The role of word accents in semantic processing in South Swedish

An ERP study with minimal pairs

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Abstract

Prosodic cues can aid speech processing by adding semantic information in lexical tones or functional information in intonational tones. Swedish word accents are considered to have stronger grammatical functions than semantic roles, although they are shaped by both lexical and intonational information structure. This has been repeatedly observed by studies using event-related potentials (ERPs), functional magnetic resonance imaging (fMRI) and reaction times, confirming that a maximal prosodic word containing a word accent is processed by decomposition of the word into partaking morphemes. The present thesis investigated another aspect of the contrast, in which the tonal representation is associated with different semantic features. A perception experiment was conducted, and contextual constraints were used to elicit predictions of semantic features of the upcoming words. Word accent incongruency caused a longer reaction time, implying that word accents play a role in the comprehension of an utterance. An N400 effect was observed, indicating that the accent tones and the word forms can be stored together in one unit in the mental lexicon. A difference in ERP was also found between the two word accents. Accent 1 also had a greater negativity compared to accent 2, starting already at 230 ms after the word onset. This was interpreted as a pre-activation negativity (PrAN), indicating that accent 1 gives a stronger predictive certainty even when different contexts are involved. It is concluded that word accents have a semantic function, in parallel with the previously supported morphological function.

Keywords: Word accents, spoken word recognition, prediction, ERP, N400

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Table of contents

List of figures

List of tables

Abbreviations

EEG	Electroencephalography
ERP	Event-related potentials
fMRI	Functional magnetic resonance imaging
PrAN	Pre-activation negativity

Chapter 1 Introduction

Speech is a multidimensional structure of information. While segments are rapidly produced in a linear fashion, prosodic layers add paralinguistic, pragmatic, or semantic variation to the ongoing message. Swedish word accents are one case where pitch variation interacts with the semantic domain. Swedish word accents are two types of distinctive melodies, and all words have either accent 1 or accent 2, although their surface realisations can vary based on their role in an utterance. Swedish word accents are, by definition, distinctive, implying that they can distinguish meanings (Elert 1964; Zetterholm & Tronnier 2017). However, it has been suggested that the word accents are used to distinguish different morphemes or to indicate that a word is a connected unit by marking the absence of boundary, rather than to distinguish meanings of lexical items (Elert 1964, 1972). These two functions of word accents have been actively studied in phonetics and phonology, as will be reviewed in the next chapter. Although a unique mechanism of word accents perception has been found, a question remains as to whether the contrast in word accents serves semantic processing in Swedish. The present master's thesis investigated the role of the word accents in semantic processing using electroencephalography (EEG).

Evidence is sparse that the Swedish word accents serve a contrastive function in the traditional sense. Firstly, the number of minimal pairs relying on this pitch pattern contrast is low (Elert 1972). Also, the pitch patterns of word accents tend to maintain their contrasts only when they have higher degrees of stress, as for Central Swedish (Malmberg 1966; Gårding, Eva & Lindblad 1973). There are even regional varieties of the language that lack tonal markings altogether, such as the dialects in Finland or Överkalix (Gårding, Eva & Lindblad 1973; Riad 1998; Althaus, Wetterlin & Lahiri 2021). Besides, this phonological contrast has functional redundancy with the morphological system (Rischel, J 1963; Elert 1972; Myrberg & Riad 2015). Additionally, accent 2 is generally manifested in words with at least two syllables making a considerable portion of the vocabulary not eligible to host it (Riad 1998).

Recent studies have focused on the perception and processing aspects of word accents based on the tight associations between Swedish word accents and morphology. The two phonetic profiles of the tones are not directly relevant to semantic features in Swedish. Rather, in a word form consisting of a stem and a suffix, the tone on the stem is induced by the suffix (Rischel 1963; Riad 1998). This makes it possible for listeners to predict how the word would end upon hearing the stem tone (Roll 2015; Roll et al. 2015; Söderström, Horne, Frid & Roll 2016; Söderström, Horne, Mannfolk, van Westen & Roll 2017; Söderström, Horne & Roll 2017). In brain imaging studies, it was found that word accents are processed through different brain routes depending on whether they have a semantic representation. While the processing of delexicalized items, such as pseudowords or non-words, was associated with a brain region involved in morphosyntactic rules, processing the real words was observed to rely on brain regions associated with lexical tone identification (Roll et al. 2015; Söderström et al. 2017; Schremm et al. 2018).

The two types of word accents do not occur with the same frequency. There are more suffixes co-occurring with accent 2 than accent 1, and all compound words have accent 2 in Central Swedish (Riad 2014, 2015). Thus, an accent 1 tone on the stem, i.e., a low tone in Central Swedish and a high tone in South Swedish, serves as a stronger cue for predicting how the word will end (Roll 2015; Roll et al. 2015). Beyond the prediction of the grammatical class of the word, evidence was also found that word accents facilitate fast speech processing, indicating that the word accents have an active role aiding spoken language recognition in Swedish (Roll 2022).

This study investigated the role of word accents among lexical items stored in the mental lexicon. A number of studies have focused on the predictive role of Swedish word accents, mainly centred around the tone–grammar association. There have also been studies on word accent processing in a delexicalized context, but a comparison has not yet been done between two words solely based on word accents. To investigate how word accents aid the processing of familiar words, a perception experiment was carried out involving minimal pairs and contextual constraints. Behavioural and electroencephalographic data were collected to analyse the neurophysiological aspects of word-accent processing.

South Swedish, a less studied regional variety, is chosen as the language of the investigation. The F0 pattern of the word accent distinction in South Swedish is invariant regardless of the presence of focal prominence (Bruce 1976). This leads to an assumption that South Swedish hosts a stronger presence of the prosodic elements attached to lexical representations, making it an ideal variety of the language for the current thesis, as it focuses on the association between the tonal accents and the whole word.

Against the backdrop of previous findings about the phonological specification and phonetic realisation of Swedish word accents and semantic prediction, the present thesis investigated whether word accents can have a lexical contrastive function during speech processing. The difference in the phonetic representation of accent 1 and accent 2 is evident, and it has been supported by previous studies that word accents on stem tones enable pre-activation of the upcoming word endings via the tight association between tone and suffix in the Swedish morphology. However, whether these differing phonetic cues facilitate semantic processing has not yet been directly tested. The present study focused on this question using minimal pairs where the members are distinguished only by their word accents. Since the two members in a minimal pair have different meanings, they are naturally associated with different semantic predictions, and this allowed me to test the association between the word accents and word forms. Three hypotheses and their test implications were formed to investigate word accents' function in semantic processing.

- Hypothesis $(H)_1$. Word accents are needed for semantic processing without a delay. Test implication $(TI)_1$. Reaction time increases for word accent – word meaning incongruence.
- H_2. Word accents are an inherent part of a word stored in full form in the mental lexicon. TI_2. Incongruent word accents result in an N400 effect.
- H_3. Accent 1 has a stronger contribution to semantic processing than accent 2. TI_3. Accent 1 yields a greater negativity effect than accent 2.

The rest of the thesis is organised as follows. Chapter 2 provides an overview of relevant theoretical backgrounds, encompassing the phonetic and phonological descriptions of the word accents. Recent findings on their roles in speech processing are discussed, as well as an electrophysiological instrument for measuring semantic prediction. Chapter 3 describes the data collection procedures including stimuli, experimental settings, and data analysis procedures. Chapter 4 presents statistical test results and the results are interpreted to answer the research question in Chapter 5. Chapter 6 concludes the implications of the findings and proposes a direction for future studies.

Chapter 2 Theoretical background

2.1 Swedish word accents

Word accents exist in North Germanic languages, and their surface representation varies among dialects. The two distinctive pitch patterns have been called accent 1 and accent 2, or acute and grave accents in Swedish; toneme 1 and toneme 2 in Norwegian; and stød and non-stød in Danish (Gårding, Eva 1989; Riad 2012, 2015; Zetterholm & Tronnier 2017). All Swedish words have either of the two accents. The following sections summarise findings and discussions from the previous studies about the Swedish word accent system.

2.1.1 Phonetic descriptions of the word accents

All Swedish words have either accent 1 or accent 2. Although the pitch patterns of the two are different, word accents inherently have an H+L string, for example in Stockholm Swedish, and each half of this sequence can be associated with the tone-bearing unit (TBU). In Swedish, TBU is a stressed syllable of a word, which means that the lexical pitch accent can only appear on a stressed syllable (Gårding & Lindblad 1973). The main stress is found on a heavy syllable, which has either a long vowel or a long consonant (Andreasson 2001). In Stockholm Swedish, a more widely studied variety of the language, accent 1 is represented when the low tone is associated with the stressed syllable, (H)L*, while accent 2 is represented when the high tone is associated with the stressed syllable, hence H*L. The two examples below show accent 1 and accent 2 appearing on the heavy stressed syllable of the words.

(1) värden [^{1}væːɖ̥ɛn] “the world”

(2) värden [^{2}væːɖ̥ɛn] “the value”

Additionally, a higher level of intonational tone H^f follows the previously explained accent patterns, yielding $(H)L^*H^f$ pattern for accent 1 and H^*LH^f pattern for accent 2 (Bruce 1977; Riad 2014). In other words, accent 1 begins with a rising contour in the stressed syllable, whereas accent 2 starts with a falling pattern in a focused position (Bruce 1977). *Figure 1* below illustrates the pitch contours of the word accents and their realisations in focused and non-focused positions in Central Swedish. In a focused position, accent 1 (black solid lines) has a L*H pattern, as in the word ^{1}*manen* "the mane", whereas ascent 2 (grey solid lines) has a H*LH pattern, as in the word ^{2}*manar* "manes". In an unfocused position, accent 1 (black dashed line) has a (H)L* contour on the stressed syllable, without the additional focal H following, whereas accent 2 (grey dashed line) has a H*L trajectory without an additional focal H (Roll 2022, p. 2).

