Pre-activation negativity in language brain potentials

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BOOK OF ABSTRACTS

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1-2 June 2023
Lund, Sweden

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Pre-activation negativity in language brain potentials

Huayuan Cui

Neural Asymmetry in the Perception of South Swedish Word Accents - Evidence from Mismatch Negativity

Talks – Day 1

The neural implementation of semantic automata

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Truth values hold a prominent position in formal semantics, as they are considered to be the extension of all declarative sentences. Several scholars have followed this theoretical stance to its natural conclusion and argued that the intension of a declarative sentence is a procedure for determining its truth value. While many may be reluctant to equate verification algorithms with the human process of intuiting meaning, in the absence of another way to formally specify such intuition, verification provides a well-defined function, whose computational and algorithmic properties can be specified. This provides a novel avenue to study the implementational level in semantic processing, and this paper attempts to outline the benefits and caveats of this approach by examining natural language quantifiers.

Van Benthem (1986) observed that the semantics of quantifiers given in generalized quantifier theory as relations between cardinalities of sets, could be modeled as strings of binary representing the objects being quantified over as having or not having a predicated property. Such strings are recognized by abstract computational models called *automata*. These are foundational tools from theoretical computer science and formal language theory that can be used to mathematically prove differences in the minimal complexity of different computational problems (Chomsky, 1956; Hopcroft & Ullman, 1979): the simplest possible algorithm to compute a function. Van Benthem (1986) demonstrated that quantifiers in natural language divide into classes depending on the minimal complexity of determining the truth value of a quantified sentence with that quantifier. In particular, *Aristotelian* – 'all', 'some', 'none' etc. – and *numerical* quantifiers – 'three', 'at least five' etc. – can be verified by simple *finite state automata* (FSAs). By contrast, *proportional* quantifiers – 'most', 'less than half' – require the additional memory component associated with *pushdown automata* (PDAs).

In three EEG experiments (Bremnes et al., 2022, Under review), the biophysical consequences of this distinction was investigated. Participants saw an array of differently colored geometrical shapes and read simple copular sentences describing the preceding picture (quantified noun phrase + copula + color adjective). In experiment 1, participants had to make a truth value judgment of the sentence relative to the picture, in experiment 2 they answered comprehension questions, and in experiment 3 they had to make a truth value judgement in addition to temporarily storing and recalling strings of (2 or 4) digits.

Since the formal proofs delineate a lower bound on the complexity of the verification algorithm – there is no strategy that can simplify the nature of the task – the theory predicts that proportional quantifiers, but not the other classes, should recruit memory systems during verification, also in human subjects. This prediction was borne out: proportional quantifiers led to specific effects in the event-related potential (ERP) compared to Aristotelian and numerical quantifiers, at different positions in the sentence when verification was necessary; moreover, the distinct effects for proportional quantifiers were modulated by overall memory load with the addition of the digit matching task. However, the nature of the effects differed between experiments with and without additional memory load. Without memory load, a late positivity was observed for proportional relative to non-proportional at the completion of the noun phrase. With memory load, an early sustained negativity was observed for the same comparison. Additionally, there was a significant interaction between Digit Load and Quantifier Class at the sentence-final adjective such that the negativity for proportional quantifiers relative to non-proportional increased in the high memory load condition.

While the discrepancy in the specific effects is a reminder that formal algorithmic results are unlikely to fully represent cognitive reality, the insight gained from their mathematical certainty is profound (Niyogi, 2006). The results demonstrate that the algorithmic complexity of a minimal verification algorithm is associated with different electrophysiological patterns, thus providing a strong argument that the psychology and neuroscience of language ought to be informed by results from theoretical computer science. Moreover, they suggest that the formal constraints on abstract machines are applicable to, and plausibly of the same nature as, the constraints on algorithms of human sentence processing. Consequently, the integration of formal and experimental results enables well-founded, plausible hypotheses that can likely reveal deep properties of the human capacity for language and cognition more generally (Bird, 2021; van Rooij & Baggio, 2021).

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The relation between quantification and negative polarity items: an ERP-study

Eva Klingvall[1] & Fredrik Heinat[2]

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We report the results from an offline acceptability study and an online EEG study on Negative Polarity Items (NPIs) in quantified contexts in Swedish. NPIs are elements (e.g. *any, ever, a bit*) that need to appear in the scope of a negative licensor to be well-formed (e.g. Ladusaw 1980). The overarching aim of the studies is to see to what degree different negative quantifiers can license polarity sensitive material. The quantifiers under investigation in the study differ with regard to whether they include an overt negative element (*inte*), a property that can have an effect of the perceived negativity (see Horn, 1989; Ross, 1973).

The acceptability study included both NPIs (*alls* 'at all', *ens* 'even', *förrän* 'until', *ett dugg* 'one bit') and elements sensitive to clause level polarity, namely tag questions and polarity sensitive co-ordination elements (*och* . . . *också* 'and . . . also', *och* . . . *heller* 'and . . . neither'). The four negative quantifying expressions were *högst* 'at most', *inte mer än* 'no more than', *få* 'few' and *inte många* 'not many'. *Högst* and *få* were selected because they are likely to show a less negative-like behaviour (for less negative-like behaviour of English *at most*, the counterpart of *högst*, see Sanford, Dawydiak and Moxey 2007, and for less negative-like behaviour of *få*, see Klingvall and Heinat 2022). *Inte mer än* ('no more than') and *inte många* ('not many') were included since they are semantically similar to the other two, but contain the overt negative element *inte* ('not'). In addition to the conditions with negative quantifiers, a condition with main clause negation (MCN) and a condition with no negation at all (POS) were included. While the former should constitute the maximal degree of negativity and thus license all types of negation sensitive material, the latter should be completely ill-formed in the same contexts.

The material for the acceptability study consisted of 240 items, of six sentences each. Each sentence featured one of the six licensing conditions (MCN, POS, and the four quantifiers), and the sentences within the same item contained the same polarity sensitive material (30 items for each of the four NPIs; 60 items with coordination – 30 negative patterns, 30 positive patterns – and 60 items with tag questions – 30 negative, 30 positive). Each participant saw only one sentence from each item and saw an equal number of all types of manipulation. The 32 participants (native speakers of Swedish), thus rated 240 sentences on a 7-grade Likert scale.

The negative quantifiers fell in between POS and MCN in the acceptability study. More precisely, all quantifiers differed significantly from POS both with regard to NPI licensing and clause level polarity. Within the group of quantifiers, *högst* ('at most') was the least negative one, and *inte många* ('not many') was the most negative one, even patterning with MCN, in some cases. The quantifiers *få* ('few') and *inte mer än* ('no more than') were rated in between the other two.

The EEG study investigated the processing of the same NPIs as in the acceptability study in the context of the four negative quantifiers, again comparing them to cases with main clause negation and no negation at all. 420 items were constructed (105 for each NPI). The sentences, which were distributed across 4 lists, were read by 42 participants (right-handed native speakers of Swedish with no diagnosed neurological disorders). One fourth of the sentences were followed by a content yes/no question. Previous studies on NPIs have found N400 and/or P600 and/or LLAN effects for unlicensed NPIs relative to licensed ones (e.g. Liu, König & Mueller, 2019; Steinhauer, Drury, Portner, Walenski & Ullman, 2010; Xiang, Dillon

& Phillips, 2009; Xiang, Grove & Giannakidou, 2016; Yurchenko et al., 2013). Based on the acceptability study, we expected POS to show effects relative to MCN, and possibly also smaller effects for the conditions with quantifiers relative to MCN, since they appeared to be weaker NPI licensers in the behavioural study. For N400 and P600, the region of interest consisted of CP3, CPz, CP4, P3, Pz, P4, O1, Oz and O2, and the relevant times were 300-500 ms after the onset of the NPI, for N400, and 600-900 ms, for P600. For LLAN, the electrodes included were F3, F7, FC3 and FT7, and the relevant time was 900-1100 ms after onset of the NPI.

The results indeed showed effects for POS, relative to MCN in the N400, P600 and LLAN time windows. The quantifiers, on the other hand, did not differ significantly from MCN in any of these time windows. Even the quantifier *högst* ('at most'), which was the least negative one in the acceptability study, was negative enough not to give rise to any disruptive effects in processing as a licensor of NPIs. This is in line with the findings in Xiang et al. (2016), where different types of negative licensors did not result in differences in processing of the NPI in the N400 window. The distinctions found between the different quantifiers in the behavioural study were thus not present to a significant degree when the processing of these expressions was examined. In this talk we will discuss the implications of our main findings: Firstly, that even licensors with lower degrees of negativity in acceptability are negative enough for successful licensing of polarity sensitive material in processing. And secondly, that while negativity is scalar in acceptability, in processing it appears to be categorical.

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Event-related negativities associated with predictive language processing: insights from Parkinson's disease.

