in the course of parallel translation activation, German participants would likely access the more common meaning of the L1 equivalent rather than its less common alternative.

Alternatively, it may be the case that upon identifying a correct target word, any competing lexical candidates are inhibited, and thus the alternative meaning of a polysemous word, albeit better suited to the sentence context, may not be accessed. This would in fact provide support for the BIA+ model of bilingual word recognition. The model features a language node enabling the incorporation of contextual information in order to influence the correct reading of an interlingual homograph (Thomas & van Heuven, 2005; Dijkstra & Van Heuven, 1998). The BIA+ proposes that, whilst bottom-up information activates word nodes for both representations of a homograph, competition between these activated word nodes results in inhibition, such that both representations of the homograph remain below the recognition threshold. Contextually driven top-down inhibition of the incorrect representation comes from the language node, enabling selection of the correct target word. Similarly, it may be the case that here, contextual information sufficiently inhibits the full activation of the alternate meaning of the L1 homophone, restricting the spread of activation to the translation equivalent alone.

In the present study it is not possible to differentiate between the two interpretations. It is difficult therefore to draw any firm conclusions regarding the findings of Study 2. As such, whilst the question of whether the semantic network(s) of a bilinguals' two languages are integrated or separate remains unclear, and future research based upon an improved design should be able to shed light on this matter.

5.1.2. **Stress**

In Chapter four we investigated how lexical stress might influence both second language processing and first language co-activation, with two studies focussed on the effects of stress on word processing in the bilingual population of North Wales. The chapter addresses three main questions: Does anomalous stress reduce intelligibility in 'stress deaf' individuals; do speakers of fixed stress languages process stress based on pre-lexical templates; and how do L1 stress patterns affect unconscious L1 activation?

In Study 3, we sought to explore whether the presence of a robust L1 fixed stress pattern might influence unconscious access to L1 word representations. We presented words with stress placed on either the 1st, 2nd or 3rd syllable, corresponding to either natural production, second-syllable, which would be anomalous in both the L1 and L2, or third syllable, so as to approximate Welsh fixed-penultimate stress. We measured ERP responses to these words by two participant groups, a native English group and a Welsh-English bilingual group. Speakers of languages for which fixed lexical stress is not assigned by morphological rules, but phonological rules such as syllabic structure (e.g., Welsh), acquire their language's stress system in infancy (Peperkamp & Dupoux, 2002; Dupoux et al., 1997). This process, in which infants establish whether their language features contrastive stress, is thought to occur prior to the establishment of a lexicon, that is, pre-lexically (Peperkamp & Dupoux, 2002). This process has been proposed to result in the generation of pre-lexical stress templates, that is, rather than stress being encoded within a word's lexical entry, abstract incoming stimuli are compared to a pre-established rule-based pattern (Honbolygo, 2004; Honbolygo, 2013). Based on English speakers' perception of Welsh penultimate stress as falling on the subsequent unstressed syllable (Williams, 1983), and current research suggesting that higher pitch and greater duration of the ultima are characteristic auditory correlates of Welsh lexical stress, we predicted that the increased duration, pitch and amplitude of third-syllable stress in English would best approximate Welsh stress in trisyllabic words. As such, should Welsh-English bilinguals process stress based on pre-lexical templates, we expected English 3rd syllable stress characteristics to heighten activation of Welsh, and consequently also implicit priming. We found no interaction between stress, Welsh phonological overlap and language group, but instead a main effect of overlap via Welsh translation across both the native English and Welsh-English bilingual language groups. This effect is most likely explained by the use of different prime words across critical conditions, limiting the comparability of L2 overlapping and non-overlapping stimuli. This effect of overlap across participant groups suggests that there was an inherent difference in the stimuli used in each condition in English. Despite a language group by overlap interaction in the behavioural measures, such that English participants responded to overlapping word pairs significantly slower than non-overlapping word pairs, the main effect of overlap in ERP results thus renders us unable to further explore, or draw any firm conclusions regarding an effect of L1 phonological overlap in Welsh.

Whilst there was no main effect of stress in the ERP data, we did find an effect of stress in the behavioural data analysis. Both participant groups responded faster to word pairs featuring a prime with anomalous stress (2nd or 3rd syllable) relative to naturally stressed primes. We tentatively proposed that the main effect of stress may have been attributable to increased duration of the 1st syllable for naturally stressed primes, resulting in a uniqueness point of recognition being reached earlier for anomalously stressed primes with shorter first syllables. As such, we proposed that the prime word may have been recognised quicker in 2nd and 3rd syllable stress conditions, with this anomalous lexical stress not significantly affecting word processing.

The significant limitations of Study 3 were addressed in the following study, Study 4, in which we tested whether L1 language stress templates influence implicit L1 priming in Welsh-English bilinguals. Whilst in Study 1 we demonstrated a facilitatory effect of

L1 accent on activation of L1 phonological representations, we sought to explore how L1 language stress patterns might differentially influence this process. Furthermore, we fully incorporated a semantic priming paradigm to determine whether anomalous stress would affect intelligibility. If it were the case that the shorter response times to anomalously stressed words do represent faster word recognition, we should see no effect of stress on semantic integration. However, this seemed somewhat unlikely, and thus the incorporation of the semantic priming paradigm sought to determine how lexical stress patterns influence semantic access. To address the limitations of Study 3, the same prime and target words were used across conditions in Experiment 1 and Experiment 2, respectively, but rotated such that prime-target pairing resulted in phonological overlap via Welsh translation, or no overlap (Experiment 1), and semantic relatedness or unrelatedness (Experiment 1).

In the two experiments in Study 4, we sought to investigate any interaction between L1 phonological overlap and lexical stress alongside two additional questions, namely, whether anomalous stress reduces intelligibility in 'stress deaf' individuals; and whether this effect, if any, of stress on intelligibility is influenced by pre-lexical lexical stress templates in word processing in the L2. Whilst some lexical access models (e.g., Shortlist-B; Norris & McQueen, 2008) are able to account for the role of stress in lexical access, the vast majority are limited in this respect. Nevertheless, substantial evidence points towards the role of stress in word recognition in native speakers of stress-variable languages. Studies investigating how stress influences lexical access and recognition suggest that it can have both an inhibitory and a faciliatory effect. Incorrect stress, for example, can create intelligibility or interpretation issues. Field (2005), for instance, showed that misplaced stress reduces speech intelligibility by comparing comprehension of disyllabic English words produced naturally or with an anomalous, shifted stress. Jesse et al. (2017) explored the use of suprasegmental information by English listeners using eye-tracking. Participants heard recorded instructions (e.g., *click on the…*) followed by words which were segmentally identical, but differed in stress (e.g., *admiral* vs *admiration*). Prior to becoming segmentally distinguishable beyond the second syllable, target words were fixated on to a greater degree than competitors, suggesting that stress information was indeed used by participants. Such findings reinforce prior evidence for a facilitatory role of stress in lexical recognition both from eye-tracking (Reinsch et al., 2010) and behavioural studies (Jesse & McQueen, 2014; van Donselaar et al., 2005). However, this research has principally tested speakers of variable stress languages. Individuals who speak fixed-stress languages (e.g., French, Hungarian, Welsh) are thought to be stress deaf. The reaction time results of Study 3 appear to suggest that word processing is unaffected by anomalous stress. Despite this, ERP studies on 'stress deaf' individuals have highlighted some brain sensitivity to stress (Domahs et al., 2012; Honbolygo, 2004; Honbolygo, 2013). Whether this brain sensitivity, despite an inability to consciously identify lexical stress patterns, results in word processing difficulties for anomalous stress patterns is unclear. Consequently, whether anomalous stress reduces intelligibility in this population, and whether this effect is influenced by a speaker's pre-lexical stress templates was explored via the inclusion of a semantic priming paradigm (Experiment 1). Secondly, as in Study 3, we further explored the notion of pre-lexical stress templates for fixed stress languages, in particular the possibility that these pervasive L1 pre-lexical stress templates affect L2 processing. We asked whether for native speakers of fixed stress languages, L1-approximate stress in an L2 context increased activation of native language representations (Experiment 2).

Results of Experiment 1 revealed only a marginal effect of stress on semantic priming, suggesting that semantic retrieval of the prime was not significantly affected by anomalous stress for Welsh-English bilinguals. This effect of stress was found to be driven by 2nd syllable stress primes. Whilst this marginal effect does not fully support either our prediction that (a) all L2 anomalous lexical stress patterns might interrupt semantic processing, or (b) that only lexical stress patterns that were incorrect in both languages (stress 2) would interrupt semantic processing, it does appear to offer tentative support for the latter. That is, for stress-deaf bilinguals, stress patterns compatible with both languages may be somewhat easier to process than those compatible with neither.

In Experiment 2, there was no interaction between stress and unconscious native language activation. We did however find a significant main effect of stress, and a significant accent by overlap interaction overall consistent with the findings of Study 1. Furthermore, whilst there was no effect of stress, accent or overlap on reaction times, participant's accuracy in response to anomalously stressed (2nd and 3rd syllable stress) primes was significantly higher than that to naturally stressed primes.

The accuracy results of Experiment 2, in combination with the RT results of the prior lexical stress study do seem to suggest that for Welsh-English bilinguals, anomalous stress does not significantly detract from lexical processing. However, as in prior research demonstrating brain sensitivity to lexical stress anomalies in stress-deaf individuals in the absence of behavioural effects, (Domahs, Genc, Knaus, Wiese, & Kabak, 2013; Domahs, Knaus, Orzechowska, & Wiese, 2012; Honbolygó & Csépe, 2013; Honbolygó, Csépe, & Ragó, 2004), we found a significant difference in ERPs in response to target words preceded by 2nd syllable stress primes, relative to 1st and 3rd syllable. Whilst stress deaf individuals may thus be able to perceive the basic phonological correlates of stress (e.g., contrasts in pitch, duration and amplitude) as demonstrated by these ERP responses, both RT results from Study 3, and the accuracy results from Study 4 (Experiment 2) suggest that awareness of these contrasts is not determinant in the lexical recognition process. It is important to highlight, however, that this interpretation is based on ERP and behavioural effects of Experiment 2 that are only found marginally in Experiment 1. However, it is important to note that the time window and topography of Experiment 1 differ from that of Experiment 2, focussing on ERP indexes of semantic processing. Thus, whilst anomalous stress may influence word processing, it may be that this does not affect processing occurring at the semantic level.

We propose two explanations for the effect of stress in Experiment 2. Firstly, it may be the case that sequential bilinguals learning a second language with variable stress may lack the strategies that enable them to lexically encode suprasegmental features, resulting in stress deafness. During the process of native language acquisition in infancy, the loss of sensitivity to stress contrasts is likely to influence the perception and processing of lexical stress in a second language. It is thought that for speakers of these languages, stress is not encoded into the lexical entry of a word, and thus, when acquiring a second language, these speakers may be unable to store lexical stress patterns of newly learnt words (Dupoux et al., 2008; Peperkamp, 2004). As such, highly fluent bilinguals may understand stress in the second language on the basis of established native-language representations such as fixed stress templates. If this is the case, the process of second language word recognition would rely, to a degree, on the linguistic sensitivities developed in infancy. That is, a model of word recognition encompassing the influence of stress cues on second language processing may be unable to represent the variability with which this cue is available for use between bilingual groups.

Alternatively, we suggest that, in the case that of primes with 3rd syllable stress, the word may have been processed up to the end of the second syllable with participants assuming secondary stress on the 1st syllable as primary. Consequently, they may have reached the uniqueness point of recognition prior to perceiving the anomalous 3rd syllable, thus selecting the correct word prior to encountering incorrect stress on the 3rd syllable. However, given the design of the present study it is difficult to distinguish between the two interpretations of the results.

5.1.3. **Limitations and future direction**

A particular limitation in this work concerns Study 2. In order to provide insight into the question of whether the semantic network(s) of a bilinguals' two languages are integrated or separate, it would be ideal to run this study with an amended design. Such a design should incorporate behavioural measures in order to ensure that any findings are comparable with the limited prior research, namely that of Elston-Güttler and Williams (2008). In their experiment, very similar in design to Study 2, participants indicated whether target words formed an acceptable sentence completion. Response times and accuracy were compared in a German bilingual group and an English control group in response to anomalous English words which translated to the incorrect of two meanings of a polysemous German word. Relative to the native English participant group, German-English bilinguals made significantly more errors and had longer response times to polysemous words in comparison to the control condition. Despite this, the authors note that due to the nature of the anomaly detection task, it is not possible to determine whether the reaction time and accuracy modulations were contaminated by explicit knowledge of the polysemous nature of the L2 translations. As such, it remains difficult to say whether the reported effect is due to contamination of responses due to the decision task employed, or whether without explicit knowledge of the manipulation and the polysemous nature of the target words, interference from L1 representations would still have occurred. Furthermore, as noted as a limitation for our study, the use of the more common translation of the L1 polysemous word as the anomalous L2 target may have reduced access to the less common translation equivalent. Future work may seek to address these issues by ensuring that the alternative meaning of polysemous words (that is, the meaning that should be implicitly access to result in priming) is more frequent than the meaning used in order to create the L1 anomaly. Furthermore, changing the task to one in which responses are made to the target word itself should provide behavioural insights regarding participants explicit processing of sentences.

Beyond this, it is a limitation of Study 4 that we are unable to tease apart the interpretations of the main effect of stress, pertaining to either the presence of L1 stress processing mechanisms, or recognition of the prime word prior to 3rd syllable stress. To address this, future research may wish to explore the processing of L1-approximate lexical stress patterns when present in the L2 in a bilingual population with a differing L1 stress system. It is interesting to consider the differences in results for Studies 3 and 4, particularly considering the similarities in the paradigms used. We attribute these differences to a number of differences between studies 3 and 4. Due to the accent manipulation in Study 4, each experiment consisted of 468 trials, relative to the 246 trials constituting the critical manipulation in Study 3. This is particularly relevant as the data for Study 3 proved, upon visual inspection, to contain considerable more electrophysiological noise. As such, in combination with the increased trial numbers of Study 4, this is likely to have resulted in a lower signal to noise ratio in the averaged data and a less stable EEG response to the event of interest.

Limitations across studies predominantly concern stimulus selection constraints. Due to the designs of the experiments, stimuli were not consistently high frequency across the studies. Whilst this may have influenced results, it should be noted that this is likely only to have increased the possibility of a type 2 error. For each study in the thesis, L2 priming paradigms and comprehension tasks conceal implicit priming via access to the native language. If second language comprehension is impeded, this should only serve to reduce activation of the native language. A further limitation for all studies is the use of a very small number of cognates. This may have heightened the likelihood of cross language activation, given the presence of native language features in L2 comprehension. However, it should be noted that across studies 1, 3 and 4, this represented a very small number of overall stimuli (<3%), so it is unlikely that these trials would have significantly affected the overall results. For Study 2 (German polysemy), a number of stimuli included overlap in initial phonemes with their L1 translations, however excluding one trial, we consistently ensured that these stimuli were only seen in the correct and anomalous conditions, such that any activation of their translations should have had no effect on the critical manipulation in the polysemous condition.

5.2. **Implications for models of word recognition**

In Chapter 2 two main models of bilingual auditory word recognition, BIMOLA (Lewy & Grosjean, 1997) and BLINCS (Shook & Marian, 2013), are discussed. In light of the research encompassed in this thesis, amongst prior work highlighting the role of a range of suprasegmental cues in word processing, it is important to consider the degree to which the models are congruent with these findings.

Both BIMOLA and BLINCS initially follow a relatively similar structure, in which acoustic input activates phonological information. However, for BIMOLA this phonological level is separated by language. Following activation at the phonological level based upon auditory input, BIMOLA posits that activation feeds forwards at the word level. At this stage, ‘global language information’ feeds back into the word level to facilitate correct selection of the target word. BLINCS on the other hand suggests that the phonological level is shared between languages. Following this, activation spreads to the phono-lexical and ortho-lexical levels, which are separated by language but integrated. Finally, activation flows between the phono-lexical level and the semantic level (which is shared between languages) by means of bidirectional excitatory and inhibitory connections.

A potentially significant limitation of both models is that processing of auditory language input occurs almost exclusively at the segmental level. Whilst our understanding of visual language processing can be quite intuitively broken down into segments, with each letter, letter combination, and their statistical regularity altering activation, auditory word activation is a complex process in which the acoustic signal often entails a host of segmental (e.g., phonemes) and suprasegmental (e.g., accent, lexical stress) cues. Where, then, does suprasegmental information feed into BIMOLA and BLINCS, as two models based on a system of segmental cues?

In addition to each level (feature, phoneme, word), BIMOLA’s ‘global language information’ layer is thought to account for contextual effects. This includes the notion of ‘language mode’, that is, the state of activation a bilingual’s languages and language-processing mechanisms at any given point in time (Grosjean, 2008).

Language mode dictates a bilingual's base and guest language, with the former being the language in which the individual is predominantly functioning, and the latter being the language with a lower resting value of activation. For the guest language, phonemes and words are thought to take longer to activate, as the bilingual switches from functioning predominantly within the base language system to accessing items from the other. This said, language mode is thought to be a continuum, with various factors influencing where on this continuum the degree of guest language activation falls. These factors suggested to influence activation vary from language proficiency, attitudes, socioeconomic status to topic, language mixing and language of use (Grosjean, 2008). It is therefore likely, though never specified, that L1 accent and lexical stress patterns may fall under this umbrella of factors that influence a bilingual's language mode, resulting in heightened activation of the guest language (L1) despite the L2 acting as the base language. However, as the model faces a significant lack of specificity regarding the influence of such suprasegmental information, the inclusion of accent and lexical stress within the 'global language information' layer must remain at this stage speculative.

Beyond this, the model potentially struggles to explain the phenomenon of L1 translation activation. Earlier work using cross-language homophones to explore bilingual cross-language activation (Spivey & Marian, 1999; Marian & Spivey, 2003) generally reports heightened activation of L1 word sharing phonology with L2 words. The structure of BIMOLA is such that the feature level feeds into a phoneme layer, separated by language. It is consequently not surprising, according to the model, that this presence of shared features would result in activation at the phoneme layer for both languages, feeding then forwards to activation of words from both the L1 and L2. However, a wealth of prior research (Thierry & Wu, 2007; Wu & Thierry, 2010; Vaughan-Evans et al., 2014), in addition to that encompassed in this thesis has demonstrated activation not only of phonologically overlapping words, but of phonological representations of translation equivalents. Whilst for the Welsh-English bilinguals in studies 1 and 4 the presence of accent may have altered language mode, the same cannot be said for the Chinese-English bilinguals, and Welsh-English bilinguals tested in the visual word priming paradigms of Thierry and Wu (2007) Wu and Thierry (2010) and Vaughan-Evans et al. (2014). Thus, activation of translation equivalents of L2 words appears difficult to explain in a system with two separate systems for each language at both the phoneme and word levels.