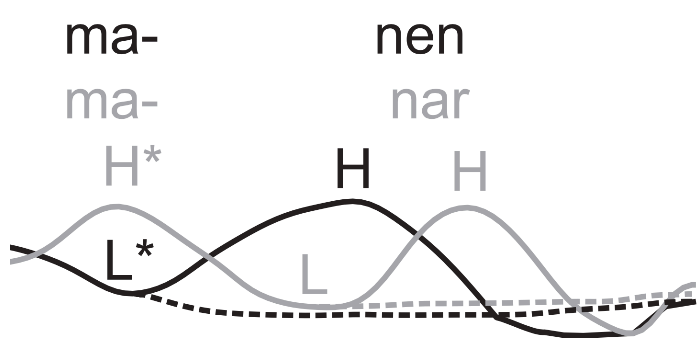

Figure 1. Pitch contours of accent 1 and accent 2 in Central Swedish (Roll 2022)

The difference between accent 1 and accent 2 is primarily the timing of the same contour (Bruce 1976). According to the Swedish intonation model (Bruce & Gårding 1978), word accents are the lexical high tone manifested at various time points as regards the stressed syllable. Thus, the absolute timing of the word accents differs between dialects, making the same F0 turning point an accent 1 in one dialect but an accent 2 in another. On the other hand, the relativity in timing between accent 1 and accent 2 remains consistent through dialects. In Central Swedish, the lexical high tone appears early in both word accents, while it is often acoustically unrealised in accent 1 as it is associated with a pretonic segment preceding the TBU (Bruce 1983).

In South Swedish, word accents are realised virtually in the opposite pattern to that of Central Swedish, as the stressed syllable begins with a higher tone in accent 1 than in accent 2 (Bruce 1976; Roll 2015). In other words, in South Swedish, the first half of the default word accent string HL is aligned with the stressed syllable in accent 1, resulting in a H*L pattern; while the high tone peak comes later in time in accent 2, resulting in L*HL pattern (Ambrazaitis & Bruce 2006). The difference between accent 1 and accent 2 is also visible in the F0 fall consecutive to the H tone. The F0 fall also comes earlier in accent 1 than in accent 2, complying with the relative timing system within the dialect (Bruce 1976). The falling pitch is observed to play an important role in the perception of words by enabling listeners to pre-attentively distinguish meaningful words (Gosselke Berthelsen 2021). A study using varying degrees of F0 rise and fall contours suggests that, for the perception of accent 2 as opposed to accent 1, both a slow rise of pitch contour at the word accent onset (rather than a jump to the high tone) and a late fall at the offset of the contour (rather than a plateau or an early fall) are necessary (Ambrazaitis & Bruce 2006). *Figure 2* below illustrates the pitch contours of word accent 1 (black line) as in *¹normen* “the norm” and word accent 2 (grey line) as in ²*norrmän* “Norwegians”.

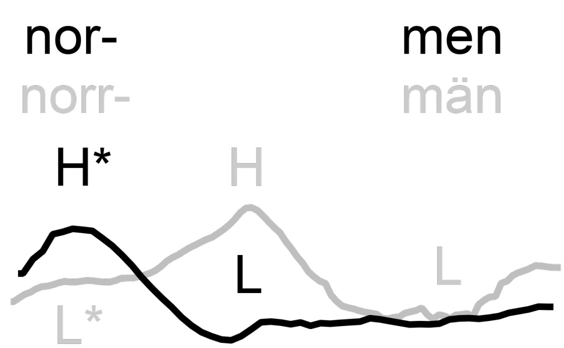

Figure 2. Pitch contours of accent 1 and accent 2 in South Swedish

In south Swedish, the onset of the stressed vowel is associated with an F0 peak in accent 1, whereas the F0 minimum appears in the same position in accent 2. This timing modulation is visible in both focused and non-fucused positions in a sentence (Bruce 1976). The accent 1 pattern appears earlier in time than in accent 2, which is consistent in other dialects. *Table 1* summarises the comparison between the Central and South Swedish.

Table 1. Phonology of Central vs. South Swedish word accents

	Central Swedish		South Swedish	
	Accent 1	Accent 2	Accent 1	Accent 2
Unfocused	(H)L*	H*L	H*L	L*HL
Focused	HL*H	H*LH	H*L	L*HL

Myrberg and Riad (2015) subcategorise the prominence level (or the focus level) of Bruce (1977) into a *big accent* and *small accent*, in order to avoid confusion between the phonological forms and the information structure of a constituent. The big accent deals with the form of the tonal pattern, which often accompanies an additional H, but it can also appear in a non-focal constituent (Roll 2006; Myrberg 2010, 2021). The current study collects word accent data from the focal positions in utterances, and thus the term "focal accent" is relevant.

2.1.2 Morphological structure of word accents

All monosyllabic words have accent 1. Polysyllabic words can have accent 1 or accent 2. Accent 2 is either lexically driven or post-lexically driven. That an item is *lexical* implies that it is a memorised form that exists in the mental lexicon or forms that can be derivates by grammatical rules (Riad 2015). Accent 2 is generally assigned by suffixes, such as *-ar* "-PL" or *-te/de* "-PST" inducing a high tone onto the preceding stem (Rischel 1963; Riad 2015). Rischel (1963) explains that a word's tonality depends on the post-stress syllable, which carries an inherent tone that is manifested in the stem. For example, a derivate form such as ^{1}*andar* "spirits" has an accent 2 induced by the singular definitive suffix. There are a few cases of accent 2 assigned by a stem vowel, such as in ^{2}*ande* "spirit", where the stem vowel -e induces an accent 2 on the stem. The other case of accent 2 is found in compound words, which is caused by having two stresses in one maximal prosodic word, such as in ²*mellan+mål* “snack”. This is a phonologically conditioned pitch pattern and not by the lexical specification of the word, hence post-lexically driven accent 2. *Table 2* below summarises the types of accent 2.

Table 2. Morphological structure of accent 2 inducing

Word	Morphological structure	Accent 2-inducer	Induction type
andar “spirits”	and-ar	suffix	Lexical
ande “spirit”	and-e	stem tone (-e)	Lexical
mellanmål “snack”	mellan+mål	compounding	Phonological/post-lexical

2.1.3 Phonological formation of word accents

The surface realisation of word accents involves an interaction between different levels of the phonological hierarchy. Myrberg & Riad (2015) modelled a prosodic hierarchy of Central Swedish based on the *culminativity* hypothesis[1]. The prosodic hierarchy consists of two domains of prosodic words, the phonological phrase, and the intonational phrase. The lowest level is the minimal prosodic word ($\boldsymbol{\omega}^{\text{min}}$), where a stress is culminative. This means that one and only one stress is assigned at the $\boldsymbol{\omega}^{\text{min}}$ level. One step higher is the maximal prosodic word ($\boldsymbol{\omega}^{\text{max}}$), where a word accent is culminative, implying that one and only one word accent is assigned in this unit. A $\boldsymbol{\omega}^{\text{max}}$ can have either single or multiple $\boldsymbol{\omega}^{\text{min}}$s. To sum, a one-to-one relationship is found, where the stress is mapped to $\boldsymbol{\omega}^{\text{min}}$, while the word accent is mapped to $\boldsymbol{\omega}^{\text{max}}$ (Riad 2014, p. 117). In the case of Central Swedish, the accent 2 tone H* is realised on the first stressed syllable and the prominence tone H is realised on the last stressed syllable, as found in the example below (Myrberg

[1] In stress-accented languages, metrical prominence in a language is operated by stressed. One of the criteria for a language to be categorised as a stressed-accented language is culminativity, which regulates that “every lexical word has at most one syllable marked for the highest degree of metrical prominence” (Hyman 2006; see also Riad 2012) The other condition is *obligatoriness*, and this condition regulates that “every lexical word has at least one syllable marked for the highest degree of metrical prominence, i.e., primary stress” (Hyman 2006, 2009).

& Riad 2015, p.124). In the absence of secondary stress, the prominence tone is realised in the posttonic syllable.

(3) *jul-lovs-morgon*

^{2}((ˈjul) $_{\omega}{}^{min}$ (ˌlov-s) $_{\omega}{}^{min}$ (ˌmorgon$_{2}$) $_{\omega}{}^{min}$) $_{\omega}{}^{max}$

"Christmas break morning"

In South Swedish, some compound words can have accent 1 instead of accent 2, unlike in Central Swedish. Bruce (1973, 1974) presents a list of compounding types where the resulting compound words get accent 1 in South Swedish. These types are presented as *accent shift blocking*, meaning that a shift from accent 1 to accent 2 is suppressed, and the blocking is a function of the syllable numbers and stress locations in the participating minimal prosodic words. Approaching the question from a diachronic perspective, Frid (2000) observed that accent-shift blocking has become weaker in northern Skåne, where some compounds that previously had accent 1 now have accent 2. In southern regions, accent 1 still tends to prevail in some compound words, while the same words get accent 2 in the northern regions. Below is an example of a compound word having accent 1 in the south Skåne, found in Löderup and Norra Rörum.

(4) ^{1}*femtiolapp*

^{1}((ˈfemtio) $_{\omega}{}^{min}$ (ˌlapp) $_{\omega}{}^{min}$)$_{\omega}{}^{max}$

"a bill of fifty crowns"

The next higher level is the phonological phrase, which contains one and only one big accent, which is the head within this level. In a phonological phrase, all prosodic words that do not receive a big accent get a small accent. Yet a higher level is the intonational phrase, in which the rightmost big accent is the head, and therefore, a *nuclear accent*. The nuclear accent is also the head of a prosodic phrase. Heads of prosodic phrases that are not a head of an intonational phrase, hence appearing on the left side in relation to the nuclear accent, tend to have a reduced F0. (Myrberg 2021).

2.1.4 Contrastive function of the word accents

The contrastive function of the Swedish word accents has been much doubted. Elert (1972) provided an exhaustive list of the minimal pairs suggesting that Swedish word accents have a low functional load. Besides the small number, counting 357 pairs, many of these pairs involve archaic forms such as in ^{1}*boken* “the beech” vs. ^{2}*boken* “rotten” or cases that involve proper nouns or infrequent nouns, such as in ^{1}*joner* “ions” vs. ^{2}*joner* “Ionians”. Some pairs involve different word classes, such as in ^{1}*lov-en* “the vacation” vs. ^{2}*loven* “Praise!”, which makes it hard to see them as a truly contrastive pair, as the two words would not occur in the same syntactic position.

Based on the shortage of evidence that word accents are contrastive in Swedish, studies have suggested alternative roles for which word accents have survived despite their low functional load in terms of semantic contrast. Focusing on the formation of accent 2 pattern, which has either a morphological specification such as *man*-ar$_2$ “manes” or a phonological specification (post-lexically induced tone with more than one stress in a maximum prosodic word, populated by either compounding or inflexion in the maximum prosodic word), it can be assumed that the role of word accents is either to distinguish different morphemes or to provide the information that the string of segments under an accent 2 tonal contour belongs to the same word (Elert 1972, 1981; see Riad 2015 (pp. 174–176) and Roll 2022 (p. 3)).