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Nowadays, it is well-established that adults pre-activate linguistic content during language comprehension, at least under some circumstances [1]. In the last years, several studies have shown that words that can be lexico-semantically pre-activated from sentence contexts are preceded by sustained anticipatory negativities and followed by a reduction in N400 amplitude (relative to contextually unpredictable words), both in speech and reading comprehension [2, 3, 4]. We recently employed these two ERP indices to concurrently assess the pre and post stages of word pre-activation in a large cohort of Parkinson's disease (PD) patients (under dopaminergic compensation) with and without mild cognitive impairment (MCI) in a sentence comprehension task [5]. Previous studies in this population had pointed to lexico-semantic difficulties in single-word predictive priming effects [6, 7], but none had investigated top-down driven pre-activation from sentence contexts. We found that PD patients without MCI showed normal ERP indices in our task (Fig. 1A), suggesting preserved top-down predictive pre-activation. In turn, PD with MCI exhibited signs of reduced anticipatory mechanisms and difficulties in handling lexically unexpected words, as reflected by a prolongation of the N400 congruity effect. Furthermore, worse verbal fluency performance (regardless of cognitive impairment status) correlated both with a reduction of the anticipatory negativity and a prolongation of the N400 congruity effect (Fig. 1B). The contribution of these findings is twofold. First, from a clinical standpoint, they suggest that different mechanisms of linguistic prediction (predictive priming vs. predictive pre-activation) might dissociate in PD, and that it is clinically relevant to evaluate language function in PD patients who progress to MCI. Second, the findings are also important for basic neurolinguistics. Specifically –along with the findings in healthy population–, they strengthen the hypothesis that constraint-related anticipatory negativities are functionally linked to top-down mechanisms involved in lexical/semantic pre-activation, and can be used by researchers as an electrophysiological measure of predictive language processing.

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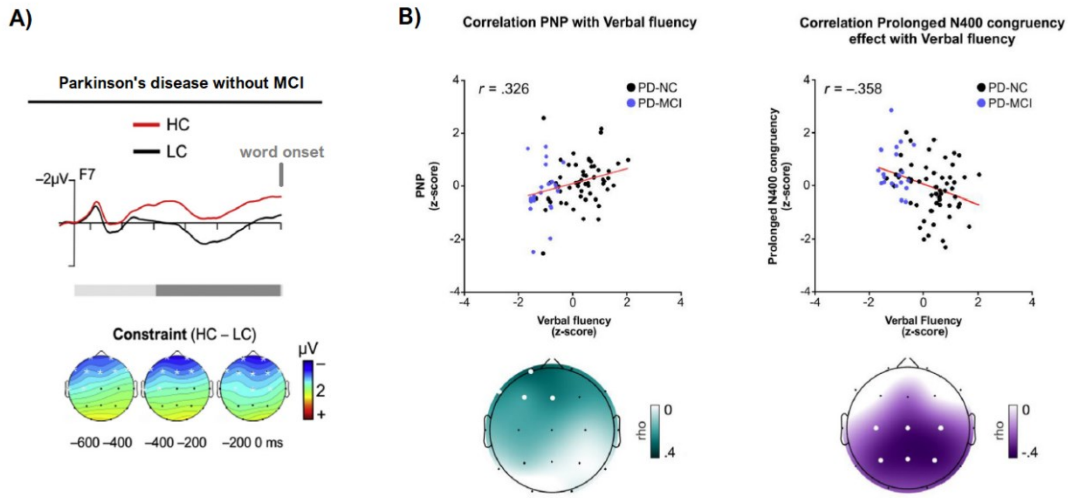

Figure 1. A) Grand-averaged ERPs and scalp maps in the 1 second interval preceding the sentence-final word of a high (HC) or low constraint (LC) sentence (F7 electrode; 100 pre-stimulus baseline), showing the prediction negative potential (PNP) in HC contexts. **B)** Scatterplots and scalp maps of the significant correlations between verbal fluency and the PNP (left), and the N400 congruency effect (right). All patients (N = 78) are included. Darker shading in the scalp maps indicates larger r-values in the direction of the correlation. For more detailed information, see León-Cabrera et al., (2021).

Using ERPs to examine lexicosemantic predictions in native and nonnative speakers of English

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A central question in current L2 research concerns adult L2 learners' ability to generate predictions online. The available evidence suggests that learners can predict, although they are less likely to do so than native speakers [1]. Under some proposals, this is explained by learners' having a reduced ability to generate expectations across all domains of grammar [2]. Alternative proposals posit that prediction is qualitatively similar in the L1 and the L2, but prediction in the L2 is obscured by factors that impact L2 processing in general [3]. One such factor is the quality of L2 lexical representations. L2 learners tend to have smaller, more heterogeneous, and more unstable semantic networks than native speakers [4]. In addition, learners might establish weaker links between words and concepts, due to their reduced experience with the L2 [5,6]. In turn, these limitations might impact L2 learners' ability to generate lexicosemantic predictions online [3] or they might render prediction less useful for learners [1,7]. The present study uses ERP to examine this question among L1-Swedish L2-English learners.

The study, which is based on previous work by Lau et al. (2013) [8], focuses on the N400, an ERP component that is modulated by different aspects of lexical access and retrieval, including lexical prediction [9]. Participants read words, presented one at a time, and pressed a button for animal words. The words were paired, and we manipulated both prime-target semantic relatedness (related: *trousers-pants*; unrelated: *cathedral-pants*) and relatedness proportion (low vs. high). Semantic relatedness is known to reduce N400 amplitude for related targets, via spreading activation across memory representations. Relatedness proportion was manipulated by increasing the proportion of related pairs from 10% in the first block to 50% in the second block (via fillers). The rationale is that, when participants implicitly notice the semantic relationship between primes and targets in the second block, they start using the primes to predict the targets. This should yield a larger N400 reduction for related targets in the high- relative to the low-proportion block [8].

Each block encompassed 40 related pairs, 40 unrelated pairs, and 40 (unrelated) animal probes (*paddle-bull*). 280 additional pairs were added to each block as fillers. In the low-proportion block, none of the fillers were related. In the high-proportion block, 160 fillers were semantically related. All related pairs had a forward association strength "FSG" over 0.5, suggesting that over 50% of participants would associate the target to the prime. This was determined via a database of free association norms with at least 100 L1-English speakers [10] and 100 L1-Swedish L2-English learners of advanced proficiency (Lextale, *M*: 87; *SD*: 9) [11]. Similar to Lau et al. (2013), primes were presented for 500ms and targets for 900ms (with a 100ms pause in between). No identical cognates or interlingual homographs were used as targets. All critical pairs were fully counterbalanced.

We report data from 36 L1-English speakers and 53 L1-Swedish L2-English learners of advanced proficiency (Lextale, *M*: 91; *SD*: 6; Age of L2 acquisition, *M:* 8 years; *SD*: 2). Analyses on the related vs. unrelated targets (*trousers/pants* vs. *cathedral-pants*) showed a significant Relatedness by Proportion interaction in the N400 time window (300-500ms) (p =.026), which was not qualified by Group. Follow-up analyses revealed significant N400 effects within each block (p <.001), with unrelated targets eliciting more negative waveforms than related ones (Fig1). Crucially, this N400 effect was larger in the high-proportion block

(Fig2), driven by the N400 for related targets becoming less negative in the high-proportion block (Fig1) (p =.022). Additional analyses showed that only the N400 effect in the high-proportion block had a posterior maximum (Fig2) (p =.001), consistent with the possibility that the N400 effects in the two blocks reflect partly qualitatively different mechanisms (priming vs. active prediction). Results suggest that (a) related targets became easier to retrieve for both groups when the context encouraged prediction [8]; (b) at an advanced level of proficiency and for lexicosemantic associations independently proven to be strong among equally proficient learners [11], prediction can be qualitatively and quantitatively similar in the L1 and L2 [3].

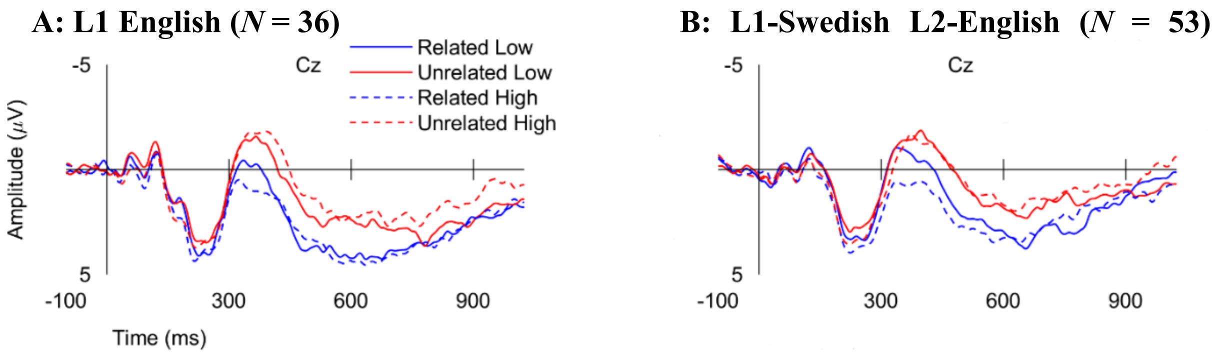

Figure 1. Grand average ERPs for related (blue) and unrelated (red) targets in the low-proportion (solid) and high-proportion (dotted) blocks. ERPs are plotted for representative electrode Cz.

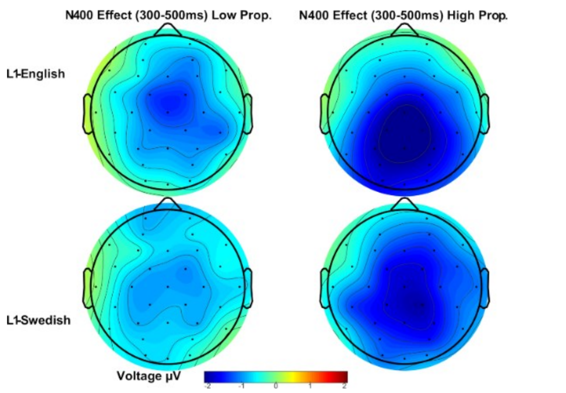

Figure 2. Topographic plots for the N400 effect in the low- (left) and high-proportion (right) blocks for L1-English speakers (upper row) and L1-Swedish L2-English learners (lower row). Plots were computed by subtracting the related from the unrelated condition between 300-500ms.