BLINCS, in contrast to BIMOLA, is a connectionist model featuring dynamic, self-organizing maps (Shook & Marian, 2013). The phonological level in BLINCS quantifies phonemes by their attributes (e.g., voicing, place of articulation) with segmental properties affecting activation at this level. The model addresses to some degree BIMOLA's inability to explain cross-language translation activation with a separate but integrated phono-lexical and ortho-lexical levels, however it is important to note that whilst it is thought that cognates and false-cognates may lie between language boundaries, the model fails to describe the processes underpinning translation activation. Despite this, in model simulations, translation equivalents do occur in co-activated word lists (Shook & Marian, 2013). It is notable however that the model lacks an equivalent to BIMOLA's global language information level. Instead, language identification and control is thought to occur by means of the self-organizing maps, in which words from the same language cluster together by means of a learning mechanism. Considering the effect that variability in the bilingual experience appears to have on language use and processing (Bak, 2016), the notion of self-organising maps in which experience influences word activation does appear logical. However, the inability for the model to account to any degree for the effects suprasegmental information, including accent and lexical stress, on language processing is a clear shortcoming.

As noted by Weber & Sharenborg (2012), models of auditory word recognition are often designed and developed with emphasis on a certain aspect of lexical processing. Considering the complexity of input that any word recognition system must be able to respond to and process, this is perhaps not surprising. However, until models of spoken word recognition are developed without such narrow and restrictive objectives, a complete understanding of how we process spoken language will remain at arm’s length.

5.2. **ERP correlates of phonological processing**

Beyond the implications of our results regarding the effects of accent and stress on bilingual language processing, it is important to consider our findings both within the established literature regarding implicit L1 phonological priming in bilinguals, and that of ERP correlates of phonological processing. Regarding prior literature on unconscious L1 activation, Thierry and Wu (2007) and Wu and Thierry (2010) both demonstrate the effects of implicit priming in Chinese-English bilinguals, with the latter narrowing the effect down to a phonological, as opposed to orthographic priming effect. Both papers reported such effects within an N400 time window across central electrode sites. It thus seems that our results reveal an effect considerably earlier than previously reported. However, it is important to note that the effects in Thierry and Wu (2007; Wu & Thierry, 2010), whilst reported as occurring in the N400 time window, occurred early within this range. In Thierry and Wu (2007) for example, the character repetition effect is found to be significant between 300 – 450 ms. Similarly, in Wu and Thierry (2010), the effect occurred between 310 – 420 ms. As such, it is important to consider that prior 'N400' modulations have concerned an epoch not that dissimilar to that reported in the current study. This is also consistent with findings in speech production as reported by Spalek et al. (2014), who showed that German-English bilinguals unconsciously accessed German word forms as early as 300 ms post picture onset when asked to produce English adjective-noun phrases.

Our results highlight the necessity to perhaps reconsider the sensitivities of ERPs to phonological processing and priming within a time window preceding the classic N400. The PMN, initially labelled the phonological mismatch negativity (Connolly, Stewart, & Phillips, 1990) has consistently been reported as representing a subprocess prior to N400 in response to phonological processing. However, it is important to note that a number of key studies fundamental to the establishment of the PMN as an individual component have significant shortcomings. In an early 1994 study, Connolly and Philips (1994) sought to disentangle the PMN and N400 as distinct components. However, results revealed covariation of the PMN and the N400, suggesting that the components are not as functionally distinct as it was argued by the authors. In a second study in 2001 (Connoly et al., 2001) presented participants with words and non-words that matched or mismatched with participants' generated expectations. Results demonstrated an effect of phonological mismatch, but a lack of sensitivity to lexicality. However, the authors have since acknowledged more recent conflicting research showing substantial differences in PMN latencies in MEG data between words and nonwords (Kujala et al., 2004), preventing firm conclusions based upon this paradigm (Newman & Connolly, 2009). Following this, Newman et al. (2003) investigated phonological processing independently from lexical/semantic influences. Participants were instructed to delete the initial consonant off a four-syllable prime word (e.g., clap, /k/) which was followed by a target that either fitted with the prime following consonant deletion (e.g., lap) or represented one of three possible incorrect targets. Incorrect targets formed three categories, wrong consonant deletion (e.g., cap); an irrelevant word (e.g., nose); or consonant cluster deletion in which both initial consonants were deleted (e.g., ap). The PMN was reported to be significantly reduced for correct targets, relative to a number of phonological mismatch conditions. However, the authors acknowledge that P300 contamination was likely to have influenced PMN amplitude in the correct condition. Furthermore, the authors interpreted this response irrespective of lexicality as indicative of PMN and N400 independence, despite P300 contamination in the condition driving the contrast; the absence of any semantic processing requirements; and no measurement of the effect of each condition on N400 modulation.

It is interesting, however, to note that the topography and time window of the PMN overlaps substantially with that of the auditory mismatch negativity. The former is a fronto-central component occurring at approximately 300 ms (Connolly, Stewart, & Phillips, 1990), whilst the latter similarly occurs fronto-centrally, between approximately 150 – 250 ms (Garrido et al., 2009). However, it would appear that thus far no study has compared the PMN source loci with those of the MMN (Näätänen et al., 2007). Whilst the PMN necessitates attention to the auditory input, the auditory MMN does not. It has been assumed thus far that this difference in the contexts that elicit these components means that the two ERP responses are generated by distinct cortical mechanisms (Näätänen et al., 2007). However, perhaps in its very nature, the generation of phonological expectations for sentences requires attention to the sentence content, whilst lower-level expectations, such as that responded to by the auditory MMN, do not.

Whilst it is beyond the scope of this thesis to provide a full review of the phonological mapping negativity and its distinguishability from the auditory MMN, it is important to consider recent research demonstrating contrasting ERP indexes of phonological processing, or ‘mapping’. Various studies show that individuals are sensitive to phonological priming within a window beyond that originally reported for phonological priming with the PMN (Holcomb & Grainger, 2006; Grainger & Holcomb, 2009; Hagoort & Brown, 2000). Furthermore, these ERP correlates of phonological processing have been shown to occur across centro-parietal topographies not entirely dissimilar from that of the N400 (Dumay et al., 2001; Praamstra et al., 1994; Rugg, 1984a, Rugg, 1984b; Newman & Connolly, 2009; Desroches et al., 2009; Malins et al., 2013; Sučević et al., 2015). Within this thesis we report two instances of implicit phonological priming that occur between 200 – 400 ms across centro-parietal sites, further contributing to the body of evidence of phonological mapping processes distinct from that of the PMN. Whilst the sensitivities, topography and timing of the N400 are well documented, further work on phonological mapping, whether it truly represents a process entirely distinct from the N400, and what can be considered typical in light of a growing body of literature requires further investigation.

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Appendices

Appendix A: Studies 1 & 4 language inventory questionnaire.

Language History Questionnaire

This questionnaire is designed to give us a better understanding of your language experience. We ask that you are as accurate as possible when answering the following questions.

1. Country of Birth______________ What is your first language______________

2. When did you start learning Welsh? Age:__________

3. How long have been learning Welsh?________________

4. How long have you spent living outside of Wales?

    1. Age:_______ No. of years: ______ No. of months______
    2. Age:_______ No. of years: ______ No. of months______
    3. Age:_______ No. of years: ______ No. of months______

5. What percentage of your time do you spend speaking each language? (Must add up to 100%)

Welsh: English: Other:

6. Up to what academic level have you studied Welsh? (please circle)

High School GCSE Undergraduate Postgraduate
Other: ________

7. Please rate your **Welsh** reading proficiency on a ten-point scale.

1 2 3 4 5 6 7 8 9 10
not proficient very proficient

8. Please rate your **Welsh** writing proficiency on a ten-point scale.

1 2 3 4 5 6 7 8 9 10
not proficient very
proficient

9. Please rate your **Welsh** conversational fluency on a ten-point scale.

1 2 3 4 5 6 7 8 9 10
not fluent very
fluent

10. Please rate your **Welsh** conversational understanding on a ten-point scale.

1 2 3 4 5 6 7 8 9 10
unable to perfectly able to
understand conversation understand
conversation

11. Apart from Welsh, have you learnt any other foreign languages? If yes, please specify

Language: ______________________________
What age did you start to learn this language? ____________________
How many years have you learnt this language? ___________________
How often do you use this language right now? ____________________
Please rate your overall proficiency in this language on a ten-point scale.

1 2 3 4 5 6 7 8 9 10
not proficient very proficient

Language 2: ______________________________
What age did you start to learn this language? ____________________
How many years have you learnt this language? ___________________
How often do you use this language right now? ____________________
Please rate your overall proficiency in this language on a ten-point scale.

1 2 3 4 5 6 7 8 9 10
not proficient very proficient

Language 3: ______________________________
What age did you start to learn this language? ____________________

How many years have you learnt this language? ___________________
How often do you use this language right now? ____________________
Please rate your <u>overall proficiency</u> in this language on a ten-point scale.

1 2 3 4 5 6 7 8 9 10
not proficient very proficient

<u>About the study</u>

1. Did you notice anything about the study, or the words that were presented to you? If yes, please specify:

2. We anticipate that some of the words may have sounded odd to participants. Please circle the sentence that best describes how well you understood what you heard/saw.

- I didn’t understand any of the words.
- I didn’t understand many of the words.
- I understood some of the words.
- I understood many of the words.
- I understood almost all of the words.
- I understood all of the words.

Appendix B: Study 1 stimuli.

Prime	Welsh trans.	Overlap		No overlap		Related		Unrelated	
		Target	Welsh trans.	Target	Welsh trans.	Target	Welsh trans.	Target	Welsh trans.
orchestra	cerddorfa	back	cefn	flour	blawd	stage	llwyfan	essay	traethawd
		mouth	ceg	taste	blas	listen	gwrando	language	iaith
		horse	ceffyl	shout	bloedd	instrument	offeryn	word	gair
payable	taladwy	father	tad	king	brenin	free	rhydd	gender	rhyw
		calm	tawel	hill	bryn	cheap	rhad	strong	cryf
		hit	taro	fragile	bregus	reward	gwobr	hero	arwr
minister	gweinidog	wind	gwynt	dear	annwyl	leader	arweinydd	cream	hufen
		white	gwyn	send	anfon	local	lleol	bush	llwyn
		bleed	gwaedu	need	angen	office	swyddfa	seed	hedyn
innocent	diniwed	city	dinas	hear	clywed	witness	tystiolwr	stem	cas
		boring	diflas	sword	cleddyf	guilty	euog	spring	gwanwyn
		valid	dilys	bell	cloch	lie	celwydd	bees	gwenyn
champion	pencampwr	tents	pebyll	order	trefn	win	ennill	witness	tystiolwr
		distance	pellter	nose	trwyn	race	hil	guilty	euog
		quartet	pedwarawd	beach	traeth	best	gorau	lie	celwydd
physical	corfforol	red	coch	book	llyfr	material	defnydd	thief	lleidr
		raise	codi	lake	llyn	human	dynol	defence	amddiffyniad
		lost	colli	dusty	llychlyd	react	ymateb	judge	barnwr
prisoner	carcharor	heart	calon	wolf	blaidd	thief	lleidr	face	wyneb
		hundred	cant	tired	blino	defence	amddiffyniad	look	edrych
		stone	carreg	year	blwyddyn	judge	barnwr	see	gweld
universe	bydysawd	short	byr	red	coch	moon	lleuad	free	rhydd
		army	byddin	raise	codi	sun	haul	cheap	rhad
		finger	bys	lost	colli	earth	daear	reward	gwobr
government	llywodraeth	book	llyfr	four	pedwar	state	cyflwr	follow	dilyn
		lake	llyn	verse	pennill	power	awdurdod	memory	cof

		dusty	llychlyd	chapter	pennod	vote	pleidlais	early	cynnar
sentences	brawddegau	king	brenin	argue	dadlau	essay	traethawd	money	arian
		hill	bryn	catch	dal	language	iaith	work	gwaith
		fragile	bregus	tears	dagrau	word	gair	give	rhoi
editor	golygydd	north	gogledd	thanks	diolch	journal	cylchgrawn	fight	brwydr
		care	gofal	revenge	dial	publish	cyhoeddi	friend	cyfaill
		station	gorsaf	clothes	dillad	script	llawysgrif	bad	drwg
interesting	diddorol	thanks	diolch	back	cefn	focus	canolbwyntio	sick	gwael
		revenge	dial	mouth	ceg	exciting	cyffrous	surgeon	llawfeddyg
		clothes	dillad	horse	ceffyl	lesson	gwers	cure	gwella
portable	cludadwy	hear	clywed	teeth	dannedd	fixed	sefydlog	win	ennill
		sword	cleddyf	solve	datrys	move	symud	race	hil
		bell	cloch	sheep	dafad	stay	aros	best	gorau
dangerous	peryglus	four	pedwar	heart	calon	fear	ofn	soft	meddal
		verse	pennill	hundred	cant	harm	niwed	stiff	anhyblyg
		chapter	pennod	stone	carreg	thrilling	anhygoel	resistant	gwrthsefyll
moderate	cymedrol	start	cychwyn	proud	balch	fair	teg	teach	addysgu
		series	cyfres	dirty	bawlyd	level	gwastad	talk	siarad
		whole	cyfan	poet	bardd	effort	ymdrech	school	ysgol
lecturer	darlithwr	argue	dadlau	short	byr	teach	addysgu	fixed	sefydlog
		catch	dal	army	byddin	talk	siarad	move	symud
		tears	dagrau	finger	bys	school	ysgol	stay	aros
enemies	gelynion	born	geni	tents	pebyll	fight	brwydr	recall	atgofio
		jaw	gen	things	pethau	friend	cyfaill	quiet	distaw
		fingernail	gewyn	quartet	pedwarawd	bad	drwg	pages	tudalennau
broadcasting	darlledu	teeth	dannedd	father	tad	advert	hysbyseb	grow	prifio
		solve	datrys	calm	tawel	waves	tonnau	age	oed
		sheep	dafad	hit	taro	speech	araith	child	plentyn
flowering	blodeuo	wolf	blaidd	researcher	ymchwilydd	stem	cas	expert	arbenigwr
		tired	blino	bathe	ymdrochi	spring	gwanwyn	trained	hyfforddedig
		year	blwyddyn	treat	ymdrin	bees	gwenyn	practise	ymarfer
hospital	ysbyty	writing	ysgrifennu	rock	craig	sick	gwael	journal	cylchgrawn

		shoulder	ysgwydd	welcome	croeso	surgeon	llawfeddyg	publish	cyhoeddi
		divorce	ysgariad	shirt	crys	cure	gwella	script	llawysgrif
recognise	adnabod	wing	adain	truth	gwir	face	wyneb	princess	tywysoges
		birds	adar	country	gwlad	look	edrych	dress	gwisg
		echo	adlais	bed	gwely	see	gweld	elegant	cain
infancy	babandod	proud	balch	take	cymryd	grow	prifio	state	cyflwr
		dirty	bawlyd	offer	cynnig	age	oed	power	awdurdod
		poet	bardd	plan	cynllun	child	plentyn	vote	pleidlais
visitor	ymwelwr	researcher	ymchwilydd	skull	penglog	house	ty	focus	canolbwyntio
		bathe	ymdrochi	ball	pêl	foreign	estron	exciting	cyffrous
		treat	ymdrin	knee	penglin	stranger	dieithryn	lesson	gwers
honesty	gonestrwydd	light	golau	singer	canwr	pledge	addewid	family	teulu
		wash	golchi	necklace	cadwyn	believe	coelio	uncle	ewythr
		finish	gorffen	branch	cangen	open	agored	aunt	modryb
villages	pentrefi	further	pellach	light	golau	county	sîr	advert	hysbyseb
		cough	peswch	wash	golchi	district	ardal	waves	tonnau
		things	pethau	finish	gorffen	rural	gwledig	speech	araith
library	llyfrgell	swallow	llyncu	north	gogledd	recall	atgofio	illegal	anghyfreithlon
		eye	llygad	care	gofal	quiet	distaw	police	heddlu
		toad	llyffant	station	gorsaf	pages	tudalennau	jury	rheithgor
interview	cyfweliad	warm	cynnes	wind	gwynt	ask	gofyn	moon	lleuad
		knife	cyllell	white	gwyn	fame	enwogrwydd	sun	haul
		sleep	cwsg	bleed	gwaedu	speak	dweud	earth	daear
summary	crynodeb	rock	craig	born	geni	outline	amlin	break	torri
		welcome	croeso	jaw	gen	report	adrodd	bandage	rhwymo
		shirt	crys	fingernail	gewyn	review	adolygiad	pain	brifo
raspberry	mafonen	big	mawr	city	dinas	cream	hufen	pledge	addewid
		son	mab	boring	diflas	bush	llwyn	believe	coelio
		detailed	manwl	valid	dilys	seed	hedyn	open	agored
balancing	cydbwyso	take	cymryd	writing	ysgrifennu	topple	disgyn	fear	ofn
		offer	cynnig	shoulder	ysgwydd	edge	ymyl	harm	niwed
		plan	cynllun	divorce	ysgariad	weight	pwysau	thrilling	anhygoel

injuring	anafu	dear	annwyl	law	cyfraith	break	torri	house	ty
		send	anfon	first	cyntaf	bandage	rhwymo	foreign	estron
		need	angen	volume	cyfrol	pain	brifo	stranger	dieithryn
masculine	gwrywaidd	truth	gwir	further	pellach	gender	rhyw	outline	amlin
		country	gwlad	cough	peswch	strong	cryf	report	adrodd
		bed	gwely	distance	pellter	hero	arwr	review	adolygiad
criminal	troseddwr	order	trefn	grave	bedd	illegal	anghyfreithlon	stage	llwyfan
		nose	trwyn	loan	benthyg	police	heddlu	listen	gwrando
		beach	traeth	verb	berf	jury	rheithgor	instrument	offeryn
capable	galluog	leave	gadael	big	mawr	expert	arbenigwr	topple	disgyn
		promise	gaddo	son	mab	trained	hyfforddedig	edge	ymyl
		hold	gafael	detailed	manwl	practise	ymarfer	weight	pwysau
feminine	benywaidd	grave	bedd	start	cychwyn	princess	tywysoges	county	sîr
		loan	benthyg	series	cyfres	dress	gwisg	district	ardal
		verb	berf	whole	cyfan	elegant	cain	rural	gwledig
relative	perthynas	skull	penglog	leave	gadael	family	teulu	leader	arweinydd
		ball	pêl	promise	gaddo	uncle	ewythr	local	lleol
		knee	penglin	hold	gafael	aunt	modryb	office	swyddfa
previous	blaenorol	flour	blawd	warm	cynnes	follow	dilyn	fair	teg
		taste	blas	knife	cyllell	memory	cof	level	gwastad
		shout	bloedd	sleep	cwsg	early	cynnar	effort	ymdrech
salaries	cyflogau	law	cyfraith	wing	adain	money	arian	material	defnydd
		first	cyntaf	birds	adar	work	gwaith	human	dynol
		volume	cyfrol	echo	adlais	give	rhoi	react	ymateb
hardening	caledu	singer	canwr	swallow	llyncu	soft	meddal	ask	gofyn
		necklace	cadwyn	eye	llygad	stiff	anhyblyg	fame	enwogrwydd
		branch	cangen	toad	llyffant	resistant	gwrthsefyll	speak	dweud

Appendix C: Study 1 as under review in *Language, Cognition and Neuroscience.*

Native accent in the second language facilitates unconscious access to first language phonological representations

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Behavioural and neurolinguistic studies have repeatedly shown that language access is non-selective in bilinguals. A notable exception comes from studies on orthographic specificity, showing that words containing language-specific letter combinations constrain lexical access. Here, we test the intuitive idea that accent can modulate cross-language activation in bilinguals. Highly fluent Welsh-English bilinguals made semantic relatedness judgements on English word pairs, unaware that some pairs concealed a phonological repetition via translation into Welsh. We found a strong modulating effect of accent, such that Welsh accented words prompted unconscious access to Welsh translation equivalents, whereas English accented primes failed to yield such an effect. Accent-dependent phonological priming was indexed by event-related brain potential modulations between 200 and 400 ms post stimulus onset, consistent with previous observations of implicit phonological priming. We conclude that native accent facilitates access to first language representations in bilinguals operating in their second language.