2.1.4 Facilitative function of the word accents

While the distinctive function of the word accents is challenged, Roll (2022) provides an overview from a processing approach that points towards a facilitative function in speech processing. There are three lines of evidence identifying the role of word accents. Firstly, word accents enable prediction of how the word will end. Neurophysiological and corpus studies have observed that listeners start predicting which suffix would end the ongoing noun phrase upon hearing the early part of the stem tone. In other words, listeners’ word recognition mechanism gets surprised when they hear that a word ends with an unexpected suffix. This becomes observable at the point where a mismatched suffix is heard because the brain has to re-analyse the structure of the heard information (Roll, Horne & Lindgren 2010; Roll, Söderström & Horne 2013; Roll 2015; Roll et al. 2015; Söderström, Horne, Mannfolk, van Westen & Roll 2018). The increased cognitive process is reflected in the ERP component 'P600,' which is an electrically positive brain wave reaching its peak amplitude at around 600 ms after a morphologically unexpected stimulus has been perceived (Rodriguez-Fornells et al. 2001). An enlarged P600 component can thus also reflect a failed expectation that has been built up by the stem tone, in other words, a prediction error. Among the two pitch contours, accent 1 is suggested to be a more useful cue for the pre-activation of the upcoming suffix, as it is associated with fewer continuations and, in turn, enables a higher certainty for the prediction. Counting the possible continuations of the unfolding word, word initial fragments (the initial speech segments including the first vowel which carries the stem tone) with accent 1 is associated with a 10.5 times smaller pool of potential candidates for continuation compared to accent 2 tone (Söderström, Horne, Frid & Roll 2016). These research outcomes reflect back on the tight relationship between word accents and morphological structure in Swedish, indicating that tone-suffix association is partially an automatic process, especially if a given word is stored as a full form in the mental lexicon. This predictive effect is even stronger for words with high frequency, which indicates direct access to their full form (Söderström, Horne & Roll 2017; Schremm et al. 2018).

Secondly, word accents assist the processing of unfamiliar words. When an unknown string of sounds is heard, a Swedish listener can refer to their knowledge of the tone-suffix association to decompose the structure of the item. This association has been investigated through non-words and pseudowords, where an accent 2 stem tone yielded brain activity in regions that process morphosyntactic structure in the absence of a full form representation (Söderström, Horne & Roll 2017b; Schremm et al. 2018). This indicates that listeners process the morphological structure to comprehend the perceived words using the pitch patterns of word accents. Accent 2 is associated with a greater number of suffixes and compound words, and therefore, upon hearing the accent 2 stem tone, many candidates for the continuation of the unfolding word get activated, which can be a supporting argument for the connective function of word accents (Roll 2022, p.9). This decompositional processing pathway is suggested to be an indirect role of the Swedish word accent for perception.

Lastly, word accents facilitate faster processing of speech. Roll (2022) investigated the relationship between listeners' reliance on pitch information and their efficiency in word processing and found a correlation between these two cognitive processes. As illustrated in *figure 3*, listeners who rely more on pitch information during word processing tend to process valid words faster, indicating a facilitation effect of word accents.

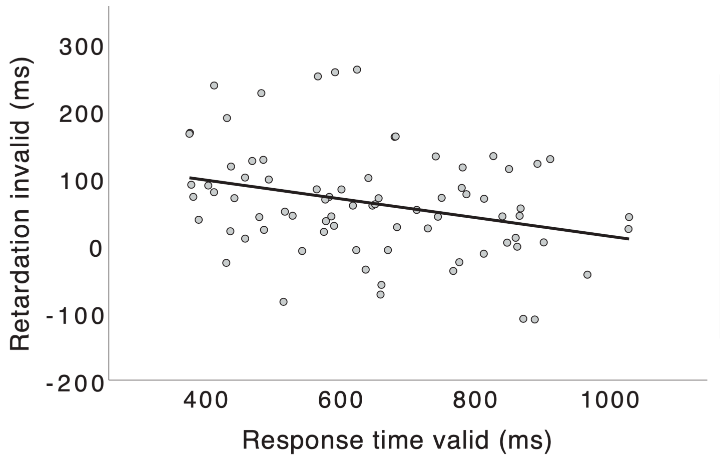

Figure 3. Response time for valid words as a predictor of retardation effect[2] (Roll 2022)

Bringing these findings together, Roll (2022) suggests that word accents have an essential role of facilitating word processing, by enabling the prediction of the word form via full form processing and decompositional processing.

[2] To quantify how actively participants employ the tonal cue when processing words, their reliance on word accents was operationalised by their *retardation effect*. The retardation effect was calculated by subtracting individual participants' response time for valid words from their response time for invalid words. The larger the retardation effect, the higher a participant's reliance on pitch information was assumed to be.

2.2 Lexico-semantic processing

2.2.1 Spoken word recognition and semantic prediction

The process of spoken word recognition breaks down into three basic functions: access, selection and integration (Marslen-Wilson 1987). Access is a process where the speech input is mapped onto lexical form representations. It is an automatic process and a direct shortcut between sensory input and items stored in the mental lexicon. The selection is a mediating process between the access and integration stages, where the best-fitting item in the mental lexicon is determined to match the sensory input[3]. The integration process maps the lexical item's syntactic and semantic information onto a higher unit for further processing of the utterance (Marslen-Wilson 1987).

The selection stage employs both bottom-up automatic feedforward processes and top-down influences from higher-level processes. Higher-order processing can influence the selection stage in the form of feedback in case of a failed selection, or even influence the selection process with prior knowledge or expectations (Friston 2005; Clark 2013). The predictive processing of the brain constantly generates hypotheses about the upcoming sensory input based on the information it previously had and updates the model with the outcome of the prediction with a goal of minimizing prediction error in the future. Therefore, spoken word recognition consists of both bottom-up and top-down processing.

Expectations on the semantic property of the upcoming word can be both internal and external to the lexical item in question. Words with a generally high frequency of usage are more expected in isolation (Rugg 1990). Contexts in the earlier part of sentences provide clues for expectation about the upcoming words (Kutas & Hillyard 1980; Kutas & Federmeier 2000). Some highly relevant words yield expectations for other words also to appear, because they often occur in association with each other (Frenck-Mestre & Bueno 1999) or because they share semantic categories (Federmeier & Kutas 1999).

[3] An extensive summary of different models for the selection process can be found in Hjortdal (2022).

2.2.2 Electroencephalography

Electroencephalography (EEG) is a method that captures electrical potentials caused by brain activities by placing electrodes on the scalp. The raw electroencephalogram is a coarse recording of multiple neural activities and noise blended together and therefore does not reveal much about different cognitive activities. To extract relevant information, the event-related potential (ERP) technique is applied. ERP can be extracted by probing neural correlates of specific cognitive activities using experimental stimuli, such as recorded speech for auditory processing. ERPs consist of electrically negative or positive deflections. The polarity does not have any meaning per se but can be used to identify specific neural patterns. ERPs are measured in the amplitude of micro-voltage (μV) which indicates the degrees of activity, and the scalp sites (electrodes) are relevant for the recorded activities (Luck 2014; Kappenman & Luck 2016). ERPs can provide information on brain activity in a highly granular time domain, which makes it an adequate method to test rapid events such as auditory processing of pitch patterns.

2.2.3 N400 and semantic processing

When a semantic expectation is violated, the cognitive reaction is reflected in the ERP component called N400 which is linked to lexical meaning processing of the brain. N400 is a negative-going deflection of electrical activity observed between 250-600 ms after the onset of a word with its peak amplitude at around 400 ms, and it is most strongly present in the central region of the scalp for auditory stimuli (Kutas, Marta & Hillyard 1980, 1984; Kutas, Marta & Federmeier 2011; Luck 2014). N400 amplitude is reported to be highly related to cloze probabilities, which is a proportion of persons choosing a specific word as the terminal word in a sentence in a large group of people. Unpredictable words elicit a larger amplitude of N400, which indicates that this component is related to lexico-semantic processing. Examples below are sentences where the terminal word has either a high or low relevance or probability with regard to the rest of the sentence (Kutas & Hillyard 1984).

(5) He liked lemon and sugar in his tea. (High probability)

(6) He liked lemon and sugar in his coffee. (Low probability)

Discussions on the N400 have focused on whether the component reflects lexical access in word recognition or integration of a recognised word within a context or both. The view that hypothesises that N400 reflects lexical access suggests that anticipation is an integral part of language processing, and the brain pre-activates certain features of words that are yet to be presented. A study using English terminal noun phrases found support for pre-activation of both semantic aspects of a terminal word and an indefinite article preceding the noun, reflected in an enhanced N400 at the article (DeLong, Urbach & Kutas 2005). In Mandarin where a noun is preceded by a classifier, a larger N400 effect was observed upon hearing an incongruent classifier, indicating pre-activation of semantic features. (Kwon, Sturt & Liu 2017). Such evidence of pre-activation suggests that language perception involves a rapid and incremental build-up of incoming information.

The integration hypothesis suggests that the N400 amplitude indexes the difficulty of integration of the retrieved word into the semantic context (van Berkum, Brown & Hagoort 1999; Hagoort 2006) and more predictable words are easier to integrate (Baggio & Hagoort 2011). There also has been an attempt to dissociate these two processes into earlier and later time windows respectively, indicating that N400 indexes both the lexical access modulated by the predictability of the target words and integration to a higher linguistic unit modulated by the plausibility of the target words (Nieuwland et al. 2020).

2.2.4 Pre-activation negativity

The pre-activation negativity (PrAN) is a left-lateralised negative-going ERP component observed between 136-280 ms after stimulus onset over frontocentral sites of the scalp. PrAN reflects pre-activation by phonological cues, and the amplitude is modulated by predictive certainty (Söderström et al. 2016; Roll et al. 2017). The predictive certainty becomes higher when there are fewer competitors for word recognition. The first two initial segments of a word elicit an increased

PrAN when there are fewer possible continuations (Roll et al. 2017). Words with a lower neighbourhood density also give rise to a PrAN effect (Söderström et al. 2016). Phonological cues that are less frequent and associated with fewer possible continuations elicits larger PrAN effect in Danish spoken word recognition, as well (Hjortdal, Frid & Roll 2022). This ERP component has actively been studied in regard to the Swedish word accents, focused on the association between accent tones and suffixes, providing evidence that the tonal cue in the stem pre-activates upcoming suffixes. As accent 1 is associated with fewer suffixes and no compounds (in Central Swedish), a stronger pre-activation is reflected in PrAN upon hearing accent 1 than accent 2 (Roll, Horne & Lindgren 2010; Roll, Söderström & Horne 2013; Roll 2015; Roll et al. 2015; Söderström, Horne, Mannfolk, van Westen & Roll 2018, Roll 2022).