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Markedness impacts the facilitative use of grammatical gender among L1-Finnish learners of L2-Swedish

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This study investigates the extent to which grammatical gender cues facilitate lexical retrieval in both native speakers of Swedish and L2 learners of Swedish whose L1 is Finnish, a language with rich inflection but without grammatical gender. Different theoretical models of L2 acquisition make different claims regarding the acquisition of gender by late learners whose L1 is [-gender]. For example, lexically-based proposals claim that learners can come to represent abstract gender in a native-like manner regardless of their L1, but difficulties with the online retrieval of lexical gender impact their ability to use gender information online [1-3]. In contrast, representational accounts of variability, such as the Representational Deficit Hypothesis "RDH" [4], posit that learners whose L1 lacks a gender feature build faulty representations for gender. For example, learners might adopt the most frequent gender as a default and memorize exceptions by tracking co-occurrence frequencies.

Swedish classifies nouns as *common* or *neuter*, and most nouns lack phonological gender cues [5], thus posing a challenge for L2ers when it comes to lexical gender assignment. With respect to markedness, it is claimed that neuter is marked for gender, while common is underspecified [6]. This claim is supported by the fact that neuter nouns represent only 25% of the lexicon and show overt inflection on adjectives, whereas common adjectives are morphologically unmarked (*fint/fin* "fine-NEUT/COM"). In the psycholinguistics literature, it has been argued that marked features are more likely to impact agreement operations in L1 speakers, due to feature activation [7]. Our study is among the first to examine whether markedness asymmetries also modulate the online use of gender in the L2 [8].

Participants read sentence frames presented word by word (500ms/word, 300ms/pause), and named a sentence-final picture as fast as possible (see 1-2, nouns provided for explanatory purposes). We manipulated the number of gender cues to the noun, to examine whether additional scaffolding might facilitate the use of gender [9]. Conditions (1a,1c) provide two gender cues: one on the article, one on the adjective. Conditions (2a,2c) involve gender-invariable adjectives, thus only providing one gender cue on the article, a category that Finnish lacks. The baseline conditions (1b,1d; 2b,2d) involve the possessive *hans* "his", which does not mark grammatical gender and makes the NP definite, a context where Swedish adjectives encode definiteness, but not grammatical gender. We used 15 items per condition and 60 fillers. Knowledge of lexical gender was tested via two gender assignment tasks (GAT).

1a. Jag läste en konstig…
I read a.COM strange.COM
1b. Jag läste hans konstiga…
I read his strange.DEF

bok "book.COM"

1c. Jag läste ett konstigt…
I read a.NEU strange.NEU
1d. Jag läste hans konstiga…
I read his strange.DEF

brev "letter.NEU"

2a. Jag läste en fascinerande…
I read a.COM fascinating
2b. Jag läste hans fascinerande…
I read his facinating.DEF

bok "book.COM"

2c. Jag läste ett fascinerande…
I read a.NEU fascinating
2d. Jag läste hans fascinerande…
I read his fascinating.DEF

brev "letter.NEU"

We report data from 48 L1-Swedish and 46 L1-Finnish L2-Swedish speakers. L1 speakers were predicted to name pictures faster after informative frames, an effect that might be larger for neuters under the hypothesis that marked features (i.e., neuter) are more informative. For L2ers, lexical models predict that facilitation from gender cues should correlate with their overall knowledge of lexical gender, as measured by the GATs. Learners might also benefit more from neuter cues if they have a native-like representation of the common/neuter asymmetry. Under the RDH, gender should not facilitate lexical retrieval. However, as pointed out by Hopp (2013), if L2ers memorize neuters (i.e., the less frequent gender) as exceptions, neuter cues might reactivate traces of memorized nouns, leading to faster naming times. If so, this facilitation effect should correlate with the co-occurrence frequencies of the specific article-adjective-noun sequences that we used (extracted from Google).

The analyses were conducted separately for the two-cue conditions (1a-1d) and the one-cue conditions (2a-2d), due to the use of different adjectives which result in different baselines for a given noun. We modeled onset naming time as a function of Gender (common/neuter), Informativeness (baseline/informative), and Group (L1/L2-Swedish) as contrast-coded fixed effects. Only trials for which participants had assigned the target gender in the two GATs were included. Random effects were included with random intercepts for item and subject, by-subject random slopes for Gender, and by-item random slopes for Group. Both models returned significant main effects of Group (p >.001) and Gender (p >.002). L1 speakers had overall shorter naming times, and both groups named common nouns faster. In the two-cue conditions, analyses also revealed a significant main effect of Informativeness (p > .001), which interacted with Gender (p = .024). Follow-ups showed that both groups named neuter nouns faster in informative vs. baseline sentences (1c vs. 1d), while for common nouns this effect did not emerge. In the L2ers, this facilitative effect in the conditions with neuter nouns was not explained by the learners' overall knowledge of gender, as measured by the GAT. The facilitation effect did also not correlate with the co-occurrence frequencies of the article-adjective-noun sequences in either group.

Our results suggest that gender facilitates lexical retrieval in both L1 and L2 speakers, and that markedness impacts this process similarly in both groups, more in line with lexical accounts [8]. However, neither proposal is fully supported. That the co-occurrence frequencies did not correlate with the facilitation effect in the two-cue conditions is unexpected under the RDH [4], if L2ers are tracking the input. That facilitation was also not explained by the learners' overall mastery of lexical gender is at odds with lexical accounts [3]. Interestingly, facilitation was restricted to the conditions with gender-marked adjectives, which could be a result of the additional morphological scaffolding provided by the adjective [9], its adjacency to the noun, or its word class (content word).

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Discrimination of homophone forms – morphology, phonology or both?

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Morphology and phonology are mostly studied as two separate phenomena in fMRI studies of language processing. Conditions with morphological anomalies (e.g. anomalously inflected verbs) are often contrasted with conditions with phonological anomalies (e.g. pseudohomophone spelling errors). This strand of research has shown distinct patterns for the two types of anomalies. Reading morphological anomalies is associated with increased activation of left inferior frontal gyrus (Carreiras et al. 2010; Carrieras et al. 2015), while phonological anomalies also tend to engage auditory areas (e.g. Newman & Joanisse 2011).

In naturally occurring texts, the distinction between phonological and morphological anomalies is less clear. In written Danish, the infinitive and the present tense of verbs are frequently confused. For verb stems with final -r, the infinitive and the present tense form are homophone – for other verb stems there is an audible difference between forms. For instance, there is an audible difference for *overveje/overvejer* (‘consider/considers’), but not for *vurdere/vurderer* (‘evaluate/evaluates’). In our fMRI study we investigated whether the processing of verbal inflection in Danish involves both morphological and phonological processes. Twenty-eight Danish participants (age 20-31) read 128 short stories while they performed a semantic/pragmatic coherence judgment task in the scanner. The stimulus sentences contained a critical verb presented in one of the four conditions:

1. Anomaly with homophones: **Han må vurderer situationen* (English: ‘He must evaluates the situation’),
2. Anomaly with non-homophones: **Han må overvejer situationen* (English: ‘He must considers the situation’),
3. Baseline for homophones: *Han må vurdere situationen* (English: ‘He must evaluate the situation’),
4. Baseline for non-homophones: *Han må overveje situationen* (English: ‘He must consider the situation’).

Functional images were acquired in an EPI sequence on a Siemens Magnetom Trio 3-T MR scanner with a 32-channel head coil. The acquisition specifications were the following: TR = 1340 ms, TE = 29.6 ms, flip angle = 75°, voxel size = 1.8 x 1.8 x 1.8 mm. We conducted four planned ROI analyses for left IFG, primary and secondary auditory cortices, VWFA and left STG/MTG. When FWE corrected ($p < 0.05$), the whole brain analysis and the planned ROI analysis showed no effect of grammar anomaly, no effect of homophony and no interaction. Yet, the behavioral coherence judgment task showed lower accuracy for stories with anomalous inflection than those with correct inflection ($p <0.001$). Accuracy was also lower for non-homophone conditions compared to homophone conditions ($p <0.001$). A subsequent uncorrected whole brain analysis ($p<0.001$) also showed effects of grammaticality and homophony. For non-homophone forms, the left VWFA, STG and the left insula were more activated than for homophone forms. For grammatical forms, the SFG and IFG were more activated than for ungrammatical forms.

While the manipulation of the study seemed too subtle to detect with FWE correction, both the behavioral data and the uncorrected fMRI findings suggest that the non-homophone forms require extra processing effort, engaging extra activation in areas in the brain that are known for being involved in phonological processing (STG) and written word recognition

(VWFA). These results point out the importance of taking phonology into account when studying morphological processing.

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The neurophysiology of phonemic contrasts perception in multilingual speakers

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With increasing global migration and the strengthening status of English as a *lingua franca*, bi- and multilingualism has become the norm rather than the exception. While the phenomenon undoubtedly comes with many advantages, it also involves numerous challenges: one of the key components of successful language learning is associated with the learner's ability to discriminate foreign sound contrasts. Several event-related brain potential (ERP) studies focused on pre-attentive phonemic perception and observed reduced discrimination mechanisms in the L2 when compared with the L1 (Jakoby, Goldstein & Faust, 2011; Liang & Chen, 2022; Song & Iverson, 2018). What remains unexplored are the differences in language processing dependant on language dominance and proficiency, with possible differences between the first foreign language (L2) and next one (L*n*) still remaining to be examined in neurophysiological research.