Keywords: Event-related potentials; word processing; implicit-priming; cross-language activation; speech processing; lexical access

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1. Introduction

A listener processing a stream of speech must use multiple cues to access lexical representations at a pace compatible with that of the signal. Prominent theories of language perception suggest that the identification of each word encountered begins with the activation of numerous phonologically overlapping candidates, with retrieval of the correct item from the mental lexicon involving rejection of competing items (McClelland & Elman, 1986; Marslen-Wilson, 1990; Norris & McQueen, 2008). This process of lexical activation is further complicated in bilinguals, who face competition from representations in either of their languages. Consequently, over the last two decades a substantial amount research has focussed on whether bilingual word recognition involves retrieval from one integrated lexicon, in which both L1 and L2 representations are stored, or discrete systems for each language.

More recently, studies have shown that lexical access is largely language non-selective in fluent bilinguals, in both visual word recognition (van Heuven & Dijkstra, 1998; Duyck, 2005) and auditory word perception (Spivey & Marian, 1999; Ju & Luce, 2004; Thierry & Wu, 2007; Wu & Thierry 2010; Lagrou, Hartsuiker & Duyck, 2013), consistent with the notion of an integrated lexicon. Beyond the wealth of evidence obtained through behavioural investigation (e.g., Spivey & Marian, 1999; Duyck *et al.*, 2007; Van Heuven *et al.*, 1998), studies using event-related potentials have established that cross-language interference effects occur spontaneously and unconsciously. For instance, Thierry & Wu (2007; Wu & Thierry, 2010) found evidence for unconscious L1 activation in Chinese-English bilingual participants, as demonstrated by implicit L1 priming in a solely L2 context. In the 2007 study by Thierry & Wu, participants were presented with English prime words, which, via translation into Chinese, concealed an orthographic and phonological overlap with critical target words. The authors observed that character repetition resulted in an N400 reduction similarly to that elicited by semantically related targets, suggesting that participants had accessed L1 translation equivalents, in the absence of any behaviourally measurable effect. In a second experiment intended to provide further insight into the nature of the mental representation accessed, Wu & Thierry (2010) presented participants with a similar L2 semantic relatedness paradigm and separately tested orthographic and phonological priming through the L1. Results showed that whilst prime-target phonological overlap in Chinese produced significant N400 attenuation, orthographic overlap did not yield a significant priming effect. The authors concluded that Chinese-English bilinguals accessed the phonological –not the orthographic– representations of L1 words when functioning in their L2.

The factors that enable bilinguals to function within a single-language context despite unconscious L1 co-activation have been explored to a lesser degree. In a 2002 study, Rodriguez-Fornells *et al.* investigated the mechanisms by which bilinguals might prevent interference from a non-target language. Using ERPs and fMRI, they reported that lexical frequency of words in Catalan failed to modulated N400 amplitude when bilingual participants responded to Spanish target words whilst ignoring Catalan words. The authors interpreted the results as showing that, under certain conditions, semantic representations of words in the ignored language are inhibited. They proposed that such a language-specific pattern of response could originate at a sub-lexical level, involving an indirect phonological access route to the target language lexicon that avoids interference. A number of

limitations of the methodology of this study have been highlighted (Grosjean & Li, 2008), in particular that graphemic cues afforded by the stimuli may have curtailed access to the non-target language. Subsequently, a number of other studies provided independent support for language-selective access constrained by sub-lexical orthographic cues. Casaponsa & Duñabeitia (2016), for instance, explored the influence of orthotactics in language priming tasks. Participants were presented with naturalistically learnt L2 words either containing language-specific bigram combinations (orthographically marked), or orthographic patterns acceptable in both languages (orthographically unmarked) in a modified Reicher–Wheeler paradigm and a masked translation priming experiment. In the Reicher-Wheeler paradigm, participants were presented with a forward mask (e.g., ####) followed by the referent word or nonword, then a backward mask alongside two letters, and asked to indicate which of the two letters appeared in the word. In the second experiment, the same participants made lexical decisions on Spanish targets preceded by their translations in Basque, which were either orthographically marked or unmarked. Results from the Reicher-Wheeler experiment showed that marked stimuli (both words and nonwords) yielded slower reaction times than unmarked stimuli, suggesting that letters from marked stimuli received less reinforcement from spread of activation at the lexical level than unmarked stimuli (common to Basque and Spanish). In the second experiment, participants showed significant translation masked priming effects only for words preceded by orthographically unmarked primes, demonstrating that unconscious sensitivity to statistical orthographic regularities can yield language-selective access.

Research on the role of sub-lexical features in mediating parallel language access in auditory word processing is relatively sparse. Current findings suggest an influence of sub-lexical phonetic cues on language non-selective access (Lagrou, Hartsuiker & Duyck, 2013) and invite further questions regarding the role of acoustic-phonetic information in lexical activation. In particular, since the 1960s studies have explored whether accent assists or hinders comprehension and intelligibility in bilinguals listening to their second language. Whilst early studies found a beneficial role of native accent (Brown, 1968; Wilcox, 1978; Flowerdew, 1994; Bent & Bradlow, 2003) and generally concluded that speech in a speaker's own accent may be easier to understand, others have suggested that mere familiarity with an accent is enough to aid comprehension (Pihko, 1997; Gass & Varonis, 1984).

Exploring whether accent could influence lexical access, Lagrou, Hartsuiker & Duyck (2011) tested Dutch–English bilinguals in auditory lexical decision tasks conducted in both Dutch and English. In an initial experiment, participants listened to English words produced by either a native English speaker (L2 Dutch) or a native Dutch speaker (L2 English). Target stimuli included items which were either inter-lingual Dutch-English homophones (e.g., lief [sweet] – leaf /li:f/), control stimuli, fillers, or non-words. Recognition of homophones was consistently slower than that of control words, but reaction times (RTs) were overall slower across target types for words produced by a native Dutch speaker. When testing native English speakers using the same paradigm, the effect of accent was similar, with non-native Dutch-accented target words eliciting longer reaction times. Noting that in the case of English-accented target words the speaker tended to stretch pronunciation, resulting in significantly longer target word durations, the authors acknowledge that the increase in reaction times could either be due to increased opportunity for lexical activation prior to response or to the mismatch between non-native production and stored lexical representations. In a third experiment, intended to disentangle the two prior hypotheses, Lagrou *et al.* (2011) re-ran the same paradigm in the participants' native language. When tested in the L1 Dutch, RTs were significantly faster to non-accented than English accented speech, suggesting that lexical access was facilitated by the match between non-accented productions and stored lexical representations. Interestingly, a lack of interaction between accent and the homophone effect suggested that sub-phonemic cues present in accent do not reduce parallel activation of a listener's languages.

Following this, Lagrou, Hartsuiker & Duyck (2013) tested Dutch-English listeners to investigate the role of three potential factors in language non-selective access, namely sentence context, semantic constraints, and native language of the speaker. Dutch-English bilinguals listened to English sentences produced by either a native Dutch speaker or a native English speaker and made a lexical decision on the last word of the sentence. The inter-lingual homophone effect found, i.e., longer reaction times for inter-lingual homophones compared to control stimuli, supported the notion that, in bilinguals, non-selective language access occurs in auditory word perception as well as in visual word recognition. Furthermore, accent modulated the homophone interference effect, with participants responding faster to English-accented than Dutch-accented sentences. The authors concluded that further research is necessary to determine whether these effects reflect an increase in the salience of the participants' L1 leading to greater interference, or a decrease in overall intelligibility when L2 speech is L1 accented.

Studies investigating cross-language activation in bilinguals have typically revealed sensitivity to unconscious priming in a time window encompassing the N250 and P325 (Holcomb & Grainger, 2006), Phonological Mapping Negativity (PMN; Connolly & Philips, 1994; Desroches *et al.,* 2009; Vaughan-Evans *et al*., 2014), and N400 range (Thierry & Wu, 2007; Wu & Thierry, 2010). In the present study, we sought to determine whether the presence of sub-phonemic native accent cues would facilitate access to the inactive L1 lexicon in an L2 context, supporting the increased L1 salience account, or whether the accent effect is more attributable to intelligibility difficulties, with native accented speech providing a closer match to the listener's stored representations. Testing highly-fluent Welsh-English bilinguals in a paradigm intended to elicit unconscious L1 phonological priming effects similar to that observed by Wu & Thierry (2010), we investigated whether L2 (English) words produced with an L1 (Welsh) accent would elicit priming effects mediated by phonological overlap in the L1. Welsh-English bilingual participants made semantic relatedness decisions on English word pairs, some of which featured a word-initial phoneme overlap through translation into Welsh, e.g., interview (*cyfweliad*) – warm (*cynnes*). We hypothesised that L1 accent may facilitate access to the L1 in an all-in-L2 context, resulting in an increase in phonological priming for word pairs featuring L1 accented L2 primes, manifesting as a reduction of mean amplitude within the 200–400 ms range spanning the N250-PMN-P325 range for Welsh accented relative to English accented stimuli. We also hypothesised that decreased intelligibility might translate as a reduction of N400 modulation when participants made semantic relatedness judgments on L1 accented L2 words as compared to the same words accented in L2.

2. Methods

2.1. Participants

Twenty-one highly proficient Welsh-English bilinguals participated in the experiment. Two datasets were rejected due to poor electrophysiological data quality resulting in a final sample of 19 participants (12 female, 7 male, mean age = 24.8; SD = 8.9, one left-handed). All had normal or corrected-to-normal vision, no learning disabilities and self-reported normal hearing. All had started learning Welsh at or before the age of 3, spoke Welsh at home, and had studied through the medium of Welsh up to the age of 18. Whilst age of acquisition for English varied, it was on average significantly later than for Welsh (t(23) = -6.377, p = < 0.001) and all participants self-reported equal proficiency in Welsh and English or greater proficiency in Welsh (**Table 1**). Participants all received Welsh-medium schooling up to the age of 12, with a majority taught through the medium of Welsh up to University and English taught formally as a second language from the age of six.

Table 1: Participant language background

Measure	Mean	SD
Age of Welsh acquisition	0.2	0.9
Age of English acquisition	3.8	2.29
Daily Welsh usage (%)	64.5	20.2
Daily English usage (%)	35.2	19.5

2.2. Materials

Auditory word primes were 39 familiar, mid-range frequency, three-syllabic words of English. Visual word targets were 234 familiar, mid-range frequency words of English varying in length from 2 – 4 syllables split into two lists of 117, in order to manipulate phonological overlap and semantic relatedness separately. The prime and target words were paired to form experimental conditions as follows: (1) Phonological overlap via Welsh translation (overlap condition) as in "interview – warm" (in Welsh: *cyfweliad – cynnes*); (2) Semantic relationship (related condition) as in "interview – ask" (in Welsh: *cyfweliad – gofyn*); (3) No overlap through Welsh (no overlap condition) using a stimulus from the same list as condition (1) as in "interview – wind" (in Welsh: *cyfweliad – gwynt*); and (4) No semantic relationship (unrelated condition) using a stimulus from the same list as condition (2) as in "interview – bush" (in Welsh: *cyfweliad – llwyn*). Critically, the target words of each pair were rotated across conditions (1) and (3) on the one hand and across conditions (2) and (4) on the other, meaning that all words featured as targets in the overlap condition were also featured as targets in the no overlap condition and similarly for semantically related and unrelated conditions. Furthermore, each auditory prime word was paired with three possible visual word targets, resulting in 117 (3 x 39) prime-target combinations per list.

Primes and targets were matched across conditions for lexical concreteness and frequency, with Welsh frequencies taken from Cronfa Electroneg o Gymraeg (CEG; Ellis *et al.* 2001) and English frequencies from SUBTLEX (van Heuven, Mandera, Keuleers, & Brysbaert, 2014). Concreteness measures for English materials were calculated from the corpus published by Brysbaert *et al.* (2014), and, due to corpus unavailability, assumed to be similar for Welsh translations. The 39 auditory prime words were digitally recorded by two adult female speakers at a sampling rate of 48.8 kHz and resampled using Audacity to 44.1 kHz to ensure compatibility with E-Prime stimulus presentation software.

2.3. Procedure

Participants gave written informed consent to take part in the experiment that was approved by the School of Psychology, Bangor University ethics committee. Testing took place across two separate sessions, with a break of at least one day between the two. The two accents were separated by session and counterbalanced so that half of the participants heard Welsh-accented primes in the first session, and the other half in the second session. Within each session, participants engaged in 156 trials consisting of 39 trials from each of the 4 experimental conditions. For each auditory prime word, the target was one out of three possible visually presented words, with targets rotated between participants. In each trial, participants first saw a fixation cross for 100 ms on a 17" RCT monitor at a distance of 100 cm from the eyes, followed by an auditory prime, played over loudspeakers set around the monitor. After the end of the auditory prime, a second fixation cross was displayed for a variable ISI of 160–240 ms before the visual target word was presented in black Times New Roman font, size 14 points on a light grey background (see Fig. 1). Participants were asked to indicate by button-press if prime and target pairs were related in meaning during a response window lasting a maximum of 2000 ms and response immediately triggered the next trial. Response-hand side was counterbalanced between participants. Participants performed a brief training period prior to commencing the full experiment to ensure they were familiarised with the procedure.

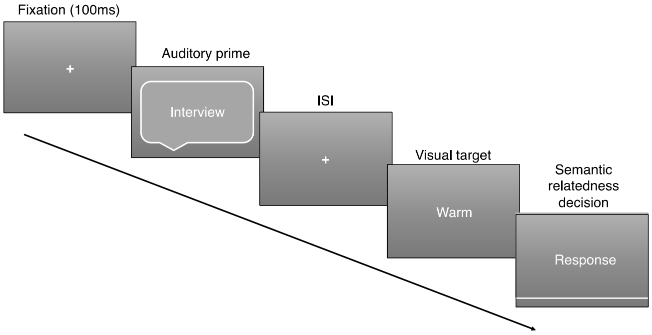

Fig. 1 – Experimental procedure. 'Interview' translates as *cyfweliad* and 'warm' translates as *cynnes* in Welsh.

2.4. ERP recording and pre-processing

EEG data was recorded using a BioSemi system from 128 active Ag/AgCl electrodes with the passive common mode sense (CMS) electrode as reference and driven right leg (DRL) as ground. Electrodes were held in place on the scalp with an elastic cap. Prior to recording, EEG electrode impedances were reduced to below 5 kΩ, and noisy electrodes were replaced by means of spherical interpolation. Data was recorded at 2048 Hz, resampled to 1024 Hz prior to analysis and re-referenced offline to the global average reference. Six facial bipolar electrodes positioned on the outer canthi of each eye and in the inferior and superior areas of the left and right orbits provided bipolar recordings of the horizontal and vertical electrooculograms (EOG). Data was filtered offline using a 30 Hz (48 dB/oct) low-pass and 0.1 Hz (12 dB/oct) high-pass Butterworth Zero Phase shift band-pass filter. Filtered data was inspected prior to ocular correction, which was conducted using Independent Component Analysis (ICA), which was run on a separate block, recorded prior to the main testing block for each session the participant attended. Participants were instructed to blink and make repeated vertical and horizontal eye movements in order to acquire eye-movement data on which ICA was computed, using the AMICA procedure (Palmer, Makeig, Kreutz-Delgado, & Rao, 2008). Data was subsequently segmented into epochs ranging from –200 to 1000 ms, time-locked to the onset of the visual target word. Baseline correction was performed relative to pre-stimulus activity before grand-averages were computed in each of the experimental conditions. There were at least 30 trials per condition for each participant.

2.5. Data analysis

Modelling of behavioural data

Accuracy was separately modelled as a function of two within-subjects factors, with one model for accent (Welsh, English) and phonological overlap (overlap, no overlap) and another model for accent (Welsh, English) and semantic relatedness (related, unrelated). We used generalized mixed-effects modelling (via the *glmer* with binomial link function in the lme4 v1.12 library; Bates, Maechler, Bolker, & Walker, 2014), with factors centred for the analyses to minimise collinearity. Random effects, including participant and item intercepts and slopes were modelled and systematically trimmed (interaction terms were removed) until the model converged (Barr, Levy, Scheepers, & Tily, 2013). Reaction times were log transformed to approximate a normal distribution, before being submitted to linear mixed effect modelling (using the *lmer* function in lme4) using the same iteration procedure as above.

ERP analysis

Previous studies reporting an effect of phonological expectancy in the phonological mapping negativity range (230-350 ms) or unconscious access to L1 phonology effects, reported maximal sensitivity over centroparietal regions (Dumay *et al.*, 2001; Praamstra *et al.*, 1994; Rugg, 1984a, Rugg, 1984b; Newman & Connolly, 2008; Desroches *et al.*, 2009; Malins *et al.*, 2013; Sučević *et al.*, 2015; Thierry & Wu, 2007; Wu & Thierry, 2010). To explore effects of phonological overlap, we thus analysed ERP amplitudes over a time window corresponding to the timeframe in which phonological priming is usually observed, i.e.,

between 200 and 400 ms at centroparietal electrode sites (Holcomb & Grainger, 2006; Connolly & Philips, 1994; Desroches *et al.,* 2009). To test effects of semantic priming, we analysed ERP mean amplitudes in the classic N400 window (350-500 ms) over central regions (Kutas and Hillyard, 1980; Kutas and Federmeier, 2011; Thierry and Wu, 2007; 2010). Both analyses were conducted by means of two-by-two repeated measures analysis of variance (ANOVA). For the phonological priming analysis, the repeated measures ANOVA was conducted over 12 centroparietal electrodes (cf. Fig. 2a) with accent (Welsh, English) and overlap in L1 (overlap, no overlap) as factors. As regards the analysis of semantic relatedness effects, N400 mean amplitudes were analysed over 15 central electrodes (spanning frontocentral and centroparietal regions; cf. Fig. 2b) where the N400 is usually maximal with accent (English, Welsh) and relatedness (related, unrelated) as independent variables.