2.2.5 The present study

Against the background of the previous findings presented above, the present thesis investigated whether word accents are processed and recognised as an inherent part of a stored representation, with semantic connections in addition to the morphological. An answer to this question would further explain the functional importance of this prosodic cue in processing of spoken Swedish, especially when the target words do not necessarily involve indirect processing via morphological decomposition. For this purpose, an experiment was designed to measure how an incongruency between accent tones and semantic specifications affects sentence comprehension (Research question 1). I hypothesised that word accents are necessary for rapid semantic processing (Hypothesis 1). The study aimed to answer whether a word accent incongruency can imply a semantic violation (Research question 2). Word accents were hypothesised to form an inherent part of words stored in full form in the mental lexicon (Hypothesis 2). Lastly, an attempt was made to investigate a functional difference between the two accents, as this difference has been an important factor in previous findings (Research question 3). Accent 1 was hypothesised to have a stronger contribution to semantic processing than accent 2 (Hypothesis 3).

Chapter 3 Method and materials

A perception experiment was conducted using spoken sentences as auditory stimuli. At the same time, electroencephalograms (EEG) were recorded. This chapter explains the procedures of data collection and analysis.

3.1 Participants

Twenty native speakers of South Swedish aged between 18 to 40 years old were recruited (M = 24.9, SD = 5.9, 11 female and 9 male). All participants were right-handed and reported having no hearing loss. All participants spoke English and most participants reported having learned an additional foreign language at school. Participants reported that the main language in their daily lives is Swedish. Participants gave informed consent before the experiment and were informed that they could withdraw from the experiment at any time.

3.2 Stimuli

The stimulus words were 42 minimal pairs of Swedish contrasting only in word accents. In other words, each pair had one member with accent 1 (e.g., ^{1}*moppen* “the mop”) and one with accent 2 (e.g., ^{2}*moppen* “the scooter”). In total, 84 words were selected for the experiment (42 pairs × 2 word accents).

Stimulus words were placed at the end of a sentence. The sentences were composed so as to form a semantic expectation towards one of the words in a minimal pair. Therefore, all stimulus words appeared in different contexts. Below are examples of the pair ^{1}*stubben* “the stubble” and ^{2}*stubben* “the stump”. The underlined words in each sentence prime a semantic expectation towards either member of the minimal pair.

(7) *Han vågar inte <u>raka bort</u>* ^{1}***stubben***.

“He does not dare to <u>shave off</u> **the stubble**.”

(8) *Bonden har <u>grävt bort</u>* ^{2}***stubben***.

“The farmer has <u>dug out</u> **the stump**.”

Sentences were recorded by a male speaker of South Swedish in an anechoic chamber. All sentences were read as an answer to a question, which was designed to elicit a focal prominence on the target word in the stimulus sentence. Each stimulus sentence was recorded four times, twice with the target words in the final position of the sentences and twice with an additional short phrase at the final position, such as *igen* “again”, *igår* “yesterday” or *sa jag* “I said”, in order to ensure that each target word was recorded with a focal prominence in at least some case among the four repetitions. Only the recordings with a focus realisation are chosen for stimuli.

The utterances were recorded using the audio editing program *Audacity* ver. 1.3.2 (Audacity team, 1999) and were saved into .wav files. Recorded files were prepared in *Praat* ver. 6. 2. 23 (Boersma & Weenink 2009). The recorded sounds were first cut into 336 files containing one sentence each. This gave 8 cases of recordings for each minimal pair. Among these 8 cases, one sentence containing a target word with accent 1 realised in a clear pitch contour and another sentence with accent 2 were selected. Speech style and general amplitude of the two sentences were selected to be similar, and when necessary, the amplitude of one sentence was enhanced to match the other counterpart in the pair. Then the two sentences were cut before the target word onsets and cross-spliced, making two sentences containing target words with an invalid word accent, as illustrated in *figure 4*.

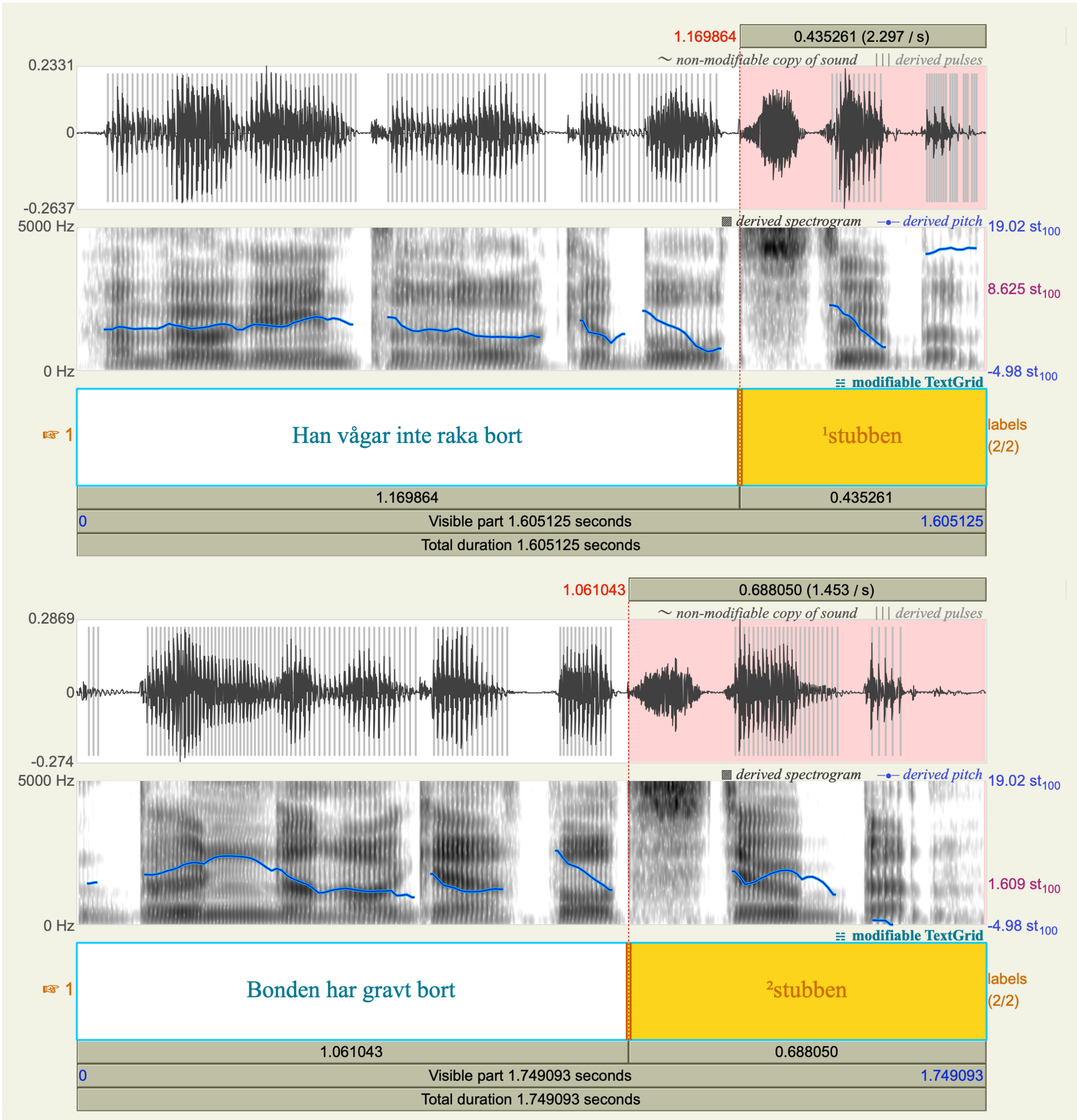

Figure 4. Making invalidly cued stimulus

This manipulation gave 84 new sentences with an invalid word accent in the target word. *Table 3* below shows a set of examples of stimulus sentences for the minimal pair ^{1}*stubben* "the stubble" and ^{2}*stubben* "the stump".

Table 3. Examples of valid and invalid stimulus sentences

Condition	Accent 1	Accent 2
Valid	*Han vågar inte raka bort* ^{1}***stubben***.	*Bonden har grävt bort* ^{2}***stubben***.
Invalid	*Han vågar inte raka bort* ^{2}***stubben***.	*Bonden har grävt bort* ^{1}***stubben***.

Through this procedure, 84 valid stimulus sentences and 84 invalid stimulus sentences were obtained. In total, 168 stimulus sentences were prepared for the experiment (42 pairs × 2 word accents × 2 conditions).

3.3 Procedures

The experiment was carried out on *Psychopy* software on a stationary Windows computer. Participants sat before the computer screen wearing an EEG cap. They listened to stimulus sentences via headphones (*Deltaco HL-9 Digital*). Stimulus sentences were presented in a randomized order. When an auditory stimulus had played, participants were to choose the most relevant image among the two on the screen as quickly as possible. One of the paired images described an accent 1 member of a minimal pair and the other, an accent 2 member. The placement of the images on the left or right sides of the screen was pseudo-randomised. Participants were asked to look at a fixation cross in the middle of the screen at all times except for when they were choosing between the images. *Figure 5* below shows the experiment screen of a trial with the minimal pair ^{1}*stubben* "the stubble" and ^{2}*stubben* "the stump".