The aim of the current ERP study was to investigate phonetic perception mechanisms in multilingual participants, whose L1 was Polish, L2 was English, and L*n* was Norwegian (23 right-handed participants, mean age = 22.4, 5 males). They were exposed to selected vowel contrasts in their L1, L2 and Ln presented within the oddball paradigm (i.e., a sequence of frequently occurring standard stimuli was interrupted by the occasional appearance of deviant stimuli). Apart from the EEG session, the participants also completed L2 and L*n* proficiency tests, language history and use questionnaires as well as a gating task assessing their speech-specific aptitude. Data collection took place in the Neuroscience of Language Laboratory (Adam Mickiewicz University).

Given that Norwegian has a very large vowel repertoire (18 monophthongal vowels), English has a moderately large vowel repertoire (12), and Polish has a rather small vowel repertoire (6), the emphasis was placed on vowel contrasts. The following vowel pairs were used respectively as standards and deviants: /ɨ/ and /ɛ/ for L1 Polish, /ɪ/ and /ʊ/ for L2 English and /i/ and /ʏ/ for L*n* Norwegian. Speech sounds were played via earphones while participants watched a silent movie. For all three languages, we observed the Mismatch Negativity (MMN) as a reaction to deviant stimuli, i.e., a negative-going wave deflection typically elicited by changes in auditory stimuli with a peak at around 150-250 milliseconds from change onset (Näätänen et al., 1997).

Based on previous studies, we hypothesized that the response to the change would be deficient for non-native languages when compared to L1, and this hypothesis was confirmed. However, we have additionally observed differences between L2 English and L*n* Norwegian: for the former one, the MMN response had a lower amplitude when compared with L1 Polish and L*n* Norwegian in the early (i.e., 100-150 ms) MMN time window (see Figure 1). Such findings clearly suggest that foreign language status as L2 or L*n* modulates auditory language processing, which at the same time opens the discussion on the participants' language proficiency and dominance as factors influencing phonetic perception mechanisms.

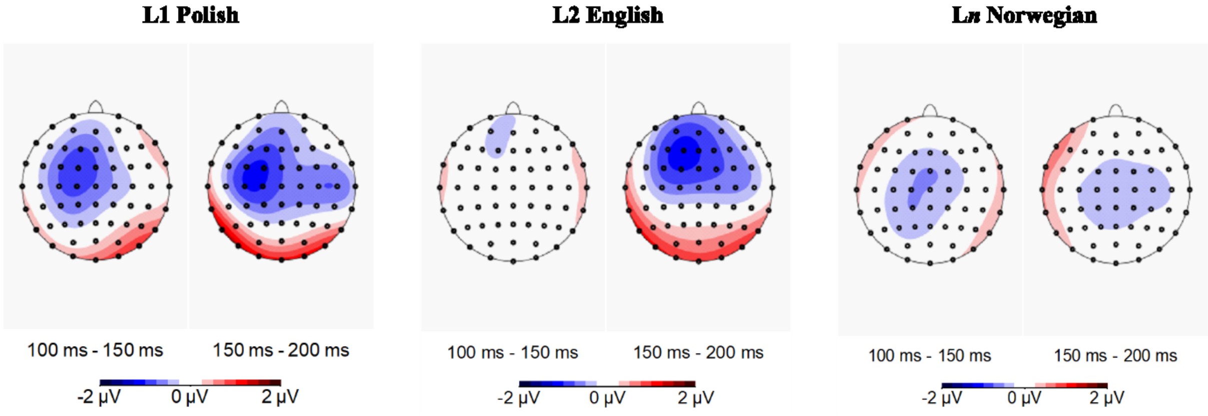

Figure 1: Topographic distribution of voltage differences between deviant and standard conditions in the three investigated languages

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Auditory prediction due to coarticulatory cues

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Introduction. Speech perception is a complex task that we perform every day without thinking much. The workings of coarticulation and auditory prediction are important for understanding how the brain processes speech sounds and how we are able to perceive and interpret spoken language efficiently. Both speech perception and production are thought to involve predictive mechanisms (Forseth et al., 2020), and listeners use auditory and visual cues for prediction (Huizeling et al., 2022). Coarticulation – the phonetic influence of a specific speech sound on a following or preceding sound – plays a significant role in spoken word recognition (McQueen, Norris & Cutler, 1999). Most studies investigating the effect of coarticulation on prediction have focused on eye-tracking methods with contextual cues and carrier phrases (McMurray et al., 2018).

Methods. Gating studies of coarticulation, investigating progressively longer portions – or gates – of fricative sounds, have reported that coarticulatory cues to the upcoming speech sound are present in fricative sounds (Schreiber & McMurray, 2019), and that listeners are sensitive to cues (Galle et al., 2019). While previous research shows that coarticulation is used predictively, we do not yet know the exact moment where anticipatory coarticulation affects word recognition since—to our knowledge—no gating study has investigated word onset prediction for very short gates (in the order of 15 ms). In this study, we investigated the time point at which coarticulatory cues come into play in the prediction process using a behavioral gating experiment (Grosjean, 1980). No context was given to the participants, in order to isolate the effect of auditory prediction using only auditory cues.

Results. Previously, within-word coarticulation studies have mainly used cross-spliced mismatch to assess the cue effect of coarticulation (Salverda et al., 2014). In this study on Swedish fricatives, we use gated stimuli without mismatch. Word onset fricatives are divided into four slices: 15, 35, 75, and 135 ms from word onset. Native Central Swedish listeners ($n = 20$, age range = 18-40 years) hear increasingly longer chunks of the recorded onset consonants until, finally, the full word is presented. They are asked to select one of two words appearing on the screen as the one they think they are hearing. The experiment contains 20 words with /s/ and 20 words with /f/ onsets. Words were recorded in isolation in citation form by a Central Swedish speaker. The acoustic effects of the consonant-vowel coarticulation were analyzed in detail. Previous findings indicate that features such as roundedness and height may be perceivable and useful for prediction within 15 ms of hearing the onset consonant (Lulaci et al., 2021).

A generalized linear mixed-effects model was used to examine the earliest point where coarticulation-based prediction is possible, as well as differences between the predictability of different vowel features. The relationship between prediction and roundedness for words with /s/ onset was tested, with participant and item included as random effects. The results suggest that it is possible to use cues from roundedness to predict the upcoming speech sound as early as in the 15-ms gate. Linear mixed models were used to examine the relationship between prediction and height and backness for words with /f/ onset. The results suggest that it is possible to use height and backness cues to predict the upcoming speech sound in the 75-ms gate. Roundedness for words with /s/ onset was the fastest cue to affect the accuracy, influencing word choice already in the 15-ms gate.

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Computational architecture of speech comprehension

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Humans understand speech with such speed and accuracy, it belies the complexity of transforming sound into meaning. The goal of my research is to develop a theoretically grounded, biologically constrained and computationally explicit account of how the human brain achieves this feat. In my talk, I will present a series of studies that examine neural responses at different spatial scales: From population ensembles using magnetoencephalography and electrocorticography, to the encoding of speech properties in individual neurons across the cortical depth using Neuropixels probes in humans. The results provide insight into (i) what auditory and linguistic representations serve to bridge between sound and meaning; (ii) what operations reconcile auditory input speed with neural processing time; (iii) how information at different timescales is nested, in time and in space, to allow information exchange across hierarchical structures. My work showcases the utility of combining cognitive science, machine-learning and neuroscience for developing neurally-constrained computational models of spoken language understanding.

Poster presentations – Day 1

The *Agent* and the *Causer* in the Processing Race

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Psycholinguistics investigates real-time processing of language, a live realisation of theoretical linguistics. Theoretical linguistics introduced external and internal thematic roles, describing their positions in relation to the verb phrase, VP [6;17]), that affect processing. External roles are usually *agents*, occurring first in common active voice. External roles are absorbed by passive morphology in passive voice, so missing, but implied or added optionally in the *'by'*-phrase. An internal *causer* or *theme* role is projected from the post-verb complement to sentence subject instead. Object-experiencer (OE) actives and passives pattern analogously to these agentive sentences when they contain an *agent*. However, an unusual stative OE subtype has no *agent*, an internal *causer* or *theme* role projected to subject from the post-verb complement in actives [3;9;12;16]. An internal active thematic role cannot be absorbed, so these passives are adjectival (aP [2;3;8;12]).

More recently, theoretical linguistics proposed we replace psycholinguistic investigation of thematic roles, with investigations of 'little v' – *event* structure [11]. Psycholinguistics has overlooked little v, a light verb, often phonetically null, placed immediately above the VP in a theoretical syntactic processing hierarchy ("tree" [10;11]; Figure 1). Some researchers have added 'Voice' [7;14] and others, Applicative ('Appl' [11;13]) above little v, as additional *event* structure assigners. 'Appl' assigns the external argument subject for the event structure - an *agent* or *causer* for an *eventive/causative* little v, or an *experiencer* or *theme* for a *stative* little v [1;5;12]. (Whether *stative* arguments are external or internal to the VP is contentious [12;13].) 'Voice' denotes an active or passive.

A key distinction between thematic role versus event structure theories is whether, in the absence of an *agent*, a *causer* is external or internal in active voice, and whether these passives are adjectival [2;8]. Projected internal thematic roles cause a processing slowdown after the verb, as comprehenders reactivate the nouns in the position from where they have moved [4;15].

Method: Unlike other roles, *agents* intentionally interact in sentence *events*. So, we investigated whether 63 fluent-English-speakers interpreted the active subject or passive *'by'*-phrase object, as an *agent* in English agentive and OE sentences (NP1-(*'was'*)VP(*'by'*)-NP2-PP; N=480), by their rating of intent on a Likert scale, ranging from, *no intention,* to *strong intention*. Each sentence for Likert judgement was introduced in a self-paced reading design, uniquely allowing us to isolate the relative processing speed when an *agent* is present compared to when one is not.