3. Results

3.1. Behavioural results

In the model of phonological overlap effects on accuracy, we found no main effect of either accent or phonological overlap and no interaction. in the model of semantic relatedness effects on accuracy, a main effect of relatedness emerged, such that participants were more accurate for unrelated than related pairs (b = 3.43, SE = <0.5863, z = -5.852, p = <0.001). There was no effect of accent and no interaction between accent and relatedness.

As regards reaction times, there was no main effect of either accent or phonological overlap and no interaction. In the model of semantic relatedness, however, there was a main effect of relatedness, such that participants responded faster to unrelated than related pairs (b = -0.03, SE = <0.007, t = -4.42, p = <0.001). There was no effect of accent and no interaction between accent and relatedness.

3.2. Electrophysiological results

The repeated measures ANOVA on ERP mean amplitudes in the phonological priming window failed to reveal a main effect of accent, F(1, 18) = 0.001, p = .974, η_p^2 = 0.000, nor an effect of overlap, F(1, 18) = 0.048, p = .829, η_p^2 = 0.003 (Fig. 2a). However, there was a significant interaction between accent and overlap, F(1, 18) = 5.13, p = 0.036, η_p^2 = 0.222, such that ERP amplitudes were modulated by phonological overlap in the Welsh accent condition, t(18) = -2.12, p = 0.048, but not in the English accent condition, t(18) = -1.53; p = 0.141.

In the 350-500 ms time window there was a significant main effect of semantic relatedness on mean ERP amplitudes, F(1, 18) = 18.32, p < 0.001, η_p^2 = 0.504, such that N400 amplitude was significantly more negative in the unrelated than the related condition, t(18) = -4.28, p < 0.001 (Fig. 2b). There was no effect of accent, F(1, 18) = 0.119, p < 0.734, η_p^2 = 0.007, and no interaction between accent and relatedness, F(1, 18) = 0.182, p = .674, η_p^2 = 0.010.

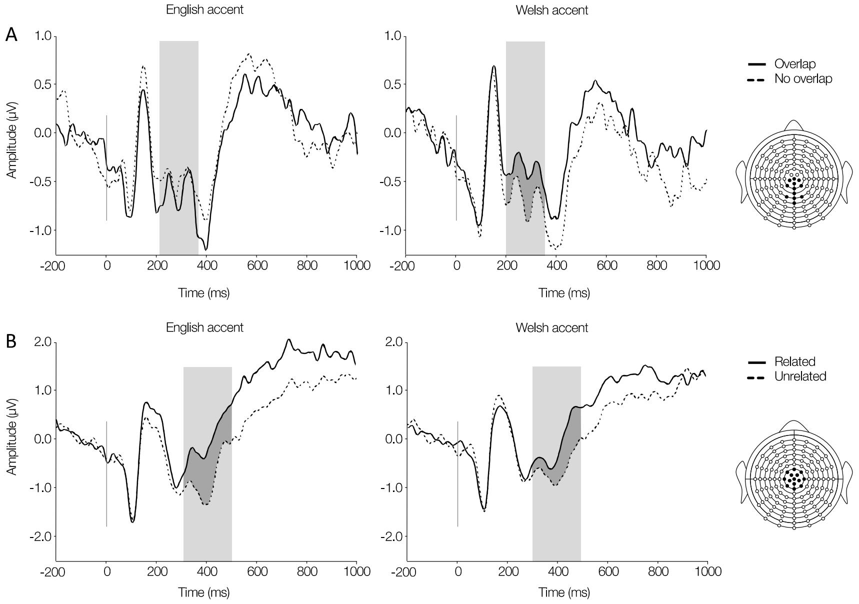

Figure 2. Event-related potentials elicited by target L2 words in the phonological overlap contrast and the semantic relatedness contrast. (A) Comparison of phonological overlap and control conditions for L2 accented primes (left) and L1 accented (right). (B) Comparison of semantically related and unrelated conditions for L2 accented primes (left) and L1 accented (right). Head maps show location of electrodes included in each of the two analyses.

4. Discussion

We manipulated speaker accent in an implicit phonological priming paradigm with Welsh-English bilingual participants involving spoken word primes and visual word targets. Beyond a classic semantic relatedness effect widely reported in the literature (Kutas & Hillyard, 1980a; Kutas & Hillyard, 1980b; Thierry & Wu, 2007), we found a significant effect of L1 phonological overlap for spoken L2 word primes produced with a Welsh accent, but not for primes pronounced with an English accent. However, we found no significant modulation of semantic priming by accent. Whilst the former finding provides support for the existence of a modulating effect of accent on cross-language phonological activation, the latter result suggest that intelligibility is not critically affected by accent in fluent bilinguals.

Consistent with previous studies showing implicit access to L1 phonological representations in participants tested entirely in their L2 (Thierry & Wu, 2004; 2007; Wu & Thierry, 2010), we found a reduction of mean ERP amplitudes for semantically unrelated word-pairs concealing a phonological overlap via L1. To our knowledge, this is the first report of a modulatory effect of accent on cross-language activation. It is noteworthy, in addition, that the phonological priming effect found here occurred earlier than that reported previously, e.g., in Chinese-English bilinguals. Whilst there is general agreement that ERP modulations in the N400 window indexes lexical and post-lexical priming, earlier modulations are generally associated with sub-lexical priming, whether orthographic or phonological (Grainger & Holcomb, 2009). In masked priming experiments, ERP modulations in the N250 range have been shown to reflect sub-lexical access (Kiyonaga *et al.,* 2007; Meade, *et al.,* 2018; Schoonbaert *et al.*, 2011). In their review of lexical masked priming and ERPs, Grainger & Holcomb (2009) proposed that access to sub-lexical representations occurs approximately 250 ms post-stimulus onset, followed by whole-word representation processing at around 325 ms. Accordingly, we suggest that the effect observed in the current study reflects sub-lexical phonological priming. In Thierry & Wu's (2007) and Wu & Thierry's (2010) studies, priming *de facto* likely happened at the lexical level since overlap between primes and targets concerned a full Chinese character, rather than one or two initial phonemes as in the current study. In addition, in these previous studies, priming was intra-modal (visual or auditory) rather than cross-modal (here auditory-to-visual) and the Chinese-English bilinguals tested, despite being highly fluent, dealt with typologically distant languages and did not master them to the same extent as simultaneous Welsh-English bilinguals.

The early effect reported may be explained further by the particular bilingual population studied. Our Welsh-English bilinguals have lived in North-Wales, an area with a unique bilingual context in which Welsh is a minority language protected by revival programmes and spoken as a native language on an equal stand with English. Welsh monolingualism only occurs in elderly individuals living in relatively isolated in rural areas, or in young pre-school children before they become exposed to the strongly bilingual community beyond home. Thus, even though the native language of participants involved in this study was Welsh, proficiency levels in English were essentially native-like. It follows that access to Welsh translation equivalents of English words should be more efficient than that of Chinese translation equivalents of English words in late Chinese-English bilinguals. This interpretation is also consistent with findings in speech production as reported by Spalek *et al.* (2014), who showed that German-English bilinguals unconsciously accessed German word forms as early as 300 ms post picture onset when asked to produce English adjective-noun phrases.

It must be noted that the topography of the priming effects found in the current study was centroparietal in contrast to N250 modulations found in masked priming experiments (Grainger & Holcomb, 2009; Holcomb & Grainger, 2006; Van Hell & Kroll, 2013), which tend to be maximal over frontocentral regions. The N250 is thought to index the mapping of sub-lexical form to orthographic representations. Translation priming effects shown to modulate the N250 have been suggested to reflect either activation of translations via direct lexical links, or activation of form-level representations as a result of the semantic representation feedback (van Hell & Kroll, 2013). However, the topography of the modulation is consistent with that of the P325, a differential effect attributed to phonological overlap in masked priming experiments with a centroparietal distribution (Holcomb & Grainger, 2006). In fact, the cross-language phonological priming effect reported here is closer in topography to that of the N400, which is characteristically centroparietal and sensitive to a breadth of perceptual, feature-level, and semantic factors (Kutas & Federmeier, 2000). Furthermore, whilst the PMN typically occurs over frontocentral regions, phonological expectation effects over parietal regions have been consistently reported in phonological priming experiments (Dumay *et al.*, 2001; Praamstra *et al.*, 1994; Rugg, 1984a,

Rugg, 1984b; Newman & Connolly, 2009; Desroches *et al.*, 2009; Malins *et al.*, 2013; Sučević *et al.*, 2015). We speculate that the centroparietal distribution of the effect in the current study may relate to the cross-modal nature of the priming paradigm used. Indeed, only studies that have used a visual priming paradigm have reported PMN modulation over the frontocentral regions (Connolly & Philips, 1994).

Recall that our study aimed to shed light on the alternative between the increased L1 salience and reduced L2 intelligibility accounts put forward by Lagrou *et al.* (2011; 2013). In the latter studies, the authors observed longer RTs for native-accented L2 speech, whilst L2 accented stimuli reduced (albeit did not eliminate) the inter-lingual homophone effects. A reduced intelligibility account would lead to the prediction of more demanding semantic processing of native accented L2 words. However, in our study, no such effect of accent on semantic processing was detectable, whether indexed by accuracy or RT in the semantic relatedness task or N400 modulations elicited by semantic relatedness. Instead, our results support the alternative interpretation that L1 accented L2 speech increases L1 salience given that L1 phonological priming was only found when L2 prime words were L1 accented. This said, we cannot conclude from the current results that reduced intelligibility may not be at play in the case of bilinguals with lower proficiency in their L2.

This being said, in our study L1 accented L2 speech failed to elicit any measurable phonological priming, whereas the interlingual homophone effect of Lagrou *et al.* (2013) was only reduced in magnitude by accent as opposed to being suppressed entirely. We contend that this difference relates primarily to the use of an implicit priming paradigm in our study, in which overt L1 language cues (e.g., homophones) are absent, lessening the likelihood of L1 activation. For instance, when the word 'interview'–*cyfweliad* is used as a prime for the word 'warm'–*cynnes,* no information regarding a potential phonological overlap between prime and target is afforded by the stimuli in the L2 (overlap uniquely concerns the L1). In contrast, when the word *lief*–'sweet' in Dutch in presented at the end of a sentence, the overlap with its interlingual homophone in English 'leaf' is obvious, likely heightening the activation level of native language representations, and increasing the intensity of cross-language priming effects.

The findings of the current study may have implications for second language acquisition. If native accent heightens activation of L1 representations, as suggested by our results, the establishment of L2 representations during L2 learning may be adversely affected by L1 accent. Moreover, in lower proficiency bilinguals or L2 learners, we cannot rule out that L1 accented L2 speech may also reduce intelligibility. Nevertheless, it is important to stress that the population tested here is not representative of unbalanced bilinguals who have different levels of exposure to their two languages, and who are not required to switch between their languages on a frequent basis. In addition, it is noteworthy that Welsh accent in Wales is also a regional accent, i.e., it is possible to encounter native speakers of English with a Welsh accent who speak little or no Welsh. Future studies will determine how semantic access is affected by foreign-accented speech in relation to proficiency in the L2, and whether L1 accent in L2 learners can affect intelligibility. Furthermore, follow-up investigations in different communities will hopefully tease apart contributions of foreign and regional accents in cross-language activation.

Conclusion

In sum, for the first time, we show that lexical access to L1 representations is stronger in bilinguals listening to L2 words when speech is L1 accented. Since phonological priming did not occur when L2 words were heard in a canonical L2 accent, suggesting that accent can act as a sort of gating mechanism, regulating activation of a bilingual's language representations. Importantly, accent manipulation had no detrimental (or boosting) effect on semantic processing, suggesting that access to phonological representations and meaning are not regulated by a common mechanism. Future studies manipulating accent in unbalanced bilinguals will shed critical light on this matter, since access may be less selective in such bilinguals.

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Appendix D: Study 2 language inventory questionnaire.

Language History Questionnaire

This questionnaire is designed to give us a better understanding of your language background. We ask that you are as accurate as possible when answering the following questions.

1. Country of Birth_____________ What is your first language? _____________

2. When did you start learning English? Age:__________

3. How long have been learning English in total? _______________

4. How long have you spent living in an English speaking country?

    4. Age:_______ No. of years: ______ No. of months______
    5. Age:_______ No. of years: ______ No. of months______
    6. Age:_______ No. of years: ______ No. of months______

5. What percentage of your time do you spend speaking each language? (Must add up to 100%)

    German: English: Other:

6. Up to what academic level have you studied English? (please circle)

High School GCSE Undergraduate Postgraduate
Other: ________

   a. If you have an IELTS score, please specify __________
   b. How long ago was this examination taken? _____________
   c. Do you feel this score is still representative of your English proficiency level? (please circle)

Yes No (please specify any changes:______________________)

7. Please rate your **English** reading proficiency on a ten-point scale.

1 2 3 4 5 6 7 8 9 10

not proficient very proficient

8. Please rate your **English** writing proficiency on a ten-point scale.

1	2	3	4	5	6	7	8	9	10

not proficient very proficient

9. Please rate your **English** conversational fluency on a ten-point scale.

1	2	3	4	5	6	7	8	9	10

not fluent very fluent

10. Please rate your **English** conversational understanding on a ten-point scale.

1	2	3	4	5	6	7	8	9	10

unable to understand conversation perfectly able to understand conversation

11. Apart from English, have you learnt any other foreign languages? If yes, please specify

Language: ______________________________
What age did you start to learn this language? ____________________
How many years have you learnt this language? ___________________
How often do you use this language right now? ____________________

Please rate your overall proficiency in this language on a ten-point scale.

1	2	3	4	5	6	7	8	9	10

not proficient very proficient

Language 2: ______________________________
What age did you start to learn this language? ____________________
How many years have you learnt this language? ___________________
How often do you use this language right now? ____________________

Please rate your overall proficiency in this language on a ten-point scale.

1 2 3 4 5 6 7 8 9 10
not proficient very proficient

Language 3: ______________________________
What age did you start to learn this language? ____________________
How many years have you learnt this language? __________________
How often do you use this language right now? ___________________

Please rate your overall proficiency in this language on a ten-point scale.

1 2 3 4 5 6 7 8 9 10
not proficient very proficient

About the study

3. Did you notice anything about the study, or the words that were presented to you? If yes, please specify:

Appendix E: Study 2 stimuli.

Sentence	German	Correct	Polysemous	Filler	Control
Thanks to the harsh winter, skaters had a good layer of ice on the	Bahn	rink	railway	river	shade
The poker player had been dealt a great	Blatt	hand	leaf	card	tax
The leak from upstairs dripped down through the	Decke	ceiling	duvet	floor	imagination
After the public had been seated, he solemnly took his place at the grand	Flügel	piano	wing	court	tap
The biggest bird that lived on the African farm was the	Hahn	rooster	tap	ostrich	meal
She shuffled the deck and dealt him a good	Karte	card	map	hand	speeding
The bouncer hit me and broke my	Kiefer	jaw	pine	glasses	spring
He spent Sunday emptying and cleaning his	Laster	truck	vice	shed	electricity
The tennis player felt confident she would win the game with her new	Schläger	racket	thug	move	feather
The gardener stored his tools in the	Schuppen	shed	dandruff	truck	rod

The monks were looked after by a charitable	Stift	monastery	pen	organisation	jaw
The musicians helped deliver a grand	Vorstellung	performance	imagination	piano	panes
Before cleaning the toilet, she lifted up the	Brille	seat	glasses	rug	paragraph
A puff of smoke came from the	Pfeife	pipe	whistle	dragon	sound
The wind was so strong that it blew away my	Drache	kite	dragon	umbrella	hinge
The accused knight was summoned to the	Gericht	court	meal	castle	pipe
The birds were gathered on the	Rasen	lawn	speeding	pine	performance
They did not order enough pizza and had to fight over the last	Scheiben	slices	panes	piece	dandruff
They slipped on the frozen	Strom	river	electricity	rink	thug
The oldest member was chosen as the leader of the	Verband	organisation	bandage	tribe	shield
After the break the chess player took his opponent's	Läufer	bishop	rug	seat	whistle
He lost control of the car and drove over the	Schild	billboard	shield	railway	pen
In the rough seas the captain used both hands to hold on to the	Steuer	wheel	tax	map	clay
The interior designer matched the colour of the bedroom lamp base to the	Schirm	shade	umbrella	duvet	wing
The knights stormed into the	Schloss	castle	lock	monastery	ceiling
In that station you take the elevator to get to the next	Stock	floor	stick	train	toes
Instead of crushing garlic, you can use whole	Zehen	cloves	toes	slices	wheel

Without his glasses Sam couldn't read the	Absatz	paragraph	heel	billboard	cloves
The pupil asked for a new sheet of paper to stick to her	Bogen	piece	bow	kite	heel
After the wedding the bridesmaids rushed to catch the	Zug	train	move	bouquet	trunk
She added some flowers to improve the look of the	Strauß	bouquet	ostrich	lawn	racket
In the morning, she was woken up by a loud	Ton	sound	clay	rooster	bandage
The bird finished his nest with a	Feder	feather	spring	stick	vice
The door swung open and broke the	Angel	hinge	rod	lock	leaf
The chief went hunting for wild boar with his	Stamm	tribe	trunk	bow	bishop

Appendix F: Study 2 norming questionnaire.

Hello,

Thank you for taking the time to help with our research! We are looking for native speakers of English to complete a short task. The following email should take approximately 5 minutes to complete.
Your participation is entirely voluntary. Your response will be treated confidentially and will not be identifiable.

Instructions:

1. Please press 'forward', and enter the recipient elp8d5@bangor.ac.uk
2. Write your native language here:
3. Read the following sentences one at a time. For each one, please indicate whether you feel the **last word** of each sentence make sense as an ending.

Scale:

-2	-1	0	+1	+2
Strongly disagree	Slightly disagree	Neither	Slightly agree	Strongly agree

Example:

Sentence	Score
I like my tea with milk and **dog**	-2

Please only make your judgement on whether the **last word of the sentence** is a suitable ending.