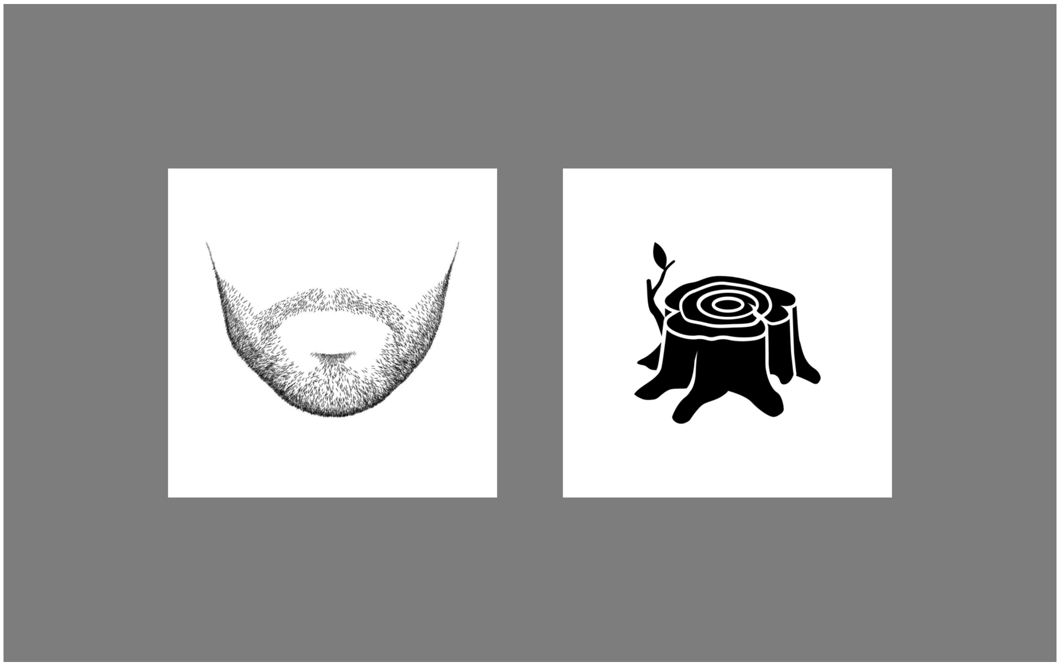

Figure 5. A sample response screen

Four practice trials were presented before the actual trials, so that the participants could get used to the experiment routine. They could also adjust the volume of the headphones during the practice session. The experiment was divided into 4 blocks of 42 trials. Participants were offered to take a break between blocks.

3.4 EEG recording and data pre-processing

Electroencephalograms (EEG) were recorded with 30 scalp electrodes using *Easycap* and a *Synamps 2* amplifier. Additionally, two electrodes were placed on the mastoids, two at the canthi of the eyes to monitor horizontal eye movements, and two electrodes below and above the left eye to monitor vertical eye movements. The impedance was kept below 5 kΩ for the scalp electrodes, below 2 kΩ on average for the two mastoids, and below 6Ω for the eye electrodes. EEG was recorded at a sampling rate of 1,000 Hz using *Curry 7* software by *Neuroscan*. A central electrode

(CZ) was used as an online reference during the recording. Time-locking points were at the onset of each stimulus word.

Collected data was pre-processed using *EEGLab* (Delorme & Makeig 2004). First of all, unnecessary parts of the recording made during the breaks were cut out from the continuous data. Then EEG channels were re-referenced to the average of the two mastoid electrodes. Then a bandpass filter of 0.05 Hz and 30 Hz was applied to reduce high-frequency noises. Next, an Independent Component Analysis (ICA) was carried out using the runica algorithm of *EEGLab*. Ocular artefact components were identified through this process and were removed from the data. Then the data were segmented into epochs, including 200 ms baseline prior stimuli onsets and 800 ms after the onset of the target words. Epochs with ERPs exceeding ±100 µV were removed. From the data of 20 participants, 29 trials from valid conditions and 21 trials from invalid conditions in total were rejected. Among 168 trials, 0-7 cases out of 84 valid conditions were rejected per participant, and 0-5 cases out of 84 invalid trials were rejected from invalid conditions. The highest number of rejected trials for any participant was less than 10% in either condition, thus all participant data was included in the analysis.

ERP amplitude averages were calculated by condition and participant. A central region of interest involving electrodes FZ, FC3, FCZ, FC4, C3, CZ, C4, CP3, CPZ, CP4, and PZ was created. N400 time window is predefined as 300-600 post stimulus onset (Kutas & Hillyard 1980). *Figure 6* below shows the location of all scalp electrodes.

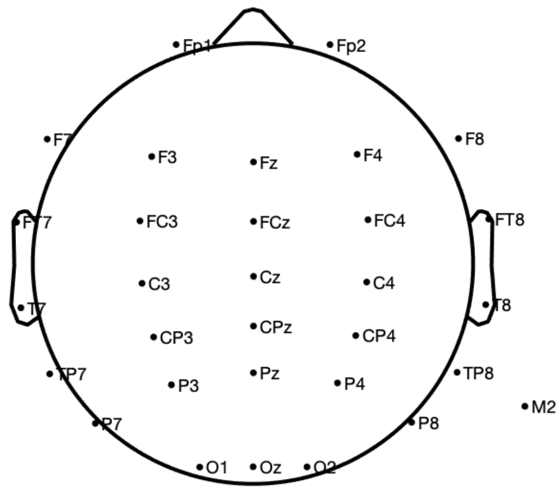

Figure 6. Location of the 30 scalp electrodes

ERP amplitudes (μV) from this spatiotemporal window were extracted and averaged per condition and per participant. Amplitudes were averaged in order to minimise the influence of noise that came along with the data since the recording, such as electrical activity from external devices and skin potentials, etc. This is because noise adds random variability to the measurements, either reducing statistical power, or making peak amplitudes seem larger than they are, biasing the data in a particular direction (Luck 2014). Through this averaging process, 40 data points were obtained for a statistical test.

3.5. Statistical analysis

To recapitulate, the three test implications are that 1) reaction times increase for word accent-word meaning incongruence, 2) incongruent word accents result in an N400 effect, and 3) there is a difference between accent 1 and accent 2 in N400 time window.

To see whether there were significant differences between the samples, two-way repeated measures analysis of variance (ANOVA) was conducted. Samples here are data collected using stimuli in the same condition. ANOVA tests if there is a significant difference between the two sample means. Two-way indicates that the data samples were formed by two factors, which are the condition of validity (valid vs. invalid conditions) and the types of word accents (accent 1 vs. accent 2). Repeated measures means that there is more than one value collected from each participant. Therefore, two-way repeated measures ANOVA is a suitable tool for a test in this study. ANOVA tests the significance of the mean difference between the two test groups by comparing the data variation between groups vs. within groups. If the between-group variation is high compared to the within-group variation, the F-statistic of ANOVA is high, and the p-value gets lower. In this study the two sample groups are the ERP amplitudes grouped by the validity condition. To recapitulate, below were the hypotheses of this study.

The data analysis software *R* ver. 4.1.1) was used for the statistical test (R Core Team 2022). The dependent variable was the reaction time (ms) to test the first hypothesis, and ERP amplitude (μV) which had been averaged over the N400 window through trials per person for the last two hypotheses. The dependent variables were, therefore, numeric variables. The Independent variables were the validity condition which is a categorical variable of two levels (valid and invalid) and the accents which is a categorical variable of two levels (accent 1 and accent 2). In a statistical test, it is the null hypothesis (H_0) that gets tested. If the p-value from the results is lower than pre-defined alpha value (0.05 in the current study), the null hypothesis can be rejected and the alternative hypothesis can be accepted by a confidence level which is a subtraction of the pre-defined alpha level from 100% (95% in the current study). If the p-value of the test result is larger than 0.05, we fail to reject the null hypothesis and, therefore, cannot accept the alternative hypothesis (Huck 2012; Rasinger 2013).

Chapter 4 Results

This chapter presents the results of data analysis. Section 4.1 describes the response accuracy and reaction time from the perception task. Section 4.2 examines the ERPs and tests the first hypothesis. Section 4.3 investigates the relationship between the response data and ERP data to answer the second hypothesis.

4.1 Behavioural results

Participants were asked to listen to the stimulus sentences and choose an image that described the sentence the best. A high response accuracy was found for the valid condition, reaching 90.4 %. The average response accuracy for the invalid condition was 64.6 %. A Chi-square test was conducted on the effect of validity on response accuracy, and the effect was significant (df = 1, $p < 0.001$). There was no significant difference in the accuracy of accent 1 and accent 2. *Table 4* below summarises the accuracy rate response per stimuli type.

Table 4. Response accuracy frequency and ratio

Condition	Word accent	Correct response	Number of trials	Accuracy rate (%)
Valid	Accent 1	773	840	92.0
	Accent 2	744	839	88.7
	Mean	759	840	90.4
Invalid	Accent 1	543	839	64.7
	Accent 2	540	838	64.4
	Mean	542	839	64.6

Recorded reaction time originally ranged from 332 ms to 10832 ms (M = 1255 ms). Outliers were removed using the interquartile range[4]. The average reaction time, after the outlier removal, for the valid condition was 1001 ms (SD = 476 ms). The average reaction time for the invalid condition was 1075 ms (SD = 481 ms). Reaction time for valid condition was shorter than that of the invalid condition for both accent 1 (70 ms shorter) and accent 2 (77 ms shorter). *Table 5* below summarises the average reaction time per trial type.

Table 5. Reaction time for accurate responses

Condition	Word accent	Reaction time mean (ms)	Reaction time Standard deviation (ms)
Valid	Accent 1	1008	473
	Accent 2	995	480
	Mean	1001	476
Invalid	Accent 1	1078	487
	Accent 2	1072	475
	Mean	1075	481

Two-way repeated measures ANOVA was conducted, to see if the difference of the reaction time among trial types were significant. Condition and word accent were set as independent variables (categorical), and reaction time was the dependent variable (numeric). Only the reaction time of correct responses were submitted to the ANOVA, as incorrect response could involve an extraneous effect that is irrelevant to word accent validity. There was a significant difference between valid and invalid conditions, $F(1, 19) = 15.432$, $p = 0.001$, indicating that validity had a meaningful effect on reaction time. On the other hand, there was no significant difference in reaction times between accent 1 and accent 2, $F(1, 19) = 1.095$, $p = 0.308$. Thus, it is concluded that the individual word accents did not influence the reaction time but only the accent

[4] Data points of which reaction time value were lower than $Q1 - 1.5 \times IQR$ or higher than $Q3 + 1.5 \times IQR$ were considered to be outliers.

validity did *Figure 7* below illustrates the distribution of reaction time by accent validity and accent type.