Results: Silhouette plots then a 2-cluster kmeans analysis grouped the verbs into like ratings of intent. 116 OE actives and passives (*'The artist (was) provoked (by) the creator of the epic tragedy'*) fit best in the *eventive* cluster, its mean rating of intent ($\bar{X}$=2.38) indicating an intentional, *agent* interpretation of the role. 124 OE actives and passives (*'The announcer (was) agitated (by) the runner in the thin jacket'*) fit best in the *stative* cluster (mean rating of intent, $\bar{X}$=1.09). The *stative* (*"agitated"*) cluster showed a spread of ratings across the Likert scale, so, we further split this labile group at the mean into instances rated "low" and instances rated "high". Comparable first-noun reading speed was sustained for actives at the verb, with passives lagging. At the second noun, _agent_-first sentences led *causer/theme*-first sentences (p=0.002) whether active or passive. Adjectival passives with _experiencers_ first, *causers/themes* second were quickest at the prepositional phrase (p=0.009; p=0.028) (Figure 2).

Conclusion: OE actives with a stative interpretation ("low") do not have an external _agent_ thematic role; and have corresponding "adjectival" passive sentences without an _agent_ in either the subject position or in the *'by'*-phrase. If this non-_agent_ active subject is a *causer* in an event or state, it is not external, as processing slowed at NP2, consistent with reordering for comprehension; and it speeded up at PP when, unlike eventives with an _agent_, reactivation was not required to comprehend stative "adjectival" passives. If little v is to account for human sentence processing, it needs to be multi-tiered, independently assigning thematic roles, an external argument, and voice. States may have *causers*, _causers_ may be external if they are _agents_ or internal if not, and internal subjects may be in active voice.

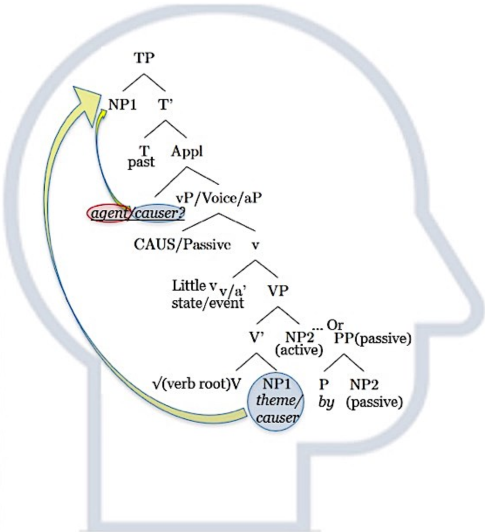

Figure 1. Amalgam Theoretical Processing "Tree".

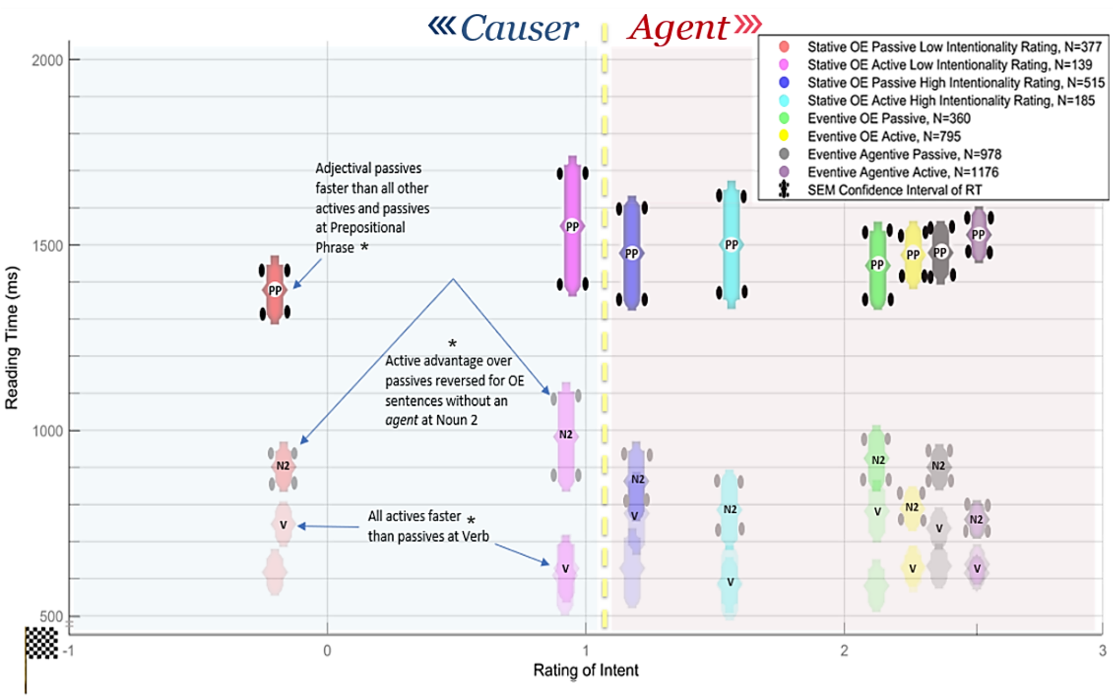

Figure 2. "The Processing Race" 95% Confidence Intervals for "Low" OE Actives and Passives (no _agent_), versus "High" Eventive OE and Agentive Actives and Passives (_agent_), at Noun 1 (most transparent 'car', N1), at the Verb (V), at Noun 2 (N2) and at the Prepositional Phrase (PP).

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Compounds and Aphasia: Recent Developments in Theoretical and Experimental Neurolinguistics

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As the complex system of compounds is at present poorly understood, primary research emphases include how complex words are represented and accessed in the mental lexicon. Behavioural studies concern how production errors could exhibit mental representations of complex words. Evidence is looked for in the error patterns in a typical population compared to patients with acquired and developmental language impairments, namely aphasic and neurodegenerative conditions.

Three dominant models include: (i) full listing, (ii) decomposition or full parsing, and (iii) dual route. The full listing account supports the approach that complex words are stored as whole words and accessed as such. Even though it promotes storage economy, such a view would not make a difference between simple and complex words. The strongest evidence for the difference between compound storage and simple word storage is the compound effect (Semenza and Mondini 2010, among others). Moreover, structural and rule knowledge is evident in error patterns and independent of phonological form. Mondini et al. (2003) tested aphasic population compared to a typical population on naming simple nouns and verbs followed by compound nouns in the picture naming tasks. They confirmed the earlier prediction in differentiating simple lexical items from compounds, showing close to perfect results in naming simple words, and grouping error patterns in compound production. Error types such as substitution and omission of compound constituents support compositional approach in word retrieval. The headedness effect is taken as the main predictor to determine mental representation of compounds (Mareli et al. 2013, Lorenz et al. 2014), followed by numerous factors in processing, such as semantic transparency and frequency effect. Results speak in favour of the dual route account, which considers activating both holistic and decompositional methods, depending on semantic transparency and lexical frequency of the head constituent.

In addition to omissions and substitutions, errors such as misordering, paraphasia, neologisms and circumlocutions gave compelling evidence for the mental representation of compounds that supports two stage lexical access of Levelt et al. (1999): (i) semantic–conceptual level, followed by lemma level, where grammatical properties of morphologically complex word are accessed, and (ii) phonological level. Constituent errors included their omission or substitution, or phonological distortion in a compound picture naming task and naming to definition tasks. Furthermore, neologisms and circumlocutions of one of constituents indicated that the origin of errors leads to the existence of semantic level. Failure to retrieve the exact phonological from speaks in favour of the existence of phonological level of representation.

Lexical processor identifies at some point the morphological structure of compounds. In support of this claim, subjects did not produce substitution errors when targets were single words (Mondini et al. 2003, Lorenz et al. 2014, Marelli et al. 2014). Lorenz et al. (2014) support the dual route approach, and suggest both full form and decompositional representation at the lexical level, which will depend on several factors. Unlike grammatical class (defined at lemma level), semantic transparency and opacity categories are held to be differently represented and processed, as indicated by the transparency effect with constituent errors. More constituent errors in transparent compounds than opaque ones could suggest that compositional access of transparent ones would include activation of all neighbouring concepts (parallel activation of semantically related concepts at the conceptual level), while opaque access include full form access. On the other hand, more semantic errors were present with less semantic transparency. Such results fit nicely within the account by Libben (1998), assuming the connection between full form and constituent elements at semantic level only in case of transparent compounds, but not the opaque ones.

Research on compound processing in agrammatism in stroke–induced and primary progressive aphasia (PPA) population (Kordouli et al. 2018) shed light on the compound processing in acquired aphasic conditions also in relation to neurodegenerative disorders. It investigates the presence of grammatical, morphological, and semantic knowledge in stroke–induced agrammatism and agrammatism induced by PPA, with cross–linguistic evidence from Greek as a language with reach morphology. Morphological impairments related to inflection and derivation in aphasic agrammatism, both stroke–induced and PPA, are reflected predominantly in verbal inflection in production. Ability to detect morphological violations in comprehension of derived nominal, verbal, and adjectival forms is severely impacted in PPA, but relatively preserved in stroke–induced agrammatism.

The results complement nicely developed models of compound mental representation and processing, where total decomposition and dual route approaches in word retrieval are supported by the errors concerning compound constituents and not only whole compounds. Looking at other types of complex words, such as derivation by prefixation and suffixation in word formation, decompositional mechanism in case of prefixed words and holistic approach in case of suffixed forms have already been enclosed and described (Ciaccio et al. 2020).