Sentence	Score
In the morning, she was woken up by a loud clay	
The pupil asked for a new sheet of paper to stick to her kite	
She shuffled the deck and dealt him a good card	
The door swung open and broke the hinge	
The oldest member was chosen as the leader of the tribe	
The accused knight was summoned to the meal	
They did not order enough pizza and had to fight over the last dandruff	
She shuffled the deck and dealt him a good speeding	
The biggest bird that lived on the African farm was the meal	
Thanks to the harsh winter, skaters had a good layer of ice on the shade	
After the wedding the bridesmaids rushed to catch the trunk	
The musicians helped deliver a grand piano	
After the public had been seated, he solemnly took his place at the grand wing	
Thanks to the harsh winter, skaters had a good layer of ice on the river	
Without his glasses Sam couldn't read the billboard	
The musicians helped deliver a grand imagination	
The birds were gathered on the performance	
The birds were gathered on the pine	
The bird finished his nest with a vice	
The accused knight was summoned to the castle	
The bird finished his nest with a stick	
The knights stormed into the monastery	
The gardener stored his tools in the shed	
They slipped on the frozen electricity	
A puff of smoke came from the pipe	
The interior designer matched the colour of the bedroom lamp base to the umbrella	
The interior designer matched the colour of the bedroom lamp base to the duvet	
Before cleaning the toilet, she lifted up the paragraph	
He spent Sunday emptying and cleaning his shed	
He lost control of the car and drove over the pen	
They slipped on the frozen river	
The pupil asked for a new sheet of paper to stick to her heel	
After the public had been seated, he solemnly took his place at the grand court	
In that station you take the elevator to get to the next floor	
Without his glasses Sam couldn't read the heel	
The gardener stored his tools in the rod	
In the rough seas the captain used both hands to hold on to the tax	
She added some flowers to improve the look of the bouquet	
The monks were looked after by a charitable pen	
The leak from upstairs dripped down through the duvet	
The door swung open and broke the leaf	
Instead of crushing garlic, you can use whole toes	

In that station you take the elevator to get to the next toes	
The wind was so strong that it blew away my kite	
Before cleaning the toilet, she lifted up the rug	
The tennis player felt confident she would win the game with her new feather	
The knights stormed into the ceiling	
A puff of smoke came from the sound	
The oldest member was chosen as the leader of the bandage	
The bouncer hit me and broke my pine	
The chief went hunting for wild boar with his trunk	
The leak from upstairs dripped down through the ceiling	
The monks were looked after by a charitable monastery	
Instead of crushing garlic, you can use whole cloves	
They did not order enough pizza and had to fight over the last slices	
The chief went hunting for wild boar with his tribe	
The tennis player felt confident she would win the game with her new move	
He lost control of the car and drove over the billboard	
The poker player had been dealt a great tax	
The bouncer hit me and broke my jaw	
She added some flowers to improve the look of the ostrich	
He spent Sunday emptying and cleaning his vice	
The biggest bird that lived on the African farm was the ostrich	
After the break the chess player took his opponent's seat	
After the wedding the bridesmaids rushed to catch the train	
In the rough seas the captain used both hands to hold on to the wheel	
In the morning, she was woken up by a loud rooster	
After the break the chess player took his opponent's whistle	
The wind was so strong that it blew away my dragon	
The poker player had been dealt a great hand	
The bird finished his nest with a spring	
The wind was so strong that it blew away my umbrella	
Thanks to the harsh winter, skaters had a good layer of ice on the rink	
The knights stormed into the castle	
The door swung open and broke the lock	
The tennis player felt confident she would win the game with her new racket	
The chief went hunting for wild boar with his bishop	
A puff of smoke came from the whistle	
Thanks to the harsh winter, skaters had a good layer of ice on the railway	
They slipped on the frozen rink	
She added some flowers to improve the look of the lawn	
The biggest bird that lived on the African farm was the tap	
The monks were looked after by a charitable organisation	
The poker player had been dealt a great leaf	
He lost control of the car and drove over the shield	
The chief went hunting for wild boar with his bow	

Before cleaning the toilet, she lifted up the glasses	
The knights stormed into the lock	
Instead of crushing garlic, you can use whole wheel	
The bouncer hit me and broke my spring	
In that station you take the elevator to get to the next stick	
After the public had been seated, he solemnly took his place at the grand piano	
The pupil asked for a new sheet of paper to stick to her piece	
The biggest bird that lived on the African farm was the rooster	
The tennis player felt confident she would win the game with her new thug	
The birds were gathered on the speeding	
The wind was so strong that it blew away my hinge	
A puff of smoke came from the dragon	
She added some flowers to improve the look of the racket	
The musicians helped deliver a grand panes	
The birds were gathered on the lawn	
The monks were looked after by a charitable jaw	
The poker player had been dealt a great card	
He lost control of the car and drove over the railway	
The door swung open and broke the rod	
In the morning, she was woken up by a loud bandage	
The accused knight was summoned to the court	
Before cleaning the toilet, she lifted up the seat	
He spent Sunday emptying and cleaning his truck	
The interior designer matched the colour of the bedroom lamp base to the wing	
The interior designer matched the colour of the bedroom lamp base to the shade	
He spent Sunday emptying and cleaning his electricity	
The gardener stored his tools in the dandruff	
After the wedding the bridesmaids rushed to catch the move	
Without his glasses Sam couldn't read the paragraph	
The musicians helped deliver a grand performance	
She shuffled the deck and dealt him a good hand	
Instead of crushing garlic, you can use whole slices	
The oldest member was chosen as the leader of the shield	
The oldest member was chosen as the leader of the organisation	
The bird finished his nest with a feather	
The bouncer hit me and broke my glasses	
After the public had been seated, he solemnly took his place at the grand tap	
In that station you take the elevator to get to the next train	
She shuffled the deck and dealt him a good map	
They slipped on the frozen thug	
After the break the chess player took his opponent's rug	
After the break the chess player took his opponent's bishop	
The gardener stored his tools in the truck	
Without his glasses Sam couldn't read the cloves	

After the wedding the bridesmaids rushed to catch the bouquet	
The leak from upstairs dripped down through the imagination	
In the rough seas the captain used both hands to hold on to the clay	
The leak from upstairs dripped down through the floor	
They did not order enough pizza and had to fight over the last piece	
The pupil asked for a new sheet of paper to stick to her bow	
In the morning, she was woken up by a loud sound	
In the rough seas the captain used both hands to hold on to the map	
They did not order enough pizza and had to fight over the last panes	
The accused knight was summoned to the pipe	

Thank you for your time!

Jennifer Lewendon
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Appendix G: Study 2 norming results (avg.)

Expected	Control	Filler	Polysemous
0.22	-1.96	1.78	-1.74
1.96	-1.91	1.87	0.26
1.65	-0.74	2.00	0.00
1.74	-1.30	1.65	-1.22
1.83	-1.39	1.87	-2.00
1.17	-1.43	1.91	-0.43
1.96	-1.39	1.87	-1.39
1.61	-1.96	1.83	-1.78
1.57	-0.26	1.83	-1.83
1.83	-0.96	1.13	-0.30
1.96	-1.96	1.61	-1.96
1.17	-1.30	1.83	-1.65
0.26	-2.00	1.83	-1.61
1.74	-1.43	0.57	-1.26
1.61	-1.74	1.83	-1.52
1.43	-1.65	1.48	-0.91
1.83	-1.35	1.70	-0.96
1.83	-0.30	1.83	-1.04

1.65	-0.83	1.70	-0.52
1.30	-2.00	1.78	-1.57
1.43	-1.48	1.74	-2.00
1.52	-0.78	1.48	-1.96
1.52	-1.57	0.91	-1.17
1.48	-1.91	1.17	-1.17
1.48	-2.00	1.65	-1.57
1.48	-2.00	1.48	-1.96
1.57	-1.61	1.83	-1.48
0.17	-2.00	1.78	-1.83
1.78	-1.13	1.04	-0.22
0.65	-1.78	1.83	-1.91
1.48	-1.96	1.57	-1.78
1.83	-1.83	1.65	-1.91
1.26	-1.96	1.04	-1.52
1.78	-1.43	0.61	-0.22
1.57	-1.74	1.83	-1.87

Appendix H: Study 3 language inventory questionnaire.

Language History Questionnaire

This questionnaire is designed to give us a better understanding of your language experience. We ask that you are as accurate as possible when answering the following questions.

1. Country of Birth______________ What is your first language______________

2. When did you start learning Welsh? Age:__________

3. How long have been learning Welsh?_______________

4. How long have you spent living outside of Wales?

    7. Age:_______ No. of years: ______ No. of months______

8. Age:_______ No. of years: ______ No. of months______
9. Age:_______ No. of years: ______ No. of months______

5. What percentage of your time do you spend speaking each language? (Must add up to 100%)

Welsh: English: Other:

6. Up to what academic level have you studied Welsh? (please circle)

High School GCSE Undergraduate Postgraduate
Other: ________

7. Please rate your **Welsh** reading proficiency on a ten-point scale.

1 2 3 4 5 6 7 8 9 10
not proficient very proficient

8. Please rate your **Welsh** writing proficiency on a ten-point scale.

1 2 3 4 5 6 7 8 9 10
not proficient very proficient

9. Please rate your **Welsh** conversational fluency on a ten-point scale.

1 2 3 4 5 6 7 8 9 10
not fluent very fluent

10. Please rate your **Welsh** conversational understanding on a ten-point scale.

1 2 3 4 5 6 7 8 9 10
unable to understand conversation perfectly able to understand conversation

11. Apart from Welsh, have you learnt any other foreign languages? If yes, please specify

Language: ____________________________

What age did you start to learn this language? ____________________
How many years have you learnt this language? ___________________
How often do you use this language right now? ____________________
Please rate your <u>overall proficiency</u> in this language on a ten-point scale.

1 2 3 4 5 6 7 8 9 10
not proficient very proficient

Language 2: ______________________________
What age did you start to learn this language? ____________________
How many years have you learnt this language? ___________________
How often do you use this language right now? ____________________
Please rate your <u>overall proficiency</u> in this language on a ten-point scale.

1 2 3 4 5 6 7 8 9 10
not proficient very proficient

Language 3: ______________________________
What age did you start to learn this language? ____________________
How many years have you learnt this language? ___________________
How often do you use this language right now? ____________________
Please rate your <u>overall proficiency</u> in this language on a ten-point scale.

1 2 3 4 5 6 7 8 9 10
not proficient very proficient

<u>About the study</u>

4. Did you notice anything about the study, or the words that were presented to you? If yes, please specify:

5. We anticipate that some of the words may have sounded odd to participants. Please circle the sentence that best describes how well you understood what you heard/saw.

- I didn’t understand any of the words.

- I didn’t understand many of the words.

- I understood some of the words.

- I understood many of the words.

- I understood almost all of the words.

- I understood all of the words.

Appendix I: Study 3 stimuli.

Overlap				No overlap				Related & filler		
Prime	Welsh trans.	Target	Welsh trans.	Prime	Welsh trans.	Target	Welsh trans.	Prime	Target	Welsh trans.
architects	penseiri	further	pellach	adequate	digonol	rock	craig	adjective	grave	bedd
		cough	peswch			welcome	croeso		loan	benthyg
		distance	pellter			shirt	crys		verb	berf
balancing	cydbwyso	take	cymryd	applicant	ymgeisydd	flour	blawd	anarchy	take	cymryd
		offer	cynnig			tasted	blasodd		offer	cynnig
		plan	cynllun			shout	bloedd		plan	cynllun
broadcasting	darlledu	teeth	dannedd	articles	erthyglau	city	dinas	angrily	flour	blawd
		solve	datrys			boring	diflas		tasted	blasodd
		sheep	dafad			valid	dilys		shout	bloedd
capable	galluog	leave	gadael	bravery	dewrder	law	cyfraith	barrister	law	cyfraith
		word	gair			friend	cyfaill		friend	cyfaill
		hold	gafael			volume	cyfrol		volume	cyfrol
champion	pencampwr	far	pell	charity	elusen	wind	gwynt	basketball	argue	dadlau
		things	pethau			white	gwyn		catch	dal
		tents	pebyll			wife	gwraig		tears	dagrau
criminal	troseddwr	order	trefn	cleanliness	glanweithdra	wing	adain	calendar	wolf	blaidd
		nose	trwyn			birds	adar		tired	blino
		beach	traeth			echo	adlais		year	blwyddyn
dangerous	peryglus	four	pedwar	confident	hyderus	born	geni	campervan	far	pell
		verse	pennill			jaw	gen		things	pethau
		chapter	pennod			fingernail	gewyn		tents	pebyll
editor	golygydd	north	gogledd	criticize	beirniadu	far	pell	capital	valid	dilys
		care	gofal			things	pethau		boring	diolch
		station	gorsaf			tents	pebyll		city	dilyn
enemies	gelynion	born	geni	decorate	addurno	short	byr	cardiac	heart	calon
		jaw	gen			army	byddin		hundred	cant

		fingernail	gewyn			finger	bys		stone	carreg
everywhere	ymhobman	research	ymchwil	entrances	mynedfeydd	argue	dadlau	catering	proud	balch
		edge	ymyl			catch	dal		dirt	baw
		treat	ymdrin			tears	dagrau		poet	bardd
feminine	benywaidd	grave	bedd	envelopes	amlenni	truth	gwir	cavalry	back	cefn
		loan	benthyg			country	gwlad		mouth	ceg
		verb	berf			bed	gwely		horse	ceffyl
flowering	blodeuo	wolf	blaidd	ethical	moesegol	red	coch	cavernous	wing	adain
		tired	blino			raise	codi		birds	adar
		year	blwyddyn			lost	colli		echo	adlais
government	llywodraeth	book	llyfr	families	teuluoedd	book	llyfr	chattering	teeth	dannedd
		lake	llyn			lake	llyn		solve	datrys
		lick	llyfu			lick	llyfu		sheep	dafad
hardening	caledu	sing	canu	fisherman	pysgotwr	wolf	blaidd	cuticle	born	geni
		step	cam			tired	blino		jaw	gen
		branch	cangen			year	blwyddyn		fingernail	gewyn
honesty	gonestrwydd	light	golau	genius	athrylith	heart	calon	cutlery	warm	cynnes
		wash	golchi			hundred	cant		knife	cyllell
		finish	gorffen			stone	carreg		slept	cysgodd
hospital	ysbyty	writing	ysgrifennu	habitat	cynefin	grave	bedd	dialect	leave	gadael
		shoulder	ysgwydd			loan	benthyg		word	gair
		during	ystod			verb	berf		hold	gafael
infancy	babandod	proud	balch	hurricanes	corwyntoedd	swallow	llyncu	difficult	writing	ysgrifennu
		dirt	baw			eye	llygad		shoulder	ysgwydd
		poet	bardd			toad	llyffant		during	ystod
injuring	anafu	dear	annwyl	imitate	dynwared	father	tad	digested	swallow	llyncu
		send	anfon			calm	tawel		eye	llygad
		need	angen			hit	taro		toad	llyffant
innocent	diniwed	city	dinas	industry	diwydiant	north	gogledd	elderly	king	brenin
		boring	diflas			care	gofal		hill	bryn
		valid	dilys			station	gorsaf		fragile	bregus
interesting	diddorol	thanks	diolch	instrument	offeryn	advice	cyngor	forestry	sing	canu

		follow	dilyn			shadow	cysgod		step	cam
		clothes	dillad			first	cyntaf		branch	cangen
interview	cyfweliad	warm	cynnes	isolate	ynysu	hear	clywed	fossilised	rock	craig
		knife	cyllell			sword	cleddyf		welcome	croeso
		slept	cysgodd			bell	cloch		shirt	crys
lecturer	darlithwr	argue	dadlau	loyalty	ffyddlondeb	warm	cynnes	gentleman	father	tad
		catch	dal			knife	cyllell		calm	tawel
		tears	dagrau			slept	cysgodd		hit	taro
library	llyfrgell	swallow	llyncu	manager	rheolwr	writing	ysgrifennu	geography	truth	gwir
		eye	llygad			shoulder	ysgwydd		country	gwlad
		toad	llyffant			during	ystod		bed	gwely
masculine	gwrywaidd	truth	gwir	melodies	alawon	take	cymryd	grandmother	wind	gwynt
		country	gwlad			offer	cynnig		white	gwyn
		bed	gwely			plan	cynllun		wife	gwraig
minister	gweinidog	wind	gwynt	membership	aelodaeth	teeth	dannedd	gratitude	thanks	diolch
		white	gwyn			solve	datrys		follow	dilyn
		wife	gwraig			sheep	dafad		clothes	dillad
moderate	cymedrol	start	cychwyn	modify	addasu	proud	balch	medicine	further	pellach
		series	cyfres			dirt	baw		cough	peswch
		whole	cyfan			poet	bardd		distance	pellter
opposite	cyferbyn	advice	cyngor	mystery	dirgelwch	sing	canu	mountainous	big	mawr
		first	cysgod			step	cam		son	mab
		shadow	cyntaf			branch	cangen		detailed	manwl
orchestra	cerddorfa	back	cefn	nominate	enwebu	big	mawr	pineapple	start	cychwyn
		mouth	ceg			son	mab		series	cyfres
		horse	ceffyl			detailed	manwl		whole	cyfan
payable	taladwy	father	tad	nursery	meithrinfa	drown	boddi	postboxes	dear	annwyl
		calm	tawel			cheek	boch		send	anfon
		hit	taro			morning	bore		need	angen
physical	corfforol	red	coch	pottery	crochenwaith	leave	gadael	presipice	research	ymchwil
		raise	codi			word	gair		join	ymyl
		lost	colli			hold	gafael		treat	ymdrin

portable	cludadwy	hear	clywed	practising	ymarfer	dear	annwyl	rectangle	petryal	four	pedwar
		sword	cleddyf			send	anfon			verse	pennill
		bell	cloch			need	angen			chapter	pennod
previous	blaenorol	flour	blawd	principle	egwyddor	back	cefn	showering	cawod	light	golau
		tasted	blasodd			mouth	ceg			wash	golchi
		shout	bloedd			horse	ceffyl			finish	gorffen
prisoner	carcharor	heart	calon	probable	tebygol	start	cychwyn	stationary	llonydd	book	llyfr
		hundred	cant			series	cyfres			lake	llyn
		stone	carreg			whole	cyfan			lick	llyfu
raspberry	mafonen	big	mawr	serious	difrifol	four	pedwar	strawberry	mefusen	red	coch
		son	mab			verse	pennill			raise	codi
		detailed	manwl			chapter	pennod			lost	colli
recognise	adnabod	wing	adain	spiritual	ysbrydol	order	trefn	suffocate	mygu	drown	boddi
		birds	adar			nose	trwyn			cheek	boch
		echo	adlais			beach	traeth			morning	bore
relative	perthynas	skull	penglog	suffering	dioddef	light	golau	terminate	terfynu	skull	penglog
		end	pen			wash	golchi			end	pen
		knee	penglin			finish	gorffen			knee	penglin
salaries	cyflogau	law	cyfraith	timetable	amserlen	further	pellach	tourism	twristiaeth	order	trefn
		friend	cyfaill			cough	peswch			nose	trwyn
		volume	cyfrol			distance	pellter			beach	traeth
satisfy	bodloni	drown	boddi	vehicles	cerbydau	skull	penglog	trainspotter	gwyliwr trenau	north	gogledd
		cheek	boch			end	pen			care	gofal
		morning	bore			knee	penglin			station	gorsaf
sentences	brawddegau	king	brenin	villages	pentrefi	thanks	diolch	uniform	gwisg ysgol	short	byr
		hill	bryn			follow	dilyn			army	byddin
		fragile	bregus			clothes	dillad			finger	bys
summary	crynodeb	rock	craig	visitor	ymwelwr	king	brenin	warrior	rhyfelwr	hear	clywed
		welcome	croeso			hill	bryn			sword	cleddyf
		shirt	crys			fragile	bregus			bell	cloch
universe	bydysawd	short	byr	welcoming	croesawgar	research	ymchwil	yesterday	ddoe	advice	cyngor
		army	byddin			edge	ymyl			shadow	cysgod

		finger	bys			treat	ymdrin		first	cyntaf

Appendix J: Study 4 stimuli.