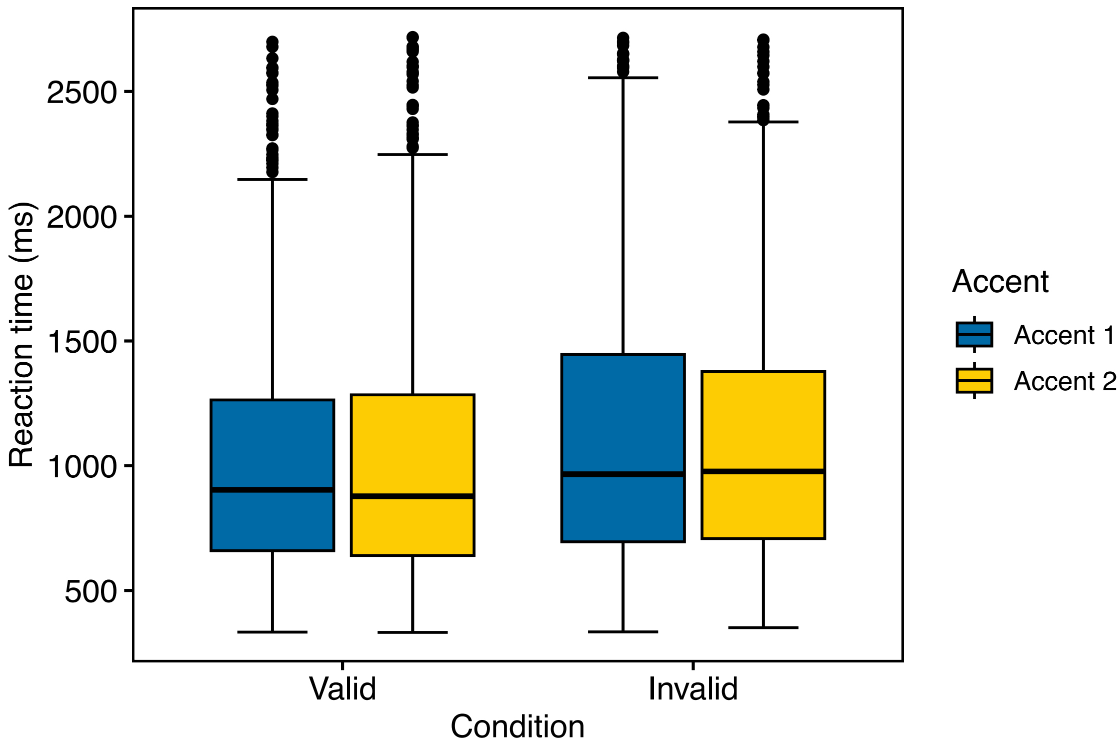

Figure 7. Distribution of the reaction time data

4.2. ERP data

The distribution of ERP amplitudes data is illustrated in *figure 9* below. The average potential was slightly more negative in the invalid conditions (M = -1.570 µV) compared to that of valid conditions (M = -0.886 µV). Across validity, accent 1 (M = -1.674 µV) tended to yield more negativity compared to accent 2 (M = -0.753 µV). There was no outlier in the ERP data.

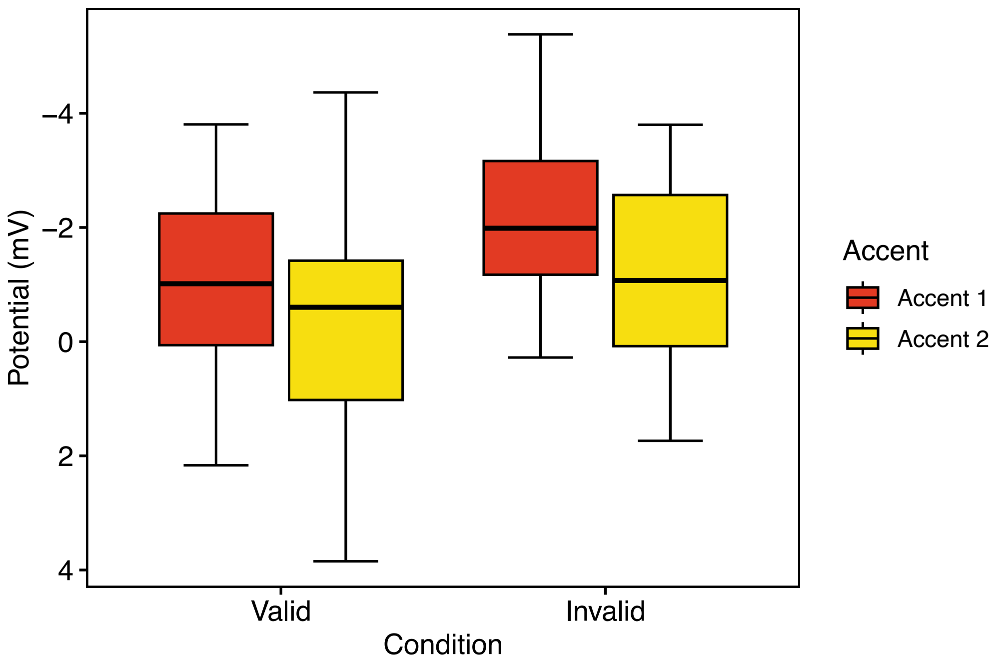

Figure 8. Distribution of the ERP data

Invalid word accents yielded a larger negative amplitude compared to the valid ones, with the deflection lasting from 300-600 ms post-stimuli onset, peaking around 400 ms. The increased negativity was centered around the central electrode site CZ, implying an N400 effect. There was no enhanced positivity observed in the later time window, indicating an absence of a P600 effect. *Figure 9* below summarises the ERP trend for valid (blue lines) and invalid conditions (red lines). The enhanced negativity can be compared in the topographical plots in *figure 10*.

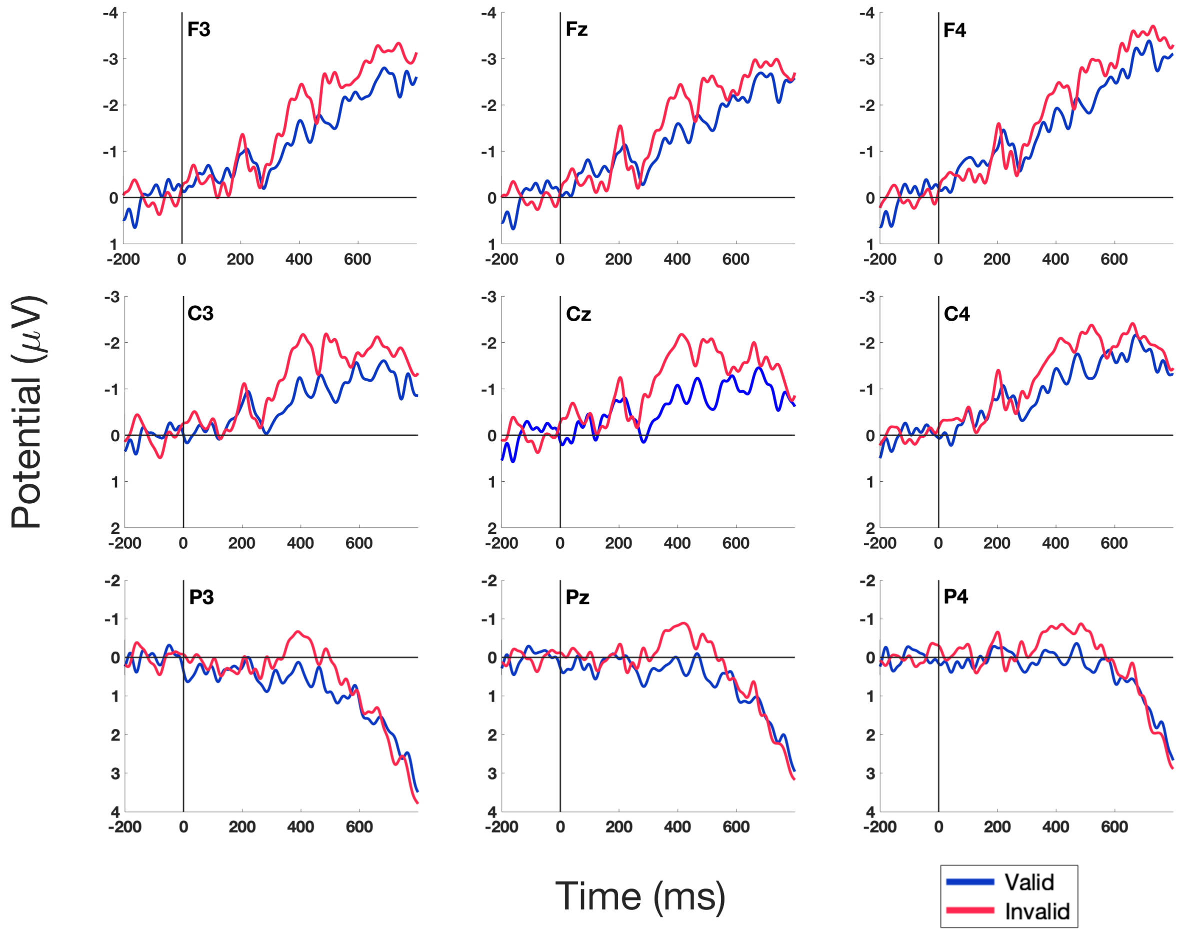

Figure 9. Grand averaged ERP comparison between valid (blue) and invalid (red) conditions

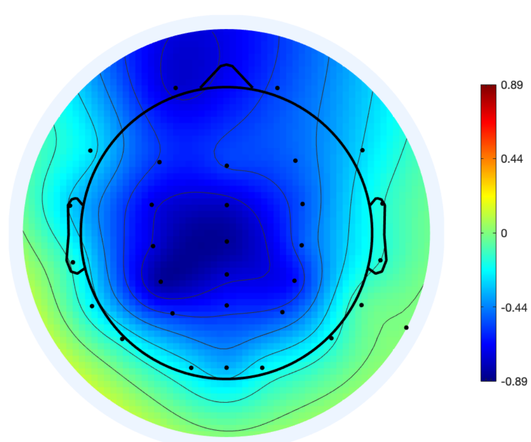

Figure 10. Topological plot of the negativity between 300 - 600 ms post stimulus onset (subtracted from invalid by valid condition)

Comparative negativity was also found in the same window (300-600 ms after word onset) between word accents. Stimuli with target words in accent 1 had a larger negativity than accent 2 did, indicating an underlying difference between the cognitive processing of accent 1 words and accent 2 words during this time window. This is presented in *figure 11* and *figure 12* below.