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Towards building the Croatian Naming Test: from cognitive linguistic foundations to neurocognitive applications

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This proposal will focus on presenting research activities of the linguistic research group within the Centre of Excellence for Basic, Clinical and Translational Neuroscience, a pioneering effort to bridge the gap between Neuroscience and the Humanities in Croatia and establish a transdisciplinary dialogue. As such, our primary research goals are to develop cognitive and linguistic materials for use in testing language comprehension and production of Croatian speakers in various psycho- and neurolinguistic settings. In this proposal we will present a roadmap of these research activities focusing on the undergoing development of the Croatian Naming Test (CNT).

Different naming tasks and tests exist in various languages and these have been used for a variety of purposes (cf. Spreen & Risser, 2003). There are several standardized assessment tools in Croatian as well (e.g., Comprehensive Aphasia Test, CAT-HR; Swinburn et al., 2020, Test for the reception of grammar, TROG-2:HR; Bishop, Kuvač Kraljević et al., 2014, etc.), but no independent standardized and validated naming tests, other than the one included in the CAT-HR. The Boston Naming Test (Kaplan et al., 1978; 1983; 2001) is probably the most widely used test for clinical and research purposes, and it has undergone many translations and adaptations worldwide (e.g., Ballard et al., 2018; Grima & Franklin, 2016; Kim & Na, 1998; Patricacou et al., 2007). What many adaptations show is that there are methodological challenges (cf. Ivanova & Hallowell, 2013) when one tries to capture the notion of linguistic diversity in materials used for psycho- and neurolinguistic assessments of language impairments. These challenges are due, in part, to various linguistic models which try to disentangle the notion of linguistic diversity in various ways, thus making it still a work in progress from the perspective of linguistics. In Cognitive Linguistics, this notion encompasses typological, structural, social, and cultural aspects of language knowledge, world knowledge and use. Because of such challenges, which may be reflected in both research and clinical settings, this group of authors decided to develop a new test based primarily on criteria stemming from the Cognitive Linguistics framework. Croatian, as a Slavic language, possesses some lexical features that are not characteristic for English, notably a morphologically rich system of word formation (particularly derivation, e.g., *svjetionik* 'lighthouse', *svijećnjak* 'candlestick', *čajnik* 'teapot') and a pronounced tri-dialectal variation of many common everyday item names (e.g., *kuća* (standard), *hiža* (Kajkavian) 'house').

The stimuli selection for the CNT was therefore guided by these language-specific properties, yielding a list of 99 stimuli target words with varying degrees of word formation complexity, frequency, and cultural features. Stimuli were drawn in the black and white technique by one artist. Two pilot studies were conducted in order to assess stimuli selection, including metalinguistic judgments on item and word familiarity and frequency, as well as picture clarity. Due to the COVID pandemic both pilot studies were conducted via the SurveyMonkey platform. 99 (Pilot 1) and 80 (Pilot 2) stimuli were presented to speakers with typical language status (N = 89 (Pilot 1) and N = 109 (Pilot 2); age range 18-65).

The first results show that including a variety of word formation patterns representative of Croatian adds new insights into the important aspects of the CNT design, particularly naming difficulty, which should be regarded as a joint measure of frequency, naming agreement, and dialectal and sociolectal variation of word forms. Among others, these stand out as important factors to consider when evaluating items in a naming test design (cf. Beattey et al., 2017;

Harry & Crowe, 2014; Pedraza et. al., 2011). Pilot studies provided relevant data on how this variation should be treated in the CNT design, for example, *mrkva* (standard) - *karota* (Chakavian) 'carrot' is a low difficulty item despite variation, whereas *pleter* 'Croatian braided ornament' is a high difficulty item with low naming accuracy without variation. Qualitative linguistic findings and quantitative data could be further exploited in various psycholinguistic, neurocognitive and other research settings.

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Swedish word accents and semantic processing in the brain: An ERP study with minimal pairs

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Prosodic cues can aid speech processing by adding semantic information in lexical tones or functional information in intonational tones. Swedish word accents have stronger grammatical functions than semantic roles, although they are shaped by morphological, lexical, and information structures (Bruce, 1977). Amid the abundance of evidence that the word accents facilitate a prediction for the upcoming morphological composition via a decompositional route (Roll, 2015, 2022; Schremm et al., 2018; Söderström et al., 2016, 2017), the present neurophysiological study investigated the semantic function of the word accents.

Swedish word accents are two types of pitch contours (accent 1 and accent 2) that consist of high and low tones. In South Swedish, accent 1 has a high tone associated with the onset of the stressed vowel and followed by a pitch fall, resulting in a H*L contour, whereas accent 2 has a low tone gliding up to a high tone later in the stressed syllable and followed by a fall, forming an L*HL pattern (Bruce, 1977; Roll, 2015). Figure 1 illustrates the minimal pair ^{1}*normen* "the norm" and ^{2}*norrmän* "Norwegians" contrasting in pitch contours.

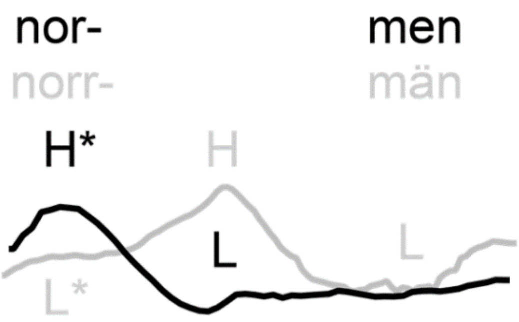

Figure 1. Word accent contours of South Swedish.

A perception experiment was conducted using minimal pairs contrasting in tonal accents. Contextual constraints were employed to build a semantic expectation of the target word. The tonal realisations in the target words were either congruent or incongruent with the semantic contexts. Online processing of the sentences was analysed using event-related potentials (ERP).

Word accent incongruency caused a longer reaction time, implying that word accents play a role in sentence comprehension. An N400 effect was observed, indicating that the accent tones and the word forms can be stored together in one lexical unit in the mental lexicon. A difference in ERP was also found between the two word accents. Accent 1 displayed a greater negativity compared to accent 2, starting between 250-400 ms post word onset. This was interpreted as pre-activation negativity (PrAN) indicating that accent 1 gives stronger predictive certainty even when different contexts are involved. It is concluded that the Swedish word accents have a semantically distinctive role in addition to their well-documented facilitative function of morphological predictions.

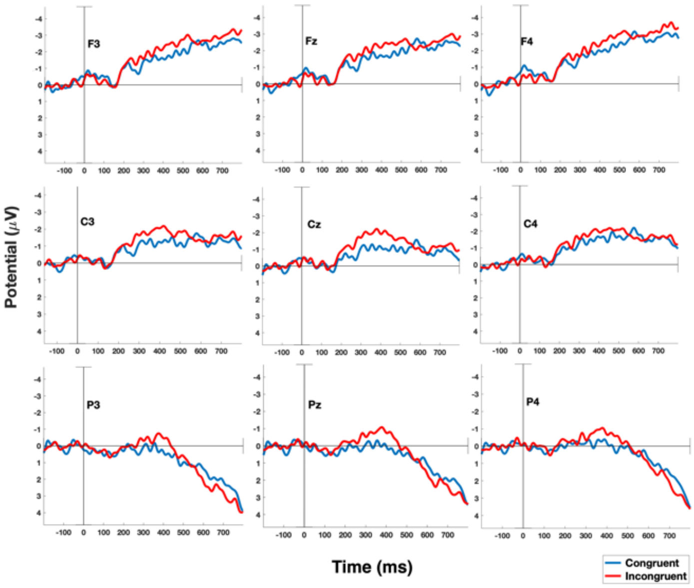

Figure 2. N400 effect of word accent violation.

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Perceiving (un-)predictable words: The perception of unexpected prosodic contours as modulated by semantic constraints

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Sentences can vary in how predictable they are, and these variations of predictiveness have been shown to influence word perception in neurolinguistic studies. However, there is ongoing debate on whether the phonological content of a word is predicted as well if the sentence context makes this possible. While some studies argue that phonological perception only happens bottom-up and is then forwarded to higher levels of analysis (e.g., to confirm or update the semantic prediction), other studies state that phonological forms themselves are predicted top-down from semantic predictions. This study tests this question on Stockholm Swedish native speakers and uses a novel approach to the problem of phonological prediction by varying both the predictiveness of the sentence, as well as the phonological realisation of the target words. In contrast to other studies, the phonological variation that is introduced to the words is a non-standard *word accent contour*, a Swedish word-level pitch accent with limited lexicality. Using EEG methodology, the study tests whether the predictability of a word modulates the amplitude of event-related potential components related to mismatch, leading to differing percepts in bottom-up vs. top-down perception. The results show that the predictive context does not significantly modulate the way a non-standard prosodic contour is perceived, however, the data shows some indication that it is the high constraint context in which it is more salient. Additionally, the type of manipulation of the prosodic contour influences the results that are obtained, indicating potential for more research into the nature of phonological word-form predictions.

Emotional language processing: Modulations of event-related potentials amplitude by induced mood in a valence judgment task

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Emotional vocabulary enjoys a processing advantage, with the emotional salience of a word detected at 200 ms post-presentation or earlier, signalling selective attention to its affective properties. An individual's affective state also impacts attention and, by extension, affects processing. This study investigates whether and how preferential processing of emotional valence is modulated by mood. Participants performed an evaluative decision task in L1 judging the valence of individually presented words in a control mood and two mood-induced conditions. Recorded event-related potentials (ERPs) were analysed in the time window of the early posterior negativity (EPN) and the late positive complex (LPC) to cover both early lexical-semantic access and more elaborate and motivated semantic processing. Mood was only found to significantly modulate affective language processing at the later stage. Mood-induced alterations of the ERPs did not follow a mood-congruent pattern: negative words elicited consistently higher amplitudes across conditions and sustained little effect of mood changes, while reactions to positive words were modulated by mood. The results are discussed against the background of associative network theory and differential attentional effects of mood.