			Experiment 1				Experiment 2			
Prime	Welsh trans.	Prime stress	Overlap	Welsh trans.	no overlap	Welsh trans.	Related	Welsh trans.	Unrelated	Welsh trans.
orchestra	cerddorfa	1	back	cefn	flour	blawd	stage	llwyfan	essay	traethawd
		2	mouth	ceg	taste	blas	listen	gwrando	language	iaith
		3	horse	ceffyl	shout	bloedd	instrument	offeryn	word	gair
payable	taladwy	1	father	tad	king	brenin	free	rhydd	gender	rhyw
		2	calm	tawel	hill	bryn	cheap	rhad	strong	cryf
		3	hit	taro	fragile	bregus	reward	gwobr	hero	arwr
minister	gweinidog	1	wind	gwynt	dear	annwyl	leader	arweinydd	cream	hufen
		2	white	gwyn	send	anfon	local	lleol	bush	llwyn
		3	bleed	gwaedu	need	angen	office	swyddfa	seed	hedyn
innocent	diniwed	1	city	dinas	hear	clywed	witness	tystiolwr	stem	cas
		2	boring	diflas	sword	cleddyf	guilty	euog	spring	gwanwyn
		3	valid	dilys	bell	cloch	lie	celwydd	bees	gwenyn
champion	pencampwr	1	tents	pebyll	order	trefn	win	ennill	witness	tystiolwr
		2	distance	pellter	nose	trwyn	race	hil	guilty	euog
		3	quartet	pedwarawd	beach	traeth	best	gorau	lie	celwydd
physical	corfforol	1	red	coch	book	llyfr	material	defnydd	thief	lleidr
		2	raise	codi	lake	llyn	human	dynol	defence	amddiffyniad
		3	lost	colli	dusty	llychlyd	react	ymateb	judge	barnwr
prisoner	carcharor	1	heart	calon	wolf	blaidd	thief	lleidr	face	wyneb
		2	hundred	cant	tired	blino	defence	amddiffyniad	look	edrych
		3	stone	carreg	year	blwyddyn	judge	barnwr	see	gweld
universe	bydysawd	1	short	byr	red	coch	moon	lleuad	free	rhydd
		2	army	byddin	raise	codi	sun	haul	cheap	rhad
		3	finger	bys	lost	colli	earth	daear	reward	gwobr
government	llywodraeth	1	book	llyfr	four	pedwar	state	cyflwr	follow	dilyn
		2	lake	llyn	verse	pennill	power	awdurdod	memory	cof
		3	dusty	llychlyd	chapter	pennod	vote	pleidlais	early	cynnar

sentences	brawddegau	1	king	brenin	argue	dadlau	essay	traethawd	money	arian
		2	hill	bryn	catch	dal	language	iaith	work	gwaith
		3	fragile	bregus	tears	dagrau	word	gair	give	rhoi
editor	golygydd	1	north	gogledd	thanks	diolch	journal	cylchgrawn	fight	brwydr
		2	care	gofal	revenge	dial	publish	cyhoeddi	friend	cyfaill
		3	station	gorsaf	clothes	dillad	script	llawysgrif	bad	drwg
interesting	diddorol	1	thanks	diolch	back	cefn	focus	canolbwyntio	sick	gwael
		2	revenge	dial	mouth	ceg	exciting	cyffrous	surgeon	llawfeddyg
		3	clothes	dillad	horse	ceffyl	lesson	gwers	cure	gwella
portable	cludadwy	1	hear	clywed	teeth	dannedd	fixed	sefydlog	win	ennill
		2	sword	cleddyf	solve	datrys	move	symud	race	hil
		3	bell	cloch	sheep	dafad	stay	aros	best	gorau
dangerous	peryglus	1	four	pedwar	heart	calon	fear	ofn	soft	meddal
		2	verse	pennill	hundred	cant	harm	niwed	stiff	anhyblyg
		3	chapter	pennod	stone	carreg	thrilling	anhygoel	resistant	gwrthsefyll
moderate	cymedrol	1	start	cychwyn	proud	balch	fair	teg	teach	addysgu
		2	series	cyfres	dirty	bawlyd	level	gwastad	talk	siarad
		3	whole	cyfan	poet	bardd	effort	ymdrech	school	ysgol
lecturer	darlithwr	1	argue	dadlau	short	byr	teach	addysgu	fixed	sefydlog
		2	catch	dal	army	byddin	talk	siarad	move	symud
		3	tears	dagrau	finger	bys	school	ysgol	stay	aros
enemies	gelynion	1	born	geni	tents	pebyll	fight	brwydr	recall	atgofio
		2	jaw	gen	things	pethau	friend	cyfaill	quiet	distaw
		3	fingernail	gewyn	quartet	pedwarawd	bad	drwg	pages	tudalennau
broadcasting	darlledu	1	teeth	dannedd	father	tad	advert	hysbyseb	grow	prifio
		2	solve	datrys	calm	tawel	waves	tonnau	age	oed
		3	sheep	dafad	hit	taro	speech	araith	child	plentyn
flowering	blodeuo	1	wolf	blaidd	researcher	ymchwilydd	stem	cas	expert	arbenigwr
		2	tired	blino	bathe	ymdrochi	spring	gwanwyn	trained	hyfforddedig
		3	year	blwyddyn	treat	ymdrin	bees	gwenyn	practise	ymarfer
hospital	ysbyty	1	writing	ysgrifennu	rock	craig	sick	gwael	journal	cylchgrawn
		2	shoulder	ysgwydd	welcome	croeso	surgeon	llawfeddyg	publish	cyhoeddi

		3	divorce	ysgariad	shirt	crys	cure	gwella	script	llawysgrif
recognise	adnabod	1	wing	adain	truth	gwir	face	wyneb	princess	tywysoges
		2	birds	adar	country	gwlad	look	edrych	dress	gwisg
		3	echo	adlais	bed	gwely	see	gweld	elegant	cain
infancy	babandod	1	proud	balch	take	cymryd	grow	prifio	state	cyflwr
		2	dirty	bawlyd	offer	cynnig	age	oed	power	awdurdod
		3	poet	bardd	plan	cynllun	child	plentyn	vote	pleidlais
visitor	ymwelwr	1	researcher	ymchwilydd	skull	penglog	house	ty	focus	canolbwyntio
		2	bathe	ymdrochi	ball	pêl	foreign	estron	exciting	cyffrous
		3	treat	ymdrin	knee	penglin	stranger	dieithryn	lesson	gwers
honesty	gonestrwydd	1	light	golau	singer	canwr	pledge	addewid	family	teulu
		2	wash	golchi	necklace	cadwyn	believe	coelio	uncle	ewythr
		3	finish	gorffen	branch	cangen	open	agored	aunt	modryb
villages	pentrefi	1	further	pellach	light	golau	county	sîr	advert	hysbyseb
		2	cough	peswch	wash	golchi	district	ardal	waves	tonnau
		3	things	pethau	finish	gorffen	rural	gwledig	speech	araith
library	llyfrgell	1	swallow	llyncu	north	gogledd	recall	atgofio	illegal	anghyfreithlon
		2	eye	llygad	care	gofal	quiet	distaw	police	heddlu
		3	toad	llyffant	station	gorsaf	pages	tudalennau	jury	rheithgor
interview	cyfweliad	1	warm	cynnes	wind	gwynt	ask	gofyn	moon	lleuad
		2	knife	cyllell	white	gwyn	fame	enwogrwydd	sun	haul
		3	sleep	cwsg	bleed	gwaedu	speak	dweud	earth	daear
summary	crynodeb	1	rock	craig	born	geni	outline	amlin	break	torri
		2	welcome	croeso	jaw	gen	report	adrodd	bandage	rhwymo
		3	shirt	crys	fingernail	gewyn	review	adolygiad	pain	brifo
raspberry	mafonen	1	big	mawr	city	dinas	cream	hufen	pledge	addewid
		2	son	mab	boring	diflas	bush	llwyn	believe	coelio
		3	detailed	manwl	valid	dilys	seed	hedyn	open	agored
balancing	cydbwyso	1	take	cymryd	writing	ysgrifennu	topple	disgyn	fear	ofn
		2	offer	cynnig	shoulder	ysgwydd	edge	ymyl	harm	niwed
		3	plan	cynllun	divorce	ysgariad	weight	pwysau	thrilling	anhygoel
injuring	anafu	1	dear	annwyl	law	cyfraith	break	torri	house	ty

		2	send	anfon	first	cyntaf	bandage	rhwymo	foreign	estron
		3	need	angen	volume	cyfrol	pain	brifo	stranger	dieithryn
masculine	gwrywaidd	1	truth	gwir	further	pellach	gender	rhyw	outline	amlin
		2	country	gwlad	cough	peswch	strong	cryf	report	adrodd
		3	bed	gwely	distance	pellter	hero	arwr	review	adolygiad
criminal	troseddwr	1	order	trefn	grave	bedd	illegal	anghyfreithlon	stage	llwyfan
		2	nose	trwyn	loan	benthyg	police	heddlu	listen	gwrando
		3	beach	traeth	verb	berf	jury	rheithgor	instrument	offeryn
capable	galluog	1	leave	gadael	big	mawr	expert	arbenigwr	topple	disgyn
		2	promise	gaddo	son	mab	trained	hyfforddedig	edge	ymyl
		3	hold	gafael	detailed	manwl	practise	ymarfer	weight	pwysau
feminine	benywaidd	1	grave	bedd	start	cychwyn	princess	tywysoges	county	sîr
		2	loan	benthyg	series	cyfres	dress	gwisg	district	ardal
		3	verb	berf	whole	cyfan	elegant	cain	rural	gwledig
relative	perthynas	1	skull	penglog	leave	gadael	family	teulu	leader	arweinydd
		2	ball	pêl	promise	gaddo	uncle	ewythr	local	lleol
		3	knee	penglin	hold	gafael	aunt	modryb	office	swyddfa
previous	blaenorol	1	flour	blawd	warm	cynnes	follow	dilyn	fair	teg
		2	taste	blas	knife	cyllell	memory	cof	level	gwastad
		3	shout	bloedd	sleep	cwsg	early	cynnar	effort	ymdrech
salaries	cyflogau	1	law	cyfraith	wing	adain	money	arian	material	defnydd
		2	first	cyntaf	birds	adar	work	gwaith	human	dynol
		3	volume	cyfrol	echo	adlais	give	rhoi	react	ymateb
hardening	caledu	1	singer	canwr	swallow	llyncu	soft	meddal	ask	gofyn
		2	necklace	cadwyn	eye	llygad	stiff	anhyblyg	fame	enwogrwydd
		3	branch	cangen	toad	llyffant	resistant	gwrthsefyll	speak	dweud

Appendix K: Study 4 as under review in *Brain Science.*

brain sciences

MDPI

Article

Electrophysiological differentiation of the effects of stress and accent on lexical integration in highly fluent bilinguals

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Abstract: Individuals who acquire a second language (L2) after infancy often retain features of their native language (L1) accent. Cross-language priming studies have shown negative effects of L1 accent on L2 comprehension, but the role of specific speech features, such as lexical stress, is mostly unknown. Here, we investigate whether lexical stress and accent differently modulate semantic processing and cross-language lexical activation in Welsh-English bilinguals, given that English and Welsh differ substantially in terms of stress realisation. In an L2 cross-modal priming paradigm, we manipulated the stress pattern and accent of spoken primes, whilst participants made semantic relatedness judgments on visual word targets. Event-related brain potentials revealed a main effect of stress on target integration, such that stimuli with stress patterns compatible with either the L1 or L2 required less processing effort than stimuli with stress incompatible with both Welsh and English. An independent cross-language phonological overlap manipulation also revealed an expected interaction between accent and L1 access. Interestingly, stress failed to modulate either semantic priming effects or covert access to L1 phonological representations. Our results are consistent with the concept of language-specific stress templates, and suggest that accent and lexical stress affect speech comprehension mechanisms differentially.

Keywords: Lexical stress; bilingualism; Event-related brain potentials; word comprehension; implicit priming; speech processing; lexical access

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1. Introduction

Bilinguals are often detectable by their native accent. Even a highly fluent, native-like speaker of a second language (L2) will often produce L2 speech with a number of native (L1) phonological and prosodic features [1–3]. Foreign accent in L2 speech is thought to result from interaction between the segmental and suprasegmental characteristics of the native and second languages [4]. The influence that this presence of native features has on second language processing has been the subject of research since the 1960s [5–9]. Whilst earlier studies often report a beneficial role of L1 accent on L2 processing, suggesting that either speech in a speaker's own or a familiar accent may be easier to understand [5–7,10–12], later studies report interference effects [8,9,13,14]. Lagrou, Hartsuiker and Duyck [9] investigated the influence of L1 accent, alongside sentence context and semantic constraints, on language non-selective access. Dutch-English bilinguals made lexical decisions for the last word of English sentences produced by a native speaker of English or Dutch. A main effect of interference was found for interlingual homophones (e.g., *lief* "sweet" – *leaf*) with response times significantly longer relative to control stimuli. Furthermore, the homophone interference effect was

modulated by accent, such that L1 Dutch-accented English sentences were responded to more slowly than English-accented English sentences. Whilst the interaction between accent and homophone interference suggests that native accent modulates language non-selective access, a main effect of accent, with faster responses to the English speaker than the Dutch speaker, lead the authors to suggest that future research should investigate whether native accent increases L1 salience, or results in an overall decrease in intelligibility.

Whilst the results of Lagrou *et al*. [8] suggest that L1 accent in second language comprehension can influence lexical access in bilinguals, foreign accent is a 'complex of interlingual or idiosyncratic phonological, prosodic and paralinguistic systems' [15] (p. 167). The realisation of L2 intonation and prosody, for example, has been shown to be particularly influenced by corresponding properties of the L1 [16–18]. Another feature that contributes towards accent is lexical stress, the perceptual prominence of a syllable in a word. Lexical stress varies in its realisation both between and within languages. In stress-variable languages it can fundamentally alter the perception of words. For example, in certain languages, lexical stress can mark the difference between the phonology of words which are otherwise segmentally identical (e.g., in English, *insight* vs *incite*). In contrast, lexical stress is fixed in other languages, occurring consistently on specific syllable *loci*. Speakers of languages without contrastive lexical stress (e.g., French, Hungarian, Welsh) often experience 'stress deafness' - a difficulty in discriminating between stress patterns of languages with variable stress [19,20]. Despite this, results suggest that age of acquisition and degree of exposure to a language with variable stress increases sensitivity [21–23]. Furthermore, whilst stress deaf individuals struggle to consciously identify and discriminate between stress patterns, a host of EEG experiments have shown brain sensitivity to stress, and particularly to violations of native fixed stress patterns [24–27]. For speakers of languages with non-contrastive stress, it is thought that stress may not be encoded in the phonological representation of words in their mental lexicon [28], as during language acquisition infants are able to infer whether stress is lexically contrastive prior to the establishment of the lexicon [21]. Instead, this sensitivity to native fixed stress patterns has been proposed to reflect pre-lexical stress templates [26].

Consistent with the fact that L1 accent transfers from the first language to the second, L1 stress patterns have been shown to influence the production and comprehension of L2 lexical stress [29–32]. Furthermore, although Lagrou, Hartsuiker and Duyck [7,8] suggest that L1 accent may decrease intelligibility of L2 speech, or increase L1 activation, accent entails a host of segmental characteristics (e.g., realization of phonemes) and suprasegmental features (e.g., prosody, including intonation, timing and stress) [16,17]. The question thus arises to what extent individual suprasegmental features contribute to these effects. The existence of different lexical stress systems across languages provides an opportunity to explore the effects of L1 suprasegmental features on L2 processing.

Two languages with such contrasting stress systems are English and Welsh. English lexical stress is variable and, despite generally conforming to certain rules, may occur on any syllable within a given word. Stress is indicated for the most part through vowel reduction (e.g., the difference between the vowel sounds in the first syllables of the noun *conflict* and the verb *conflict*), or a combination of suprasegmental features including an increase in pitch, duration and amplitude of the stressed syllable [33–36]. In contrast, lexical stress in Welsh is highly regular, consistently occurring on the penultimate syllable. Although irregular stress does occur, this is an uncommon exception predominantly found in English loanwords [37]. In comparison to English, the relative paucity of research on Welsh lexical stress means that the intricacies of its realisation and perception are less well understood, and consequently remain subject to some debate. Although the current understanding of Welsh lexical stress is incomplete, it appears to be realised on the basis of two key characteristics: shorter duration and lower pitch of the stressed penultimate syllable relative to the unstressed ultima. Thus, contrary to that of the majority of European languages [38], in which the stressed syllable is generally characterised by higher pitch, and greater duration, loudness and salience of the vowel, Welsh stress features both phonetic and phonological prominence of the final unstressed syllable relative to the stressed penult [39]. Despite the unusual linguistic context in Wales, in which Welsh, whilst increasingly spoken as a native language, coexists alongside English with

Welsh monolingualism existing solely in some pre-school children, evidence suggests that stress realisation in Welsh has not entirely converged to resemble that of English [37].

In the present study, we manipulated lexical stress and native speaker accent in a cross-modal priming paradigm (Fig. 1) to investigate how lexical stress and accent differentially affect lexical access. Highly-fluent Welsh-English bilingual participants were asked to make semantic relatedness judgments on English word pairs, with trisyllabic auditory primes manipulated so as to feature stress on the 1st, the 2nd (penult) or the 3rd (ultima) syllable. For all target stimuli, first syllable stress was consistently correct, corresponding to natural productions in English. Although second and third syllable stress were anomalous in English, the phonetic and phonological prominence of third syllable English stress best approximated Welsh penultimate stress, which is operationalized through increased duration and high pitch on the following (ultima) syllable. Critically, Welsh translation equivalents of the primes were also trisyllabic words.