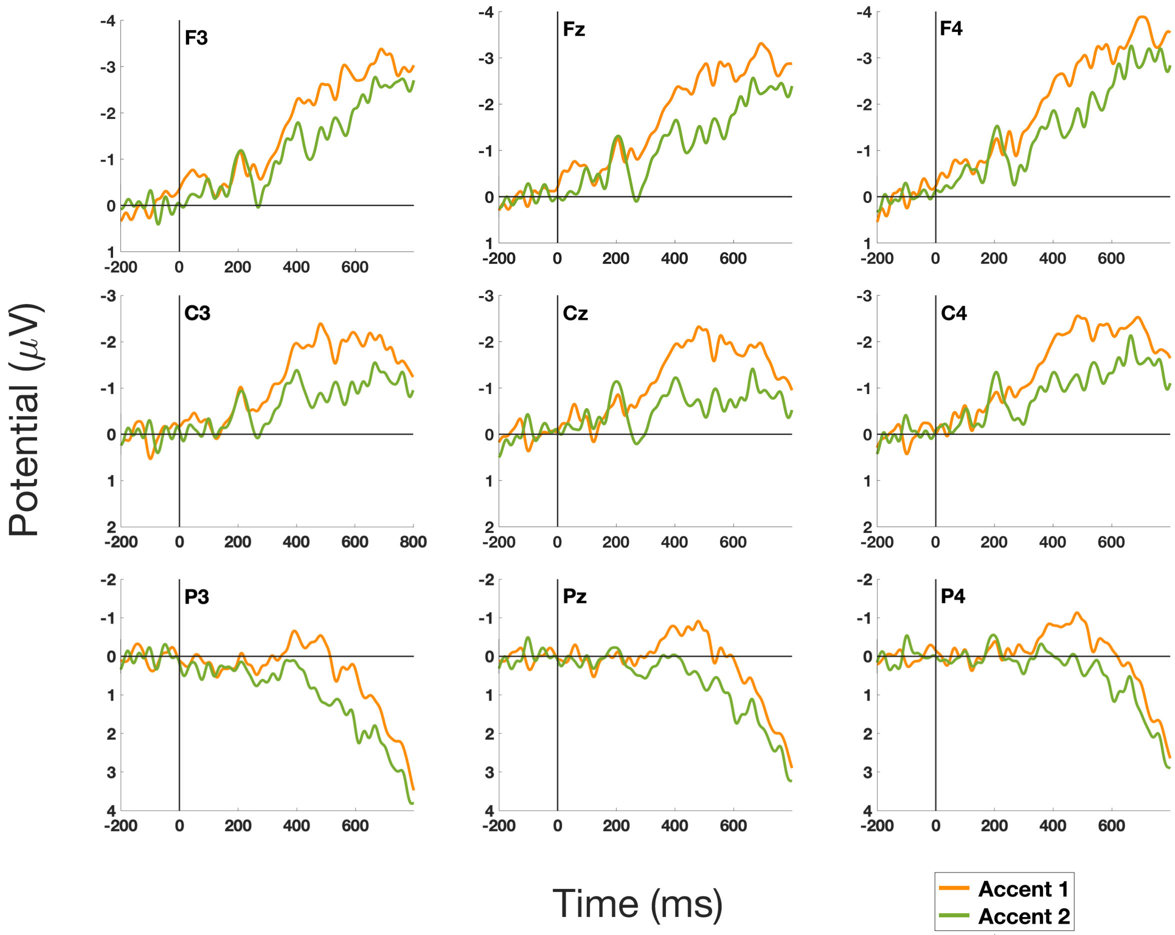

Figure 11. Grand averaged ERP comparison between accent 1 (yellow) and accent 2 (green)

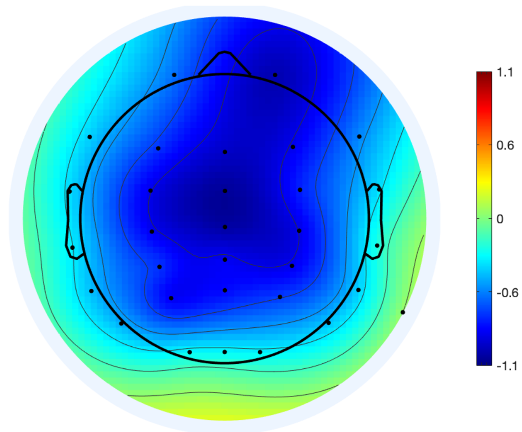

Figure 12. Topological plot of the negativity between 300 - 600 ms post stimulus onset (subtracted from invalid by valid condition)

To see whether these increased negativities were significant effects, two-way repeated measures ANOVA was conducted. Independent variables were validity and word accent (categorical variables). There was a significant difference in the ERP amplitudes elicited by valid and invalid conditions ($F (1, 19) = 5.703$ $p = 0.027$) in the central ROI. There was also a significant difference in the ERPs elicited by accent 1 and accent 2 ($F (1, 19) = 13.796$ $p = 0.001$. The two factors, validity and word accents, did not show any interaction ($F (1, 19) = 0.145$, $p = 0.707$), indicating that the two results were independent effects of validity and word accent.

Repeated measures ANOVA assumes that the data is normally distributed. To confirm that the statistics were robust, it was tested whether the data was in fact normally distributed using a Shapiro-Wilk test. Shapiro-Wilk method tests a null hypothesis that the data has a normal distribution. In the test result, the p-value was larger than the significance level 0.05 in both valid ($p = 0.760$) and invalid conditions ($p =0.983$), and in accent 1 ($p = 0.995$) and accent 2 ($p = 0.963$), thus we failed to reject the null hypotheses. In other words, the data can be assumed to have a normal distribution. This assumption is visualised in *figure 13* below, which compares the distribution of the data of the current study against a theoretical normal distribution. Each dot represents an observation point. Most of the observations are aligned with the line showing a good fit to the normal distribution. This indicates that the sample dataset does not deviate much from a theoretical normal distribution. Thus, the normality assumption is considered reasonable.

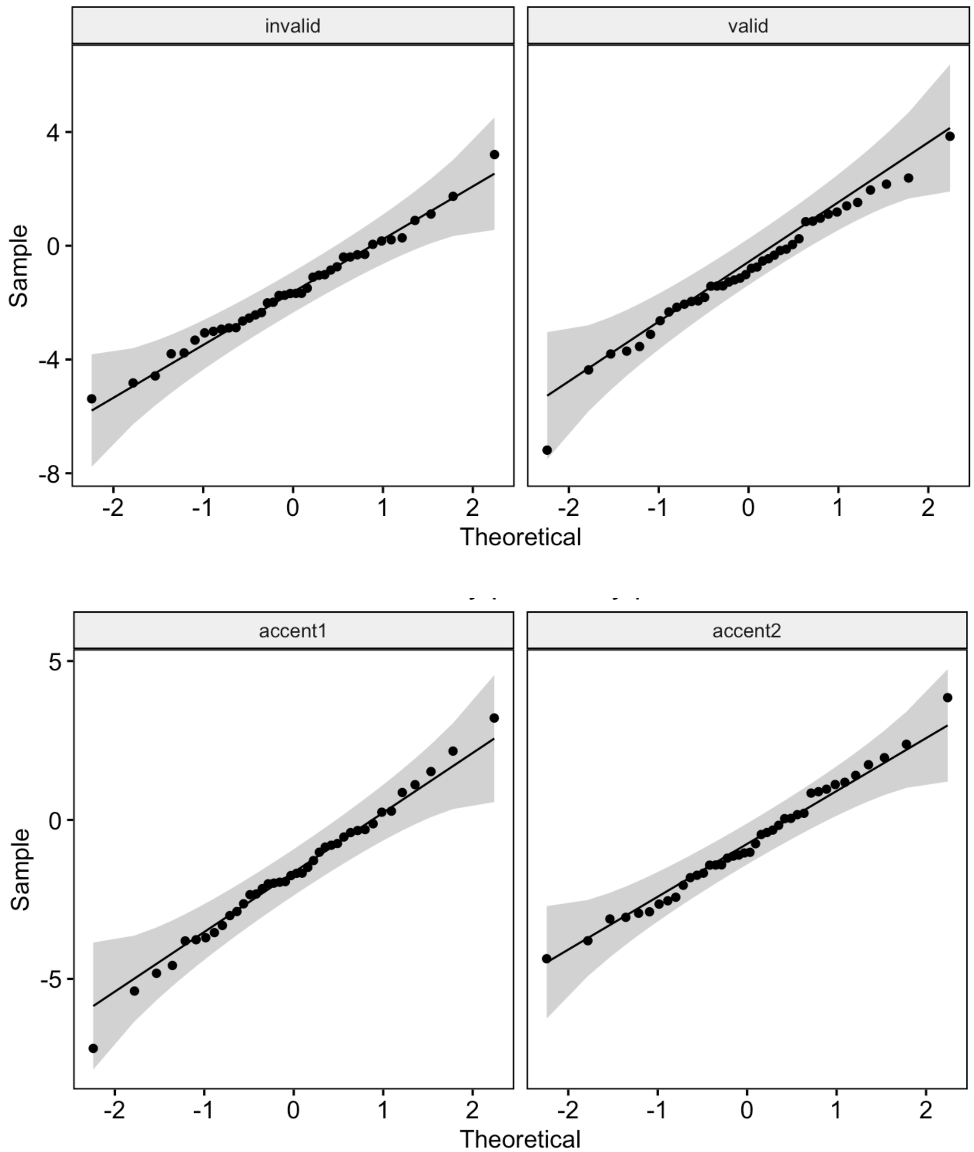

Figure 13. Normality probability plots

Therefore, the statistical results are considered robust. Valid and invalid word accents have an underlying difference by 95% confidence. The difference of accent 1 and accent 2 is concluded meaningful, in terms of their processing between 300-600 ms.

Chapter 5 Discussion

This chapter discusses the results in relation to the previous studies. Section 5.1. addresses the results regarding reaction times to evaluate the first hypothesis. Section 5.2. interprets the ERP results regarding word accent validity. Section 5.3 discusses the differences between accent 1 and accent 2 processing.

5.1 Word accent effect on sentence comprehension

Congruence of the word accent had an effect on sentence comprehension, as the accuracy was much higher for valid accents (90.4 % on average) than for invalid accents (64.6 % on average). Word accent validity had a significant effect on reaction time, where sentences with a valid word accent had a quicker response than those with an invalid word accent by 74 ms. This indicates an association between word accent validity and sentence-level comprehension. In other words, word accent congruency might impact even the processing at the utterance level. On the other hand, reaction time was not observed to be significantly different between accent 1 and accent 2.

5.2 Lexical processing and pre-activation

When it comes to neural activity, an increased negativity was observed between 300-600 ms, after the onset of the target words, and the negativity peak was around 400 ms. This activity was widely distributed around the central electrode sites and had a higher degree of negativity for invalid trials, showing characteristics of N400 effects. The N400 effect reflects semantic unexpectedness, in the form of difficulty with lexical retrieval or an effort in context integration. The negative deflection found in this study resembles the N400 component observed upon semantic anomalies in previous studies (Kutas & Hillyard 1984; Kutas & Federmeier 2011). Therefore, an N400 effect seems to be present in the current study when word accents were incongruent, in other words, when the recognised words were the other member of the minimal pairs than the expected one. Increased brain activity upon word recognition indicates that the brain needs to work additionally to proceed with the word fitting it into the general context that has been ongoing. In other words, when word accents were incongruent, the brain experienced increased difficulty integrating the word.

