The function of North Germanic word accents

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Abstract

Since 2010, it has become increasingly clear that North Germanic word accents have a strong predictive function in speech processing. Recent findings on the semantic effects of word accents might appear contradictory to this interpretation. However, we show that the predictive perspective is crucial for understanding these semantic effects.

Introduction

North Germanic word accents and Danish stød are distinctive in the traditional phonological sense (Trubetzkoy, 1958) since they can minimally distinguish word pairs such as ^{1}*moppen* 'the mop' and ^{2}*moppen* 'the moped.' However, they typically show relatively low functional load. Swedish has around 357 minimal pairs (Elert, 1972). In Norwegian, word accents have gained in functional load with minimal pair estimates ranging between 2432 (Jensen, 1958) and slightly over 3000 (Leira, 1998) due to the loss of segmental contrasts in some environments. It does not seem likely that word accents' *raison de'etre* and the cause of their survival in the language has been distinguishing around a few hundred word pairs. It has been suggested that the main role of word accents in language is their *predictive* function (Roll, 2022). Recent evidence, however, has shown that they give rise to an electrophysiological N400 effect in semantically incongruent contexts (Kwon, 2023; Kwon & Roll, in press, submitted). The results indicate an association between word accents and lexical forms since the N400 is typically interpreted as indexing full-form lexical processing (Kutas & Hillyard, 1980). This might seem like a counterargument to the predictive function, which has mainly been argued based on the association between word accents and certain suffixes (Roll, Horne, & Lindgren, 2010; Roll, Söderström, & Horne, 2013; Söderström, Horne, & Roll, 2017). Here, we will argue quite the opposite: The lexical effects of word accents are not found at odds with the predictive function, but rather *because of* it.

Markedness and brain activity

The story of the predictive function of word accents is also a story of a brain wave: the *pre-activation negativity* (PrAN). When word accent perception was first tested using event-related potentials (ERP), a difference was found in the brain activity after the F0 onset of accent 1 and 2 (Roll et al., 2010). ERPs are portions of the electroencephalographic (EEG) signal time-locked to a certain event, in this case word accents that the participants listened to. Depending on the characteristics of the underlying brain sources, potentials can be electrically positive or negative. This gives rise to characteristic components related to auditory perception in the ERP signal, such as the N1, a negative deflection peaking at around 100 ms after a sound, and the P2, with its positive peak somewhere around 200 ms. These components are typically larger for unexpected events than expected. The N400 is a negative peak at around 400 ms following events that are semantically interpretable, mostly words, but also, for example, images.

The ERP difference between accent 1 and 2 starts at 136 ms after F0 onset. It overlaps with the P2 component, and was, therefore, when first observed, naturally assumed to be caused by accent 2 enhancing the P2 (Roll et al., 2010). This was all the more natural since accent 2 is generally assumed to be *marked* both lexically and phonetically (Riad, 2014). This assumption turned out to be untenable as further evidence emerged.

If the difference in the brain's perception were due to accent 2 being lexically marked, we would expect correct accent 2 words to have faster response times than accent 1 (Felder, Jönsson-Steiner, & Eulitz, 2009). Quite the opposite has repeatedly been observed (Gosselke Berthelsen, Horne, Brännström, Shtyrov, & Roll, 2018; Söderström, Roll, & Horne, 2012). Further, if the word accent ERP effect were due to accent 2 being acoustically marked, the effect should be found for word accents outside of a lexical context. Accent 2, being a high tone, could be thought to draw passive attention allocation to it (Roll, Söderström, & Horne, 2011). However, this hypothesis, too, turned out to be contradicted by evidence. Central Swedish Accent 2 does have a stronger acoustic effect than accent 1, but it occurs before the P2 and consists of an increase of the N1 component. In other words, the acoustic markedness effect of accent 2 is clearly dissociated from the difference found between accent 1 and 2 in lexical contexts (Roll et al., 2013).

Starting to view the results in light of the rising predictive coding framework (Friston & Kiebel, 2009), a new interpretation began to take shape. What if the observed brain processing difference between the two word accents was rather an effect of accent 1 than of accent 2? What if it reflected the fact that accent 1 is a better *predictor* than accent 2? Since accent 2 is found in all transparent compounds in Central Swedish, listeners can be more certain about which word they are hearing if it starts with accent 1. There are fewer words to choose from beginning with accent 1. The word simply cannot be one of a possibly infinite array of compounds. Added to this, accent 2 is also associated with a larger number of suffixes. In line with this interpretation, in a combined ERP and functional magnetic resonance imaging (fMRI) study, accent 1 was shown to produce greater activity around the left auditory cortex, in areas known for phonetic, phonological, and lexical processing. The hemodynamic increase in activity correlated with the ERP effect of accent 1 (Roll et al., 2015). The logical next step was to see if the certainty about which word was heard increased the negative effect of accent 1. The frequencies of the stimulus words in a corpus were assessed based on their pronunciation and the number of words in the corpus that started on each occurring syllable onset and nucleus were extracted. In this way, the number of possible continuations a listener could be expected to choose between when hearing a particular word beginning could be calculated. The results were striking: The negativity of the ERPs increased with the possible certainty of the listener about the word identity. Since the ERP activity had also correlated with increased neural activity in brain areas associated with phonological and lexical activation, the effect was interpreted as showing pre-activation of a word form that had not yet been fully heard. Since this ERP component had not been observed before, it was given a name: the *pre-activation negativity* (PrAN) (Söderström, Horne, Frid, & Roll, 2016).