To differentiate between the effects of lexical stress as an isolated feature of the L1 (lexical stress) with that of accent as a whole, we manipulated speaker accent in a cross-factorial design. All primes in the 3 stress conditions were therefore produced by an L1 English speaker on the one hand, and an L1 Welsh speaker on the other. The English speaker selected was a monolingual with a SE accent, whilst the Welsh speaker was a non-native English speaker, with a regional accent typical of the Llyn Peninsular in North Wales. The Welsh speaker was selected from this area as it is a notably Welsh-dominant area. Consequently, whilst the population in Wales consists of a large number of native speakers of English with Welsh accents, it would be atypical to find a native English speaker with an accent characteristic of that of this region. The presence of L1 accent in L2 speech is thought to result in an increase in cross-language activation and reduced L2 intelligibility (Lagrou, Hartuiker [8,9]. Therefore, the inclusion of an accent manipulation, with stimuli produced by a native Welsh and native English speaker, served to both to enable comparison between the effects of L1-approximate lexical stress with that of accent on L2 intelligibility, and of L1 accent vs. stress as an isolated feature on L1 activation. Furthermore, due to variability in stress realization across the two languages, it was thought that the native English speaker would be unlikely to produce the language-specific features of lexical stress in Welsh. While the stress manipulation altered the position of stress within the word, the accent (speaker) manipulation altered the phonetic realization of stress, thus enabling us to determine whether specific differences in the phonetic parameters of stress differed in their effects on language processing.

In two experiments we tested the effects of L1 accent and lexical stress patterns on L2 semantic priming (Experiment 1) and implicit phonological priming through the L1 (Experiment 2). The two experiments were run together with each experiment serving as filler items for the other.

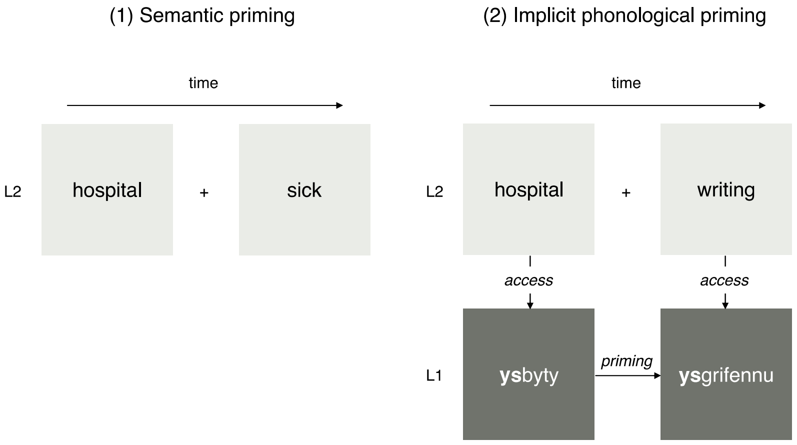


Figure 1. – (1) Semantic priming paradigm (Experiment 1) and (2) implicit phonological priming paradigm (Experiment 2). In both experiments, participants hear an L2 prime word, which is followed by a visual word target. For the implicit priming paradigm, unconscious access to L1 translations with word-initial phonological overlap results in implicit priming between otherwise unrelated L2 word pairs.

Experiment 1 tested the effects of lexical stress and accent on semantic integration. If, as native speakers of a fixed stress language, Welsh-English bilinguals process stress based on language-specific, pre-lexical stress templates [26], L2-anomalous stress should be processed with relative ease (i.e. causing minimal interference to semantical processing) when congruent with the L1. Thus, semantic processing of prime words with 3rd syllable stress should prove easier than 2nd syllable stress, since the latter fits neither the correct stress pattern of the English primes nor that of Welsh. We consequently predicted that the stress manipulation would interact with relatedness, resulting in an increase in N400 amplitude for 2nd syllable stress primes relative to 3rd syllable stress in the case of related pairs (since unrelated pairs have no reason to show priming effects). Alternatively, if stress templates are encoded within the lexical entry, naturally stressed primes should induce greater semantic priming relative to incorrectly stressed primes irrespective of goodness of fit with L1 Welsh, and thus, both 2nd and 3rd syllable stress should incur the same increase in N400 amplitudes. In both cases, we predict that ERP priming effects would occur in the classic N400 time window spanning 350 – 500 ms [37]. For both hypotheses, we predicted that reaction times and accuracy would be along the same lines as predictions for ERP results, such that, on the one hand, 2nd syllable prime stress would result in longer reaction times and lower accuracy, or alternatively, this would be true of both 2nd and 3rd syllable stress primes. Finally, if accent were to reduce intelligibility of the prime as hypothesized by Lagrou et al. [8,9], we would also expect an interaction between accent and semantic relatedness.

Experiment 2 tested whether stress and accent differentially affect unconscious access to L1 phonological representations. Prior research has shown that phonological overlap through L1 results in a priming effect, attributed to unconscious native language activation [40,41]. To test whether accent and stress influence L1 activation in an L2 context, we manipulated phonological overlap in the L1 translation equivalent of L2 English primes and targets, such that certain word pairs featured a word-initial phoneme overlap if translated into Welsh, e.g., hospital ('ysbyty') – writing ('ysgrifennu) (see Fig. 1). Note that all word pairs in this section of the experiment were semantically unrelated (see Methods). We hypothesised that (i) native accent would heighten activation of L1 phonological representations, resulting in an increase in implicit phonological priming, and (ii), if Welsh-approximate stress were to increase native language activation, that 3rd syllable stress (compatible with Welsh) would result in increased phonological priming irrespective of accent. We predict that such priming effects would manifest as a reduction of ERP mean amplitudes between 200 – 400 ms over centroparietal electrode sites for word pairs with phonological overlap in the L1 (i) with Welsh-accented primes and (ii) with third syllable stress primes. Our time window of interest, and the topography selected was in accordance with prior research demonstrating that phonological processing and expectancy influences ERPs within the range of the phonological mapping negativity [42–45], N250 - P325 [46–49] and early N400 [40,41,50,51] over centroparietal regions. Consistent with prior studies of implicit phonological priming [40,41], we predicted no effect of either accent, stress or overlap on behavioural measures.

2. Materials and Methods

2.1. Participants

Twenty-one Welsh-English bilinguals (14 females, mean age = 24.3; *SD* = 8.6) with normal or corrected-to-normal vision, no learning disabilities, and self-reported normal hearing participated in the experiment. All participants gave written informed consent before taking part in the experiment (approved by the School of Psychology, Bangor University ethics committee, approval no. 2017-16168). All participants began learning Welsh prior to the age of three at home, and had studied

through the medium of Welsh up to the age of 12. Age of acquisition for English varied, although only participants who had learnt English either as a second language through formal school tuition, or subsequent to Welsh in a bilingual home were included. For participants who had learnt English formally as a second language at school, tuition did not begin prior to the age of six. All participants except one were right-handed. Table 1 shows participants' language background for the L1 (Welsh) and L2 (English).

Table 1. Participants' language background.

Measure	Mean	SD
Age of Welsh acquisition	0.2	0.9
Age of English acquisition	3.8	2.29
Daily Welsh usage (%)	64.5	20.2
Daily English usage (%)	35.2	19.5

2.2. *Materials*

Auditory word primes were 39 trisyllabic English words digitally recorded in English by both a female native English speaker and a female native Welsh speaker at a sampling rate of 48.8 kHz and resampled using Audacity to 44.1 kHz to ensure compatibility with E-Prime stimulus presentation software. For each recording, the prime was produced with stress on the first, second or third syllable in both a Welsh and an English accent, creating six contrasting recordings for each prime word (see Table 2). During prime recording, the speakers were initially instructed to practise stress manipulations by changing pitch, duration and loudness of each syllable, whilst producing the same vowels in each case. Inspection of recordings was conducted syllable-by-syllable to ensure no vowel reduction could be auditorily perceived.

Visual word targets were two lists of 117 words of English varying in length from 2 – 4 syllables. Whilst the same auditory primes were used in both the semantic relatedness and phonological overlap conditions, two discrete target lists were used in order to manipulate phonological overlap and semantic relatedness separately. Prime and target words were paired to form experimental conditions as follows: (1) Semantic relationship (related condition), as in *hospital – sick* (in Welsh: *ysbyty - gwael*); (2) No semantic relationship (unrelated condition) using target stimuli from the same list as condition (1), as in *hospital – publish* (in Welsh: *ysbyty – cyhoeddi*), (3) Phonological overlap via Welsh translation (overlap condition), as in *hospital – writing* (in Welsh: *ysbyty – ysgrifennu*); and (4) No overlap through Welsh (no overlap condition) using target stimuli from the same list as condition (3), as in *hospital – rock* (in Welsh: *ysbyty – craig*). In the critical manipulation for Experiment 1 (related condition vs. unrelated), the prime and target were either semantically related or unrelated. For all semantically unrelated conditions (2 - 4), there were no listed associations between prime and target pairs in either the Edinburgh Associative Thesaurus [52] or the University of South Florida Free Association Norms [53] (mean = 0, SD = 0), whilst the semantic relationship condition (1) featured a greater degree of associations (mean = 3.0, SD = 8.9). In the critical manipulation for Experiment 2 (overlap condition vs. no overlap condition), the L1 translations of prime and target words overlapped or did not overlap in their initial onset phonemes. The phonological overlap was selected consistent both with the prediction of the Cohort Model [54,55], namely that word candidate activation occurs within the first 150 - 200 ms of auditory input (roughly corresponding to the first 1-2 phonemes of a word), and with prior research demonstrating ease of processing for L2 words sharing initial consonants with L1 translations equivalents [56].

Each auditory prime word was paired with three possible visual word targets in order to display a different target for each of the three stress recordings, resulting in 117 (3 x 39) prime-target combinations per list. To minimise effects of familiarity, lexical frequency, word length, and concreteness, all words were familiar and had mid-range lexical frequency. Primes and targets were matched across conditions for lexical concreteness and frequency. Frequency measures for English materials were calculated from SUBTLEX [57] (mean = 4.64, *SD = 0*.70). An analogous corpus is not available for Welsh, so frequency measures for Welsh materials were calculated from Cronfa

Electroneg o Gymraeg (CEG; [58]) (mean = 1.97, *SD = 0.65*). Concreteness measures for English materials were calculated from the *Concreteness ratings for 40 thousand generally known English word lemmas* corpus [59] (mean = 3.55, *SD* = 1.02), and, due to corpus unavailability, assumed to be similar for Welsh translations. Furthermore, 1st, 2nd and 3rd syllable versions of each prime were presented with a different target within participant. Critically, target words were rotated across conditions (1) and (2) on the one hand and across conditions (3) and (4) on the other, meaning that all targets featured in the semantically related condition also featured in the unrelated condition and all targets in the phonological overlap condition also featured as targets in the no overlap condition.

Table 2: Phonetic parameters for each stress condition by accent. Tables A1 and B1 Specify values for duration, intensity and F0 by syllable. Tables A2 and B2 specify the syllable by stress interaction for each measure, followed by posthoc comparisons by syllable.

A1. English accent

	1st syllable			**2nd syllable**			**3rd syllable**		
Stressed syllable	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
Duration	0.199	0.173	0.156	0.158	0.232	0.164	0.340	0.354	0.425
SD	0.061	0.058	0.060	0.050	0.056	0.054	0.117	0.115	0.107
Intensity	76.8	73.5	73.6	73.3	75.5	73.4	70.7	72.5	74.6
SD	1.69	2.46	2.39	2.33	1.87	2.34	2.10	2.61	1.85
Fo (mean)	226.8	189.8	187.2	184.0	202.3	187.2	158.3	157.4	171.5
SD	17.9	25.7	16.7	12.2	16.5	16.5	5.4	10.5	8.3

A2. Analysis (English)

Duration (ANOVA: F = 84.186, p < 0.001)			
	1st syllable	**2nd syllable**	**3rd syllable**
Stress 1 – stress 2	**p < 0.001**	**p < 0.001**	p = 0.301
Stress 1 – stress 3	**p < 0.001**	p = 1.000	**p < 0.001**
Stress 2 – stress 3	p = 0.102	**p < 0.001**	**p < 0.001**
Intensity (ANOVA: F = 84.404, p < 0.001)			
Stress 1 – stress 2	**p < 0.001**	**p < 0.001**	**p < 0.001**
Stress 1 – stress 3	**p < 0.001**	P = 0.094	p = 1.000
Stress 2 – stress 3	**p < 0.001**	**p < 0.001**	**P = 0.034**
Pitch (ANOVA: F = 81.870, p < 0.001)			
Stress 1 – stress 2	**p < 0.001**	**p < 0.001**	p = 1.000
Stress 1 – stress 3	**p < 0.001**	p = 1.000	**p < 0.001**
Stress 2 – stress 3	p = 1.000	**p < 0.001**	**p < 0.001**

B1. Welsh accent

	1st syllable			**2nd syllable**			**3rd syllable**		
Stressed syllable	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
Duration	0.190	0.173	0.144	0.132	0.220	0.132	0.314	0.330	0.369
SD	0.053	0.060	0.044	0.044	0.060	0.041	0.093	0.094	0.098
Intensity	72.3	71.9	71.5	69.6	72.6	70.6	73.3	71.6	73.4
SD	2.13	2.40	2.75	1.88	1.73	2.05	1.67	1.82	2.19
Fo (mean)	229.1	208.3	203.5	109.8	220.7	192.6	240.7	205.7	198.3
SD	42.4	42.2	42.3	25.1	49.0	47.5	55.8	65.9	78.2

B2. Analysis (Welsh)

Duration (ANOVA: F = 75.9, p < 0.001)			
	1st syllable	**2nd syllable**	**3rd syllable**
Stress 1 – stress 2	p = 0.447	**p < 0.001**	p = 0.373
Stress 1 – stress 3	**p < 0.001**	p = 1.000	**p < 0.001**
Stress 2 – stress 3	**p < 0.001**	**p < 0.001**	**p < 0.001**
Intensity (ANOVA: F = 26.614, p < 0.001)			
Stress 1 – stress 2	**p < 0.001**	p < 0.714	p = 405
Stress 1 – stress 3	p = 0.405	p = 1.000	**p < 0.001**
Stress 2 – stress 3	**p < 0.001**	p = 0.254	**p < 0.001**
Pitch (ANOVA: F = 5.842, p < 0.001)			
Stress 1 – stress 2	p = 0.197	p = 1.000	**p < 0.001**
Stress 1 – stress 3	**p = 0.024**	p = 0.754	**p < 0.001**
Stress 2 – stress 3	p = 1.000	**p = 0.007**	p = 1.000

2.3.Procedure

Participants were tested in two separate sessions separated by at least a day. Half of the participants were exposed to the Welsh-accented stimuli during their first session, whilst the other half heard English-accented stimuli first. Each testing session consisted of 468 trials, 234 forming the semantic relatedness paradigm and the remaining 234 forming the implicit phonological priming paradigm. A trial began with a fixation cross presented for the duration of 100 ms on a 17″ CRT monitor at a distance of 100 cm from the participant's eyes. The fixation cross was followed by an auditory prime, which was played over loudspeakers set around the monitor. Following the auditory prime, a second fixation cross was displayed for a variable ISI of 160–240 ms. This was followed by the visual target word, which was presented in black Times New Roman font, size 14 points on a light grey background. Participants were instructed to indicate whether prime and target pairs were semantically related via a button-press within a 2000 ms response window, and response-hand side was counterbalanced between participants. Participants' response immediately triggered the next trial. Prior to commencing the full experiment, participants underwent a brief training period to ensure they were familiar with the procedure.

2.4. Data analysis

2.4.1. ERP recording and pre-processing

EEG data were recorded at 2048 Hz using a BioSemi system with 128 active Ag/AgCl electrodes with the passive common mode sense (CMS) electrode as reference and driven right leg (DRL) as ground. Prior to recording, a cap was fitted to secure the EEG electrodes in place, and electrode impedances were reduced to < 5 kΩ. Six further facial bipolar electrodes positioned on the outer canthi of each eye and in the inferior and superior areas of the left and right orbits provided bipolar recordings of the horizontal and vertical electrooculograms (EOG). Participants were instructed to blink and make repeated vertical and horizontal eye movements during an EEG recording prior to the main experiments in order to acquire eye-movement data for subsequent correction. Data were resampled to 1024 Hz prior to analysis, re-referenced offline to the global average reference and filtered offline using a 30 Hz (48 dB/oct) low-pass and 0.1 Hz (12 dB/oct) high-pass Butterworth Zero Phase shift band-pass filter. Noisy electrodes were replaced on an individual basis by means of spherical interpolation. Ocular correction was conducted using Independent Component Analysis (ICA) following visual inspection of the data using the AMICA procedure [60]. Data were then

segmented into epochs ranging from −200 to 1000 ms relative to the onset of the visual target word, and baseline correction was performed relative to 200 ms pre-stimulus activity.

2.4.2. Modelling of behavioural data

For both experiments, reaction time data (RT) was log transformed so as to be normally distributed and analysed via a linear mixed effect model (*lmer* function in lme4). Fixed effects were centred to minimise collinearity, and random effects, including prime and participant intercepts and slopes were modelled and systematically trimmed such that interactions were removed until the model converged [61]. Subsequently, fixed and random effects and interactions that did not significantly contribute to model fit were systematically removed from the initial model. Accuracy data were submitted to generalized mixed-effects modelling (via *glmer* with a binomial link function in the lme4 v1.12 library [62]), after centring fixed factors to minimise collinearity. As in the reaction time analysis, random effects including participant and item intercepts and slopes were modelled and systematically trimmed until the model converged, and fixed and random effects and interactions that did not significantly contribute to model fit were systematically removed.

2.4.3. ERP analysis

In Experiment 1, mean ERP amplitudes were analysed in an epoch corresponding to the classic N400 window (350-500 ms) in which semantic priming is most observable over the central scalp regions [63] to determine whether prime stress influenced semantic integration processes. In Experiment 2, mean ERP amplitudes were analysed between 200 – 400 ms, consistent with prior research demonstrating that phonological processing and expectancy influences ERPs within the range of the phonological mapping negativity [42–45], N250 - P325 [46–49] and early N400 [40,41,50,51] over centroparietal regions.

ERP data were analysed by means of two repeated-measures analysis of variance (ANOVA), one for semantic relatedness (Experiment 1) and one for cross-language phonological priming (Experiment 2). In the case of the semantic relatedness manipulation, mean amplitudes for all time windows were analysed over 14 central electrodes where the N400 is usually maximal with accent (English, Welsh), prime stress (syllable 1, 2 or 3), and relatedness (related, unrelated) as independent variables. For the phonological priming analysis, the repeated measures ANOVA was conducted over 12 centroparietal electrodes with accent (Welsh, English), overlap in L1 (overlap, no overlap), and prime stress (syllable 1, 2 or 3) as factors.