Focusing on the integration aspect of N400 indexation, it can be argued that the ERP trend observed in this study also reflects an integrational difficulty or a reanalysis process. It can be suggested that the context instigates the prediction of a certain grammatical category, and when the target word comes with a word accent that is associated with another word class, the brain's effort increases to dissolve the mismatch. This can be a reasonable argument since some of the minimal pairs used in the experiments involve different syntactic categories. This would go well with the previous studies, where incongruency between stem tone and suffixes produced a 'P600,' a late positive brain potential peaking around 600 ms post-stimulus, which is associated with reanalysis of syntactic and discourse level incongruency. A reanalysis of the grammatical categories in this time window would point towards decompositional processing of the word accents (Roll, Horne & Lindgren 2010; Roll, Söderström & Horne 2013; Roll 2015; Roll et al. 2015; Söderström, Horne, Mannfolk, van Westen & Roll 2018).

Crucially, however, no P600 effect was not observed in this study. The N400 has been rather robustly associated with semantic processing of various stimuli in different modalities. Also, unlike the aforementioned studies of Swedish word accents, the current study did not involve non-words or pseudowords, and thus it can be assumed that most target words were stored in their full form or inflected versions in the mental lexicon. Studies have suggested that speech input that has an experienced representation are processed in the left *Planum Temporale*, located in the upper portion of the temporal lobe, where a mapping between the incoming sounds and previously experienced stored representations is hypothesized to happen. This has been reported in both Swedish with word accents (Schremm et al. 2018), and Mandarin and Thai with lexical tonal language (Xu et al. 2006). These previous results suggest that the Swedish word accents can be stored as a part of the full forms of each lexical entry in the mental lexicon. The current study corroborates this full-form-storage hypothesis in the study of perception of words under high contextual constraints. This does not oppose the possibility of a parallel decompositional pathway of word accent processing. Rather, the two processing routes can be viewed as complementary with the purpose being the facilitation of rapid speech processing and maximisation of upcoming sensory prediction.

As an alternative perspective, it could also be suggested that lexical access (pre-activation of the expected word form) can in effect be observed in the data. The negativity observed in this study has a tendency of a slight left lateralisation. Early processes of linguistic auditory events are handled in the left hemisphere, such as in the primary auditory cortex, insula and the superior portion of the temporal lobe, where linguistic tones and tone accents are recognised (Wong, Parsons, Martinez & Diehl 2004; Xu et al. 2006; Kemmerer 2014). Additionally, Broca's area in the left hemisphere is repeatedly reported to be associated with early spoken word recognition, in the form of pre-activation or selection processes (Righi, Blumstein, Mertus & Worden 2009; Zhuang, Tyler, Randall, Stamatakis & Marslen-Wilson 2012; Roll et al. 2017; Söderström, Horne & Roll 2017). Thus, the activity found in this study could have a connection to the pre-activation process, especially considering that N400 could be interpreted to have an earlier lexical access stage and a later integration stage (Nieuwland et al. 2020). Besides, Roll (2015) reported a pre-activation process reflected between 220-280 ms following F0 onset in South Swedish, which is a delayed time window compared to the counterpart in Central Swedish. This could indicate that there is a fuzzy boundary between pre-activation and semantic feature retrieval on the temporal domain reflected in ERP. This late pre-activation effect could be relevant in the current study, as the stimuli provide semantic constraints leading to the target words. This could be invested by a more thorough analysis between the degree of semantic constraints and the negativity effect.

5.3 Word accent type and semantic expectation

Accent 1 words elicited an increased negativity compared to accent 2 words through 300-600 ms post word onset time window. According to the profile of N400, this would mean that the listeners did not expect to hear the accent 1 member of the minimal pairs compared to the accent 2 words.

This can be explained by the fact that accent 2 is generally related to more possible continuations including compound words, than accent 1 is, leading the listeners to believe that the stimuli are more likely to be incongruent, upon hearing an accent 1 tone. However, if the negativity were an N400, it should have been observed with a greater effect on invalidly cued accent 1 compared to validly cued accent 1. Such interaction between accent types and validity was not observed in the statistical test. Therefore, the different ERP trends between the accent types are not likely to be an N400 effect.

An alternative possibility is that the observed negativity difference between the two word accents is a pre-activation negativity (PrAN). Studies have previously reported an enhanced PrAN elicited by accent 1 compared to accent 2, which indicates that the brain shows a higher degree of negativity upon a higher certainty of a prediction (Roll 2015, 2022; Söderström, Horne & Roll 2017; Söderström et al. 2018). The degree of certainty is based on the imbalance that accent 1 is associated with considerably fewer possible continuations than accent 2. Therefore, accent 1 giving a rise to higher negativity is likely to reflect the brain activity corresponding to prediction certainty, implying that the observed negativity is a PrAN effect. In the present study, a negative deflection began as early as 230 ms at the CZ electrode, which belongs to the mid-range of the reported PrAN time window 136 – 280 ms. This goes in line with a previous finding from South Swedish (Roll, 2015), as well as in Danish where a similar late PrAN was also observed for the predictively more useful stød (Hjortdal et al. 2022). *Figure 14* below presents the brain potentials over the scalp between 295 - 355 ms post word onset of the data from the current study. The topological representations consequently turn into a stronger fronto-central negativity reaching its peak at 400 ms post word onset. This interpretation implies that, although the word accents perform a semantic function, they also influence the prediction certainty modulated by the internal probabilities of the target words.

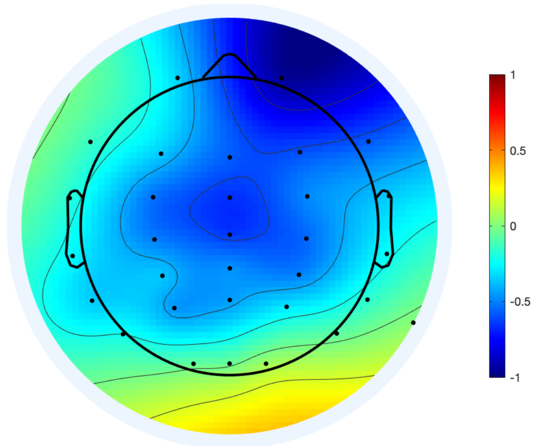

Figure 14. Topological plot between 295 – 355 ms post stimulus onset (subtracted from accent 1 by accent 2)

An explanation for the delayed PrAN effect in this thesis can be that the EFP data was analysed based on the onset of the stimulus words, unlike in previous studies where the PrAN was observed between 136 – 280 ms after the F0 onset of the word accents (Roll et al. 2015; Söderström et al. 2017). Another explanation could be that, although compound words in Swedish have accent 2 by principle, accent 1 can also be realised in some cases in South Swedish as a consequence of the accent shift blocking (Bruce 1973, 1974; Frid 2000). Even though this phenomenon does not apply to the majority of compounds even in South Swedish and is diachronically getting weaker in effect, if the local speakers have occasionally heard any compounds with a clear accent 1 realisation, it would operate when the language users are modelling the probabilities of the phonological cue. With the less clear and less categorical scarcity, accent 1 in South Swedish might have a weaker or less facilitative contribution to word recognition as compared in Central Swedish.

Chapter 6. Conclusion

The role of word accents in semantic processing in South Swedish was investigated in this study. As a result of a perception experiment involving contextual congruency, it is concluded that word accents do play a role in semantic comprehension, especially by providing a rapid confirmation in the form of a phonological cue responding to the expectation that has been built up by the context in the ongoing sentence. When the phonological cue fails to deliver confirmation of the expectations, the brain experiences some difficulty which requires more work or additional resources, and this is made visible in the increased electrical activities. Therefore, word accents are considered to provide a beneficial tool to maximise the efficiency of semantic language comprehension in speech.

The novel contribution of this thesis is the use of contextual constraints to directly compare the semantic processing between minimal pairs. This enabled the visualisation of word accent efficacy within contexts that are likely to be found in natural situations. However, the study is limited in fully elaborating on the relationship between the contextual expectations and phonological cues, in that the contextual strength has not been controlled via means such as cloze probability. An addition of quantified contextual degree, and its relation to the word accent effect would provide a more detailed explanation of the sematic aspects of word accents.

The study contributes to the domain of research in Swedish word accents, in that it observed an associative processing between word accents and the whole word forms. It has been corroborated that word accent incongruency brings an effect of a semantic violation. This means that, in addition to the main role of word accents being facilitative in morphophonological processing as suggested in previous studies, the phonetic cues still function as predictors of semantic features when the words exist in the mental lexicon.

An effect suggesting pre-activation was also captured, in line with the previous studies. Further studies with carefully quantified contextual factors can shed light on the interplay between contextually driven and phonologically conditioned pre-activation.

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Appendix

Appendix 1. Minimal pairs used in the experiment

Accent 1		**Accent 2**	
A:na	the A:s	ana	to sense
backen	the reverse gear	backen	the hill
beta	beta (β)	beta	graze
biten	the piece	biten	bitten
brunnen	the well	brunnen	burnt
gripen	the griffin	gripen	caught
hållet	the direction	hållet	held
ljuden	the sounds	juden	Jews
knuten	the corner	knuten	knotted
kullen	the brood	kullen	The hill
leder	leads (v. present)	leder	joints
malen	the moth	malen	ground
modet	the courage	modet	fashion
moppen	the mob	moppen	the scooter
normen	the norm	norrmän	Norwegians
ören	the gravel shore	ören	the (Swedish) penny
pajas	a clown	pajas	be broken
polen	Poland	pålen	the pole
regel	regulation	regel	latch
roller	a roller	roller	roles
rutten	the route	rutten	rotten

sabbat	sabbath	sabbat	ruined
släkten	the relative	skäkten	generations
skeden	the spoon	skeden	phases
skiftet	the shift	skiftet	the change
skotten	the shots	skotten	the Scotsman
skuren	the rain shower	skuren	sliced
slaget	the hit	slaget	hit
slitet	the hard labour	slitet	ripped
slutet	the end	slutet	closed
spaden	The cooking liquids	spaden	the spade
stället	the rack	stället	the spot
stegen	steps	stegen	the ladder
strider	fights	strider	battles
stubben	the stubble	stubben	the stump
tecken	the sign	täcken	blankets
tomten	the site	tomten	the Santa Clause
traven	the trots	traven	the pile
tummen	the inches	tummen	the thumb
vaken	The ice hole	vaken	awake
värden	the landord	värden	values
vreden	the knobs	vreden	The wrath