A final piece of evidence pointing towards acoustic prominence not being of major relevance for the perceptual effects was the observation of a PrAN for accent 1 also in South Swedish, where, at F0 onset, accent 1 was a high tone whereas accent 2 was low, that is, the acoustic mirror image as compared to previously studied Central Swedish (Roll, 2015). Even in Danish, the irregular vocal fold vibrations of *stød* gave rise to a similar, albeit later timed, negativity (Hjortdal, Frid, & Roll, 2022). Like accent 1, stød constrains the number of possible words more than non-stød. Unlike its Swedish counterpart, however, stød is usually considered to be phonetically marked (Basbøll, 2005). Finally, with refined lexical statistic measures, PrAN has been found to index predictive certainty rather than surprise, as has been argued for another superficially similar component, the phonological mapping negativity (Hjortdal, Frid, Novén, & Roll, 2024).

What the PrAN discovery showed about word accent perception was thus that phonological or phonetic markedness did not seem to play an important role but lexical characteristics influencing the predictive constraints in speech perception did.

Full form storage and access

Accent 1, then, increases brain activity because it constrains the number of possibilities when hearing a word beginning, allowing for a stronger pre-activation of the expected word form. We say *word form* since this has been the most common case in the literature on word accent processing. It has been shown that word accents *can* be abstractly associated with grammatical suffixes (Söderström, Horne, Mannfolk, Westen, & Roll, 2017; Söderström, Horne, & Roll, 2017). However, brain data points towards relatively frequent Swedish nouns being stored and mostly accessed as full inflected forms contrary to Finnish, where nouns are decomposed into their morphological subparts during speech processing (Lehtonen, Niska, Wande, Niemi, & Laine, 2006). Word accents are therefore strongly associated with fully inflected words in the case of frequent nouns. This is clearly seen in the fact that the proficiency in native speakers' processing of word accents in real nouns correlates with their cortical structure in brain areas involved in phonological and lexical processing. In contrast, word-accent processing skill in pseudowords is related to the structure of a brain area devoted to morphological processing (Novén, Schremm, Horne, & Roll, 2021; Schremm et al., 2018). This led Schremm et al. (2018) to conclude that word accents are most firmly associated with full word forms in real nouns in the brain. Further, although in the early works on word-accent neurophysiology, the emphasis was on the association between word accents and suffixes (Roll et al., 2010; Roll et al., 2013), since the formulation of the PrAN, the calculation of the predictive characteristics of word accents has been based on fully inflected forms occurring in corpora (Hjortdal et al., 2024; León-Cabrera, Hjortdal, Berthelsen, Rodríguez-Fornells, & Roll, 2024; Roll, Söderström, Hjortdal, & Horne, 2023; Söderström, Horne, Frid, et al., 2016; Söderström, Horne, & Roll, 2016).

Predictive and distinctive function

To return to the initial question, does the finding of an N400 for semantically incongruent word accents show that word accents have a higher functional load in the structuralist sense than previously thought? No, the fact remains that word accents have a low functional load from a structuralist point of view. Easily put, they only distinguish between a handful of minimal pairs and are thus not very useful in the phonological system seen statically as a synchronic stage in diachronic language development. However, in speech, words are not perceived statically but unfold dynamically. We hear the beginning of words before we hear their end. Since it is becoming increasingly clear that the brain is predictive in its basic functioning (Friston & Kiebel, 2009) and particularly that speech processing is based on prediction (Friston et al., 2021), the predictive function of word accents should be as important as their distinctive function. The predictive function can even be seen as a dynamic form of the distinctive function. At the point where we hear a word accent, we do not have access to the full word form, and it does have a quasi-distinctive function in ruling out all the possibilities that would have had the other word accent (Roll, 2022). Thus, hearing /spe/- with accent 1 our predictive brain can rule out all the 185 possible accent-2 forms, including *spegeln* 'the mirror,' and *spetan* 'the splinter,' and concentrate on the five possible accent-1 forms, of which the most likely would probably be *spelet* 'the game.' In other words, regarding Swedish nouns, the predictive function mainly consists of activating and inhibiting *fully inflected forms*.

There is no difference in the perception process when a semantically incongruent word accent is heard. The word accent is still mainly associated with a fully inflected form. If hearing *Han åkte iväg på* ¹*mop-* 'He went away on (the) mop-' with accent 1, the predictive perception system activates the most likely candidates, involving ¹*moppen* 'the mop' and inhibits accent-2 candidates like the semantically congruent ²*moppen* 'the moped.' Therefore, semantic integration becomes more difficult, increasing the N400.

Conclusions

Word accents have been shown to have a strong predictive function in speech processing. The predictive function has mainly been argued and calculated based on fully inflected word forms. There is also previous evidence that word accents have strong associations with full word-form representations in the brain. Therefore, in view of the previous research, in no way does the finding of an N400 effect for semantically incongruent word accents contradict their predictive function. On the contrary, it strengthens the interpretation. From a structuralist functional load perspective, word accents would not be expected to give rise to a robust semantic effect due to their low functional load. Only when seen from a dynamic predictive processing perspective does the brain's strong semantic reaction to contextually incongruent word accents make sense.

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