3. Results

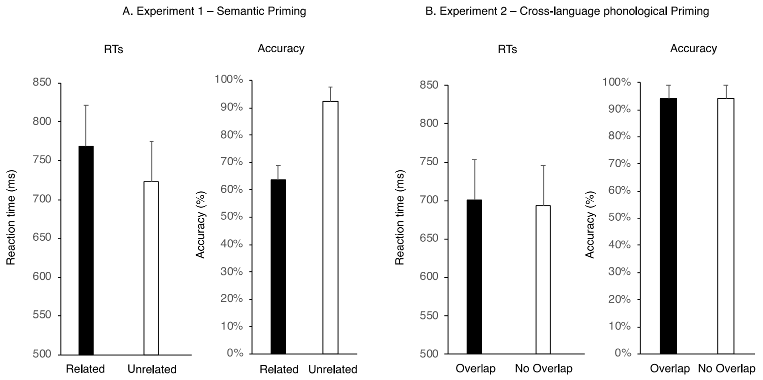


Figure 2. – Summary of the behavioural results in Experiment 1 and 2. A. Experiment 1, semantic priming. B. Experiment 2, Cross-language phonological priming. RTs: reactions times; error bars depict standard error of the mean.

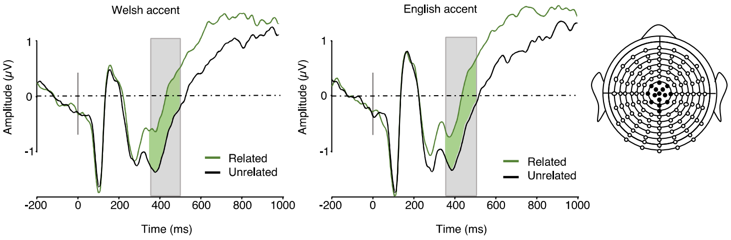
3.1. Experiment 1: Semantic priming

3.1.1. Behavioural results

RTs were modelled as a function of the three within-subject factors, accent (Welsh, English), prime stress (syllable 1, 2 or 3) and semantic relatedness (related, unrelated). Accent and stress fixed effects did not significantly contribute to model fit and were removed. Results revealed a main effect of semantic relatedness, with unrelated pairs responded to significantly faster than related pairs (b = -0.029, SE = <0.009, t = -3.22, p = 0.002). Accuracy data were submitted to generalized mixed-effects modelling, but the model failed to converge with all fixed effects included. Instead, data were analysed separately by accent. For Welsh-accented word pairs the fixed effect of stress did not significantly contribute to model fit and was removed from the model. There was a significant effect of relatedness (b = 1.376, SE = 0.287, z = 4.78, p = <0.001), such that responses to unrelated stimuli were significantly more accurate than to related stimuli. For the English-accented analysis, the final model failed to converge and the random effects structure was consequently simplified until convergence was achieved. Simplification of the random effects structure did not affect the results of the model. The results revealed no effect of stress (b = 0.057, SE = 0.051, z = 1.12, p = 0.259) but a significant main effect of relatedness (b = 1.574, SE = 0.269, z = 5.84, p <0.001), such that accuracy for unrelated word pairs was again significantly higher than for related pairs, and a significant relatedness by stress interaction (b = 0.138, SE = <0.051, z = 2.70, p = 0.006). *Post hoc* tests found no effects of stress on accuracy for either unrelated (b = 0.115, SE = 0.160, z = 0.72, p = 0.471) or related stimuli (b = 0.080, SE = 0.047, z = -1.70, p = 0.080), although the latter just failed to reach significance.

3.1.2. Electrophysiological results

A. Semantic relatedness by accent



B. Semantic relatedness by prime stress

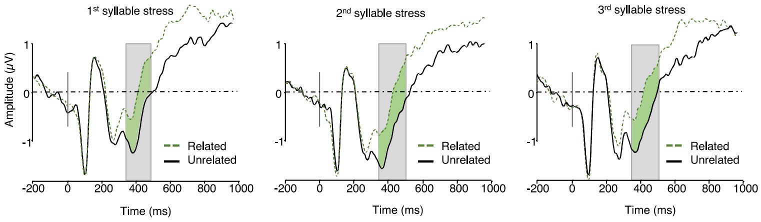


Figure 3. ERP plots from Experiment 1 (semantic priming) plotted for each of the two accents and each of the three stress conditions. (A) semantic relatedness effect by accent (no interaction). (B) semantic relatedness by stress (no interaction).

A repeated measures ANOVA on ERP mean amplitudes in the 350-500 ms time window revealed a significant N400 decrease by semantic relatedness, but no significant effect of stress or accent. Specifically, there was a main effect of relatedness (F(1, 18) = 19.80, $p < 0.001$, $\eta_p^2 = 0.524$) such that N400 amplitude was significantly more negative in the unrelated than the related condition for all stress and accent conditions (Fig. 3). There was no significant main effect of accent (F(1, 18) = 0.64, p = 0.802, $\eta_p^2 = 0.004$), but the main effect of stress was marginal (F(2, 36) = 2.84, p = 0.07, $\eta_p^2 = 0.137$). Explorative *post hoc* comparisons of the three stress conditions showed that 2nd syllable stress elicited greater ERP amplitudes than 1st syllable stress (t(18) = 2.35, *p* = 0.023). There was no interaction between relatedness and accent (**Fig. 2A**; F(1, 18) = 0. 16, p = 0.691, $\eta_p^2 = 0.009$); relatedness and stress (**Fig. 2B**; F(2, 36) = 0.10, p = 0.901, $\eta_p^2 = 0.006$); or accent and stress (F(2, 36) = 0.54, p = 0.582, $\eta_p^2 = 0.030$) and the three-way interaction was also not significant (F(2, 36) = 0.24, p = 0.781, $\eta_p^2 = 0.014$).

3.2. Experiment 2: Cross-language phonological priming

3.2.1. Behavioural results

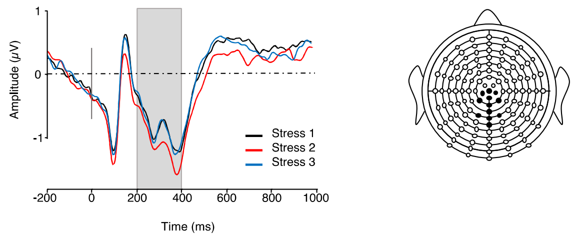
RTs were modelled for accent (Welsh, English), prime stress (syllable 1, 2 or 3) and L1 overlap (overlap, no overlap), centred to minimise collinearity. Accent, stress and overlap fixed effects did not significantly contribute to model fit and were removed. Therefore, as predicted, accent, stress and lexical overlap had no effect on RTs.

Accuracy data were submitted to generalized mixed-effects modelling and accent, prime stress and overlap were again centred to minimise collinearity. Random effects were modelled and systematically trimmed but the model failed to converge when all fixed effects were included. Data were analysed similarly to Experiment 1, modelled separately by accent. For Welsh-accented word pairs, the fixed effect of overlap did not significantly contribute to model fit and was removed. There was a significant main effect of stress (*b* = 0.239, *SE* = 0.076, *z* = 3.019, *p* = 0.002). *Post hoc* tests showed that accuracy in the 2nd syllable stress condition (Mean = 92%, *SE* = 5%) was significantly higher than that of the natural 1st syllable stress condition (Mean = 91%, *SE* = 5%, *b* = 0.431, *SE* = 0.180, *z* = -2.40, *p* = 0.043) and this was also true when comparing 3rd to 1st syllable stress (Mean = 93%, *SE* = 5%, *b* = 0.543, *SE* = 0.185, *z* = -2.94, *p* = 0.009). There was no significant difference between 2nd or 3rd syllable stress (*b* = 0.111, *SE* = 0.198, *z* = -0.56, *p* = 0.839). There was no effect of accent, stress or overlap for English accented word pairs, with the three fixed effects not significantly contributing to model fit and removed from the model.

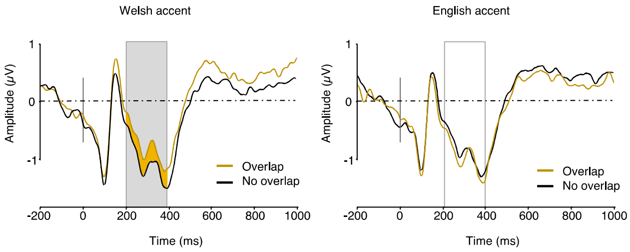
3.2.1. Electrophysiological results

The repeated measures ANOVA conducted on ERP amplitudes in the 200-400 ms window revealed a significant main effect of stress (F(2, 36) = 5.56, p = 0.008, $\eta_p^2 = 0.236$, **Fig. 4A**). *Post hoc* analyses showed that ERP mean amplitudes were significantly more negative for target words preceded by 2nd syllable stress as compared to natural 1st syllable stress primes (t(18) = 2.93, *p* = 0.006) and 3rd syllable stress (t(18) = -2.83, *p* = 0.007). There was no significant difference between target words preceded by 1st syllable stress primes relative to 3rd syllable stress primes (t(18) = 0.09, *p* = 0.92). We also found a significant interaction between phonological overlap and accent (F(1, 18) = 5.95, p = 0.025, $\eta_p^2 = 0.249$, **Fig. 4B**). Mean ERP amplitudes for overlapping pairs were significantly less negative than for non-overlapping pairs (t(18) = 2.35, p = 0.02) when primes were produced in a Welsh accent, but no such difference was found when primes were produced in an English accent (t(18) = 0.92, p = 0.36). Importantly, there was no interaction between phonological overlap and stress (F(2, 36) = 2.02, p = 0.693, $\eta_p^2 = 0.020$, **Fig. 4B**). No other main effect or interaction was significant.

A. Stress main effect



B. Native phonological overlap by accent



C. Native phonological overlap by prime stress

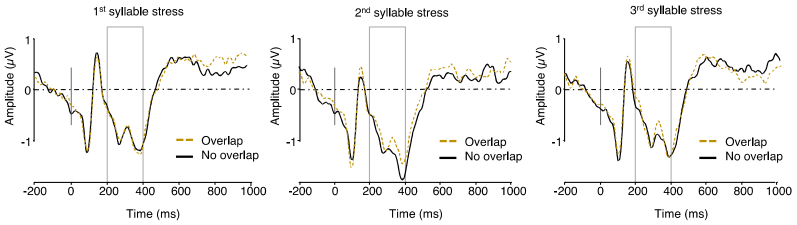


Figure 4. ERP plots obtained in Experiment 2 (cross-language phonological priming). (A) main effect of stress across both related and unrelated trials. (B) Phonological overlap by accent interaction (C) Phonological overlap by stress (no interaction).

4. Discussion

In the current study, we investigated whether lexical stress and accent differently modulate semantic processing (Experiment 1) and cross-language lexical activation (Experiment 2) in highly proficient Welsh-English bilinguals. In Experiment 1, unrelated word pairs were responded to significantly faster, and with greater accuracy than related pairs. ERP results revealed a classic effect of relatedness on N400 amplitude and a marginal main effect of stress driven by 2nd syllable stress primes. Notably, there was no effect of accent in Experiment 1 and no interaction between accent and stress. As expected, in Experiment 2 there was no effect of accent, stress, or lexical overlap on RTs, but surprisingly responses to targets following Welsh-accented primes featuring 2nd or 3rd syllable stress were more accurate than responses to 1st syllable stress. In the ERP data we found an implicit priming effect, with significantly less negative mean amplitudes for stimuli overlapping through L1 when primes were produced in a Welsh accent. Finally, we found a significant main effect of stress, with ERP amplitudes for 2nd syllable stress primes significantly more negative than 1st or 3rd syllable stress primes.

4.1. Experiment 1

Accuracy results for Experiment 1 represent classic semantic priming effects, in that unrelated word were generally responded to with higher accuracy than related words [64]. In contrast, reaction time results were unexpected, with faster responses to unrelated words than related words contrasting with that classically reported in semantic priming paradigms [65,66]. We speculate that the reduced RTs in response to related word pairs may relate to two characteristics of the experimental design: (i) Prime words were repeated 12 times, albeit with three different stress patterns and in two different accents. This may have led participants to generate incorrect expectations about any given prime (e.g., having heard a prime paired with a related target once, another iteration of the same prime word may have led to expecting an unrelated target). (ii) Given the design of the study, only 25% of word pairs were semantically related, making related pairs overall infrequent and less expected. In contrast, N400 modulation showed expected semantic priming effects, thought to index the spread of activation through the conceptual system [60]. Behavioural results and N400 effects were thus not perfectly aligned as has been shown repeatedly in ERP studies of semantic processing in which behavioural data were recorded [40,64]. This result is consistent with the view that the N400 is mostly insensitive to explicit task requirements or conscious evaluation of the stimuli [63].

In Experiment 1 we hypothesized that, as speakers of a fixed stress language, Welsh-English bilinguals may process stress based on language-specific, pre-lexical stress templates. This should have resulted in increased N400 amplitude in the 2nd syllable stress condition as compared to both the 1st syllable stress condition (natural stress), and the 3rd syllable stress condition, given that the latter best approximates Welsh stress pattern. Instead of the anticipated stress by relatedness interaction, our results showed a marginal main effect of stress driven by 2nd syllable stress primes. Although marginal, and thus any interpretation should be tentative, the effect suggests that 2nd syllable stress interfered with the processing of visual word targets, irrespective of semantic relatedness or accent. Therefore, contrary to primes stressed incorrectly on the 2nd syllable, words produced with incorrect stress patterns compatible L1 (Welsh, 3rd syllable stress) may not have repercussion for the processing of visual word targets. This may resemble a kind of stress priming effect which will require further validation in the future.

Beyond this, we sought to differentiate between the effects of lexical stress (as an isolated feature) and speaker accent to test the proposals put forward by Lagrou *et al.* [8,9] that L1 accent, when present in the L2, results either in heightened salience of the L1 or overall reduced intelligibility. In Experiment 1, we found no effect of accent on reaction times, accuracy or, critically, N400 mean amplitudes. Neither did we find any interaction between accent and semantic relatedness. This suggests that native accent in a second language context does not measurably affect intelligibility, since such an effect should have resulted in a modulation of the N400 effect across accent conditions.

4.2. Experiment 2

In Experiment 2, we found a main effect of stress on accuracy for Welsh-accented primes. This effect is not easy to interpret, because: (i) it was very small in size (maximally 2% accuracy difference); (ii) the full model testing the accent by stress interaction failed to converge and thus we cannot assume that there is an interaction between the two factors; and (iii) we must keep in mind that in Experiment 2, all prime-target word pairs were unrelated in the context of a semantic relatedness judgement task. For the latter reasons, we refrain from over-interpreting this result.

As predicted, however, in the ERP data we found an interaction between speaker accent and L1 phonological overlap on mean ERP amplitudes between 200 and 400 ms post target onset. For Welsh-accented primes, ERP amplitude was significantly less negative when prime and target words phonologically overlapped though L1 Welsh translations relative to the no overlap condition. We interpret this result as evidence of heightened L1 salience when primes were heard with a native accent, consistent with the latter of the two proposals put forward by Lagrou et al. [8,9]. Where

Experiment 1 results failed to provide evidence in favour of reduced intelligibility by native language, the latter result points toward increased L1 salience.

Furthermore, ERP results of Experiment 2 unexpectedly revealed a main effect of stress, manifesting as greater negativity in the 200 – 400 ms time-window for 2nd syllable stressed primes relative to 1st and 3rd syllable. Strikingly, this pattern is consistent with the main prediction we made for Experiment 1, namely that Welsh-English bilinguals would struggle processing stress patterns that are anomalous both with regard to the L1 and the L2. It may be considered surprising that 3rd syllable stress appeared easier to process than 2nd syllable stress, given the paucity of its occurrence in trisyllabic English words [68]. However, given that 3rd syllable stress was processed by participants in a manner similar to natural stress, we propose two interpretations for this observation:

Firstly, for speakers of fixed-stress languages, pre-lexical stress templates, developed in early L1 acquisition, may remain active in L2 processing. English (the L2 language in this experiment) is a variable stress language. Although studies report a varying role of stress in word recognition in English [69–72], lexical stress does appear to be at least partially encoded in lexical entries. As second language English speakers, however, Welsh-English bilinguals are thought to process stress in the L2 on the basis of pre-lexical L1 stress templates. When speakers of phonologically-fixed stress languages (stress that is based on phonological rules such as syllabic structure or vocalic peaks, as opposed to morphology) learn their language in infancy, it is thought they are able to establish whether their language features contrastive stress prior to the establishment of a lexicon, that is, pre-lexically [21]. Furthermore, this process of figuring out how stress matters seems to influence the degree to which stress is encoded as a feature within the lexicon [19,21,73]. This pervasive influence of L1 stress patterns may contribute towards an understanding of stress deafness. Sequential bilinguals learning a second language with variable stress, thus may lack the strategies that enable them to lexically encode suprasegmental features, or an inability to discriminate between stress patterns of variable-stress languages. It is therefore possible that our results break new ground by showing that highly fluent bilinguals understand stress in the second language on the basis of established native-language representations such as these fixed stress templates. If Peperkamp [64] and Dupoux [20] are correct, in the case of Welsh-English bilinguals, the insensitivity to lexical stress developed in infancy would mean that they are unable to incorporate stress information into the lexical entries of subsequently acquired L2 words.

Alternatively, the reason why responses to natural and 3rd syllable stress did not differ may relate to the fact that English is a language with both primary and secondary stress. Primary stress refers to the strongest emphasis of a syllable within a given word, and secondary stress corresponds to syllables which are stressed albeit to a lesser extent than the primary stressed syllable. When hearing primes with 3rd syllable stress, participants may have processed the word up to the end of the second syllable, whilst assuming secondary stress on the 1st syllable. Consequently, they would have reached the uniqueness point of recognition prior to perceiving the anomalous 3rd syllable. If so, it is possible that the correct word may have been selected even when primes were incorrectly pronounced with 3rd syllable stress. The data collected in the present study cannot tease apart these two interpretations, and future experiments involving stress manipulations in bilinguals will hopefully resolve this question.

Finally, the Experiment 2 sought to determine the degree to which stress and accent differentially affect parallel language activation in bilinguals. Remarkably, we found that stress did not interact with L1 phonological overlap and, by itself, failed to modulate cross-language activation. In contrast, the L1 accent by overlap interaction supported prior suggestions that native accent may heighten L1 salience in an L2 context [8,9]. The lack of interaction between stress and accent points to independence between these characteristics of language regarding their respective contribution to cross-language activation and lexical processing in highly fluent bilinguals. Whilst native accent heightens the activation of the non-target native language, native-like lexical stress patterns appear to have no such effect. Instead L2 stress patterns congruent with those of the native language appear to be processed with relative ease, an effect possibly deriving from pervasive L1-generated, pre-lexical stress templates.

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