Talks – Day 2

Brain potentials to three North Germanic language varieties reveal swift prosodic modulation of lexical access

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Most models of spoken word recognition assume that lexical access is an interplay between forward and backward-looking processes. Listeners probabilistically activate a cohort of possible lexical candidates which is incrementally reorganised as the signal unfolds. Neurophysiological correlates of both types of processes have been identified within 500 ms after the onset of the relevant phonemes (for a review, see Gwilliams & Davis, 2022). Suprasegmental cues such as tone and voice quality can provide lexical and morphological information in an additional dimension on top of unfolding segments. We investigated the influence of suprasegmental cues in three North Germanic language varieties which have a two-way word accent distinction. The accents have a similar distribution but are realised differently across varieties (Gårding, 1977). For instance, accent 1 is realised as a low tone on the stressed syllable in Central Swedish, a pitch fall in South Swedish and as a type of creaky voice in Standard Copenhagen Danish. We used combined pronunciation lexica and frequency lists to calculate estimates of lexical uncertainty and information gain at suprasegmental cue onset. Participants listened to target words incorporated into low-constraining carrier sentences. Using single-trial mixed-effects regression models run every 4 ms, we investigated temporally fine-grained event-related potential effects of lexical uncertainty and information gain associated with suprasegments. Only lexical certainty showed solid results: Lexical uncertainty resulted in frontal effects within 200 ms after suprasegmental cue onset and a later posterior effect after 200 ms. The findings indicate that a previously reported frontal pre-activation negativity for stronger phonological cues (Roll et al., 2015) is driven by forward-looking processes. Effects of information gain associated with the onset of suprasegmental cues did not survive correction for multiple comparisons. This could be related to task demands or because measuring points were late in words. The suprasegmental model explained the data better than a model including only segmental speech sound information at 200-350 ms at frontal sites. This indicates that in this spatiotemporal window suprasegmental info modulated lexical access.

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Early automatic processing of lexical word accents: Valid words are stored holistically irrespective of stem tones

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According to the dual route model of word processing (Pinker & Prince, 1991), morphologically irregular and frequent words are stored in the lexical memory as full-form neural representations. In contrast, regular and infrequent words are decomposed into morphemes. So far, it has been unclear whether a tonal element—a lexical word accent—is treated by the brain as a decomposable component or an integral part of the word's full form. In Swedish, all content words bear a word accent, either a low (accent 1) or a high tone (accent 2). The accent depends on the morphology, as the low or high tone is assigned to the stem by the following suffix. This compositional nature of the word accents begs the question of whether word accents are accessed decompositionally or together with full-form word representations. We designed an event-related potential (ERP) experiment using a passive listening oddball paradigm to test this through elicitation of the Mismatch Negativity (MMN) component. MMN is a useful method to disentangle full-form storage from the decompositional processing (Morris & Holcomb, 2005; Newman et al., 2007; Schremm et al., 2019). Full-form storage manifests as a *lexical MMN*, where valid deviant stimuli elicit greater negativity than invalid deviants (Pulvermüller & Shtyrov, 2003), because real words trigger a full-form neural representation and it is known that activation of memory traces translates as negativity in the recorded EEG potentials (Hanna et al., 2017). Decomposition manifests as a *syntactic MMN*, where valid morpheme combinations presented as deviants elicit smaller negativity than invalid deviants that violate a compositional rule (Leminen et al., 2013; Pulvermüller & Assadollahi, 2007), because related morphemes prime each other, and it is known that priming reduces the negativity (Bentin et al., 1985; Holcomb & Neville, 1990).

We recorded ERP responses in 17 native speakers of Swedish (6 males, mean age: 23.2 years, SD = 4.5) to Swedish words with valid and invalid combinations of stem tone and suffix. During the experiment, the participants watched a silent movie and were instructed to ignore the stimuli played to them binaurally. These stimuli consisted of four words—two valid and two invalid combinations of stem tone and suffix (valid: *[1]krok-en* and *[2]krok-ar*, invalid: *[1]krok-ar* and *[2]krok-en*) presented as standards and deviants in four blocks, where validity and suffix varied orthogonally in a fully counterbalanced fashion.

Identity MMN was calculated (Pulvermüller & Shtyrov, 2006) using suffix onsets for time locking of ERP responses. Permutation analysis revealed an increased negativity ($p = 0.033$) in the early MMN time window (80-180 ms) for valid combinations of stem tone and suffix compared to invalid combinations (Fig. 1A) which we interpret as lexical MMN pattern. The scalp topography showed a right-skewed frontocentral negativity during that time window, which is typical for an MMN. Two peaks in the global field power function were observed during this time window (Fig. 1B). Cortical source estimation showed that, during the early peak (120-140 ms), significant activity occurred in the auditory cortex of the right hemisphere, generally associated with suprasegmental and pitch-related processing, while during the late peak (160-180 ms), significant activity occurred in the mid-posterior temporal lobe in the left hemisphere, typically associated with retrieval of lexical units from long-term memory (Fig. 1C).

The results indicate a full-form lexical retrieval of valid Swedish words with both word accents. This process appears to have two stages that engage different brain areas: first the right auditory cortex, where, likely, the pitch contour of the word accent is established, and then the left lexical memory area, where the memory trace of the appropriate (that is, bearing the correct word accent) lexical unit could be activated. Moreover, these results for the first time show that word accents are used in early automatic lexical retrieval.

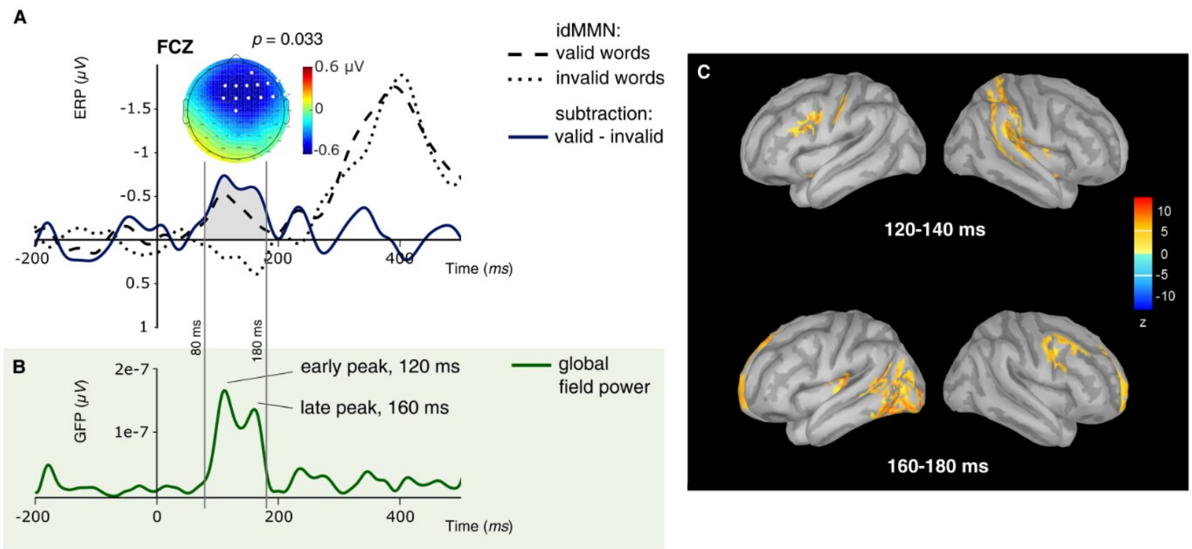

Figure 3. A) Average identity MMN responses to valid words (dashed line) and invalid combinations (dotted line), time-locked to suffix onset. Solid line shows the lexical MMN subtraction, *valid – invalid*. Grey area at 80-180 ms shows the permutation analysis time window. White dots on the scalp map show the negative cluster found during permutation analysis. **B)** GFP function of the *valid – invalid* subtraction. **C)** Significant source activation difference for the *valid – invalid* contrast during the peak GFP time windows.

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Lexical tone in bilingual spoken word recognition

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Spoken word recognition is characterized by competition, as the lexical processor needs not only to interpret the unfolding speech input, but also to inhibit the activation of non-target candidates (e.g., Luce & Pisoni, 1998). This competition has been extended to investigations in bilingualism to understand how bilingual listeners recognize spoken words in one language that sound similar to words in the other (e.g., Ju & Luce, 2004; Weber & Cutler, 2004). One linguistic dimension, namely, lexical tones, has been shown to provide independent cues for lexical access within a tonal language (e.g., Malins & Joanisse, 2010). If tones are crucial in spoken word recognition, a key question is whether this linguistic knowledge is utilized in bilingual spoken word recognition. In other words, does lexical tone play a crucial role in cross-language lexical competition? To address this question, we used the Visual World Paradigm due to its temporally sensitive measures of lexical activation and competition (Tanenhaus, et al., 1995). These measures are collected by recording eye-movements when participants are instructed to click a target matching an auditory stimulus in an array of pictures on a computer screen (see Fig 1). The experimental manipulation is realized through the presence of a competitor, the name of which bears a phonological relationship with the target, as shown in Fig 1. Here, we presented Mandarin-English participants with two types of target-competitor pairs: *Segmental* ("bay"--"cup") where 'cup' in Mandarin Chinese is '/bei/1' phonologically related to 'bay' (pronounced in statement intonation) only in segments, and *Segment + Tone* ("bay" – "quilt") where 'quilt' in Mandarin Chinese is '/bei/4' phonologically related to 'bay' (pronounced in statement intonation) in both segments and tones. The task was to click on the target (e.g., 'bay') when listening to 'bay' in English. In a within-participant design, we observed competition effect in the segment + tone condition, but not in the segmental condition. Eye-movement data analysis is based on non-linear curve fitting to show the time course of eye-movements on different objects (i.e., targets, competitors, and distractors), measured by different parameters on the curves for both targets and competitors. In particular, the competition effect is measured by showing the difference between eye-fixations on competitors and unrelated distractors across trials. Our results showed significant competition effect in the segment + tone condition (see Fig 2), when comparing eye-fixations on competitors to distractors. However, this effect was not significant in the segmental only condition (see Fig 3). In addition, the competition effect was significantly larger in the segment + tone condition than the segmental condition. Taken together, these results first demonstrate the obligatory role of lexical tones in cross-language lexical competition in VWP.

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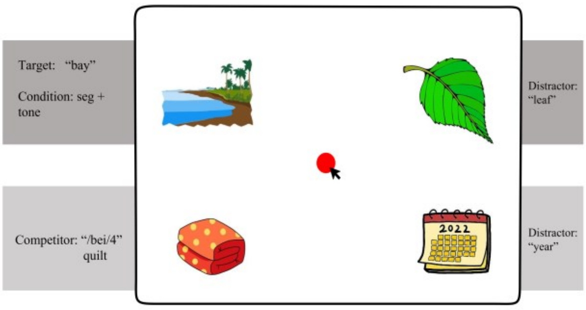

Figure 1. Cross-language lexical competition: targets (in English) are phonologically related to competitors (in Mandarin) in both segments and tones.

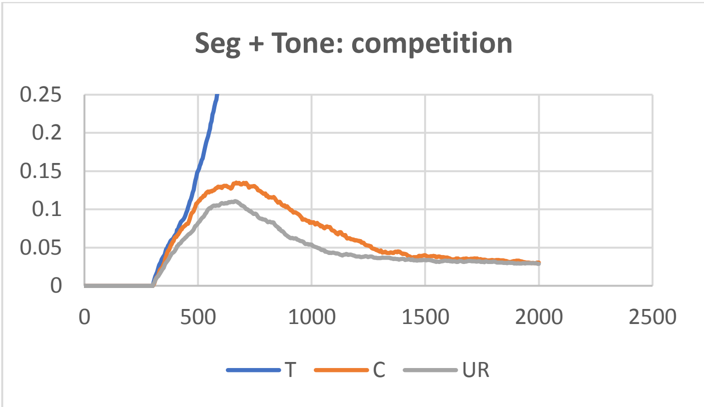

Figure 2. Segment + Tone Condition: curves (time course) for targets (blue line), competitors (orange line), and distractors (grey line). Competition is measured by the proportion of looks on competitors compared to distractors.

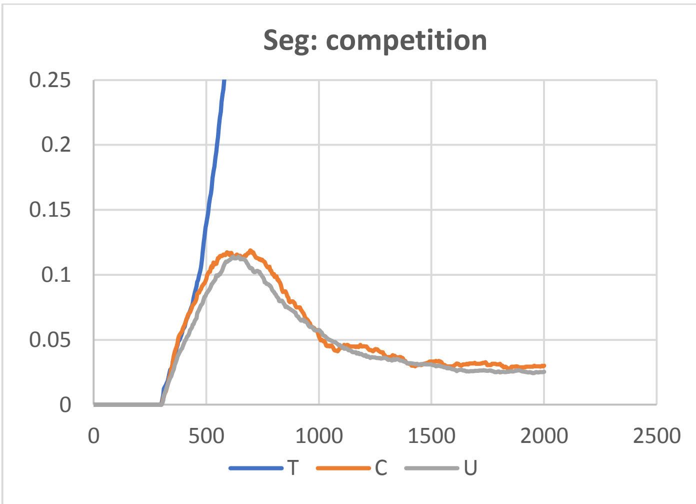

Figure 3. Segment Condition: curves (time course) for targets (blue line), competitors (orange line), and distractors (grey line). Competition is measured by the proportion of looks on competitors compared to distractors.

Language acquisition and second-language learning share convergence patterns in ERPs.

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Children are generally believed to have mastered their grammars by school age, but psycholinguistic and neurolinguistic research has shown that grammars might consolidate at the end of grade-school. It might also be that some aspects of language processing are affected by morphological regularity or syntactic complexity and thus show delayed consolidation up to high-school years. ERP patterns elicited in children who are still acquiring their first language (L1) can resemble that of second-language (L2) learners at these stages, for example eliciting N400s instead of adult-like LANs for grammatical errors (Clahsen et al 2007; Dube et al, 2018; Tippmann et al 2018).

We present results from five ERP studies investigating gender agreement processing in French children (aged 4–8), (pre-)teens (8–16) and adults (18–35) and subject-verb agreement in (pre-)teens (8–16) and adults (18–35) using audio-visual picture-sentence-matching ERP paradigms. In the gender agreement study, sentences were grammatically correct (*Je vois la clef grise* [gʁiz] *sur la* table 'I see the$_F$ grey$_F$ key on the table'), or had gender errors on determiners (…**le clef grise* … 'the$_M$ grey$_F$ key'), or adjectives which have irregular agreement patterns in French (… *la clef *gris* [gʁi] … 'the$_F$ grey$_M$ key'. In the subject-verb agreement study, sentences were all grammatical but could match or mismatch the visual stimulus (e.g., *The lion roars* presented with a picture of two lions roaring). Plural agreement on French verbs is either marked with an irregular, or sub-regular, consonant-final verb, or is marked with regular liaison between the pronoun and a vowel-initial verb.

Our studies show changing patterns for error processing in children, teens and adults. First, adjective and determiner processing elicit distinct patterns in all groups, but in teens patterns for determiner agreement, which is regular, resemble those of adults. Adjective error processing does not yet match the adult pattern in teens. Regarding subject-verb agreement, again teen patterns were different from adults. Importantly, commission errors were processed more saliently than omissions (as has been found in Italian, Cantiani et al, 2013, and English, Dube et al, 2018) and regular processes elicited more adult-like ERPs than irregular ones.

We will discuss a basis for shared ERP predictions in L1 and L2 acquisition as a function of language proficiency (Steinhauer, 2014).

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Tracking the prosodic hierarchy in the brain – cortical entrainment in German listeners

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The speech signal carries hierarchically organized acoustic and linguistic information. Recent neurophysiological and computational models posit a decisive role for cortical oscillations in explaining how the brain deals with this complexity [1–3]. Within these models, especially the theta frequency range (~4-8 Hz) is spotlighted, its importance arising from the correspondence between the syllable and salient temporal modulations in the speech signal and the biomechanical frequencies of articulator movements at that rate [4]. However, in addition to the theta range, there are also slower modulations associated with stress and the intonation contour at rates of ~2 Hz [5] and ~1 Hz [6], respectively, that coincide with a cascade of prosodic features. Phonological theories capture the relationships between these features in a prosodic hierarchy [7,8], with behavioral and neuroimaging studies showing that listeners are receptive to individual levels of the hierarchy [9–13]. However, what remains unclear is how low-frequency modulations associated with the prosodic hierarchy are concurrently represented by the brain through cortical oscillations, whether these oscillations themselves interact during speech processing, and the behavioral relevance thereof.

We addressed these issues with an EEG study where 30 young adults listened to 400 German sentences with manipulations at different levels of the prosodic hierarchy. Specifically, sentences either had a regular or an irregular stress pattern and a flattened or natural intonation contour. Syntactic structure was kept constant, and sentences were semantically unpredictable but meaningful. Following each stimulus, participants performed a syllable identification task. We evaluated single-trial cortical entrainment to the syllable/theta (3.5-4.7 Hz), stress/high-delta (1.8-2.8 Hz) and intonation/low-delta (0.6-1.1 Hz) range using pairwise phase coherence (PPC) and a series of mixed effects models. Additionally, we used driven autoregressive (DAR) models and cluster-based permutation tests to assess phase-amplitude coupling (PAC). Behavioral performance as a function of prosodic manipulations and magnitude of oscillatory activity was likewise assessed with mixed effects models.

We found that the brain concurrently entrains to all three levels, especially so in the theta and low-delta range. Subtle changes in the regularity of stress patterns significantly reduced the brain's ability to entrain to the speech signal in the theta range. Such a disruption to acoustic chunking due to altered prosodic structure is plausible if there is an underlying correspondence between the time constants of the speech motor system, auditory perceptual system, and neuronal infrastructure [3,14,15]. In contrast, entrainment in the low-delta range to speech signals containing a flattened intonation contour was only minimally reduced compared to those with a natural intonation contour, making it likely that the brain compensated for this lack of variation by applying top-down linguistic knowledge – in this case presumably of intonational phrasing [9,16]. Overall, we found results to be consistent with a hierarchical organization of prosody [17]. Moreover, sensitivity to prosodic cues and manipulations thereof showed systematic inter-individual differences. At the behavioral level, for example, participants classified as "high synchronizers" were better able to compensate for altered prosodic structure than those classified as "low synchronizers" [18]. Finally, preliminary results speak for hierarchical relationships between low-frequency oscillations: low-delta and theta and high-delta and theta oscillations show PAC that is modulated as a function of experimental manipulations, further supporting the conjecture that a nested hierarchy of cortical oscillations is integral to speech processing [19].

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Electrophysiological insights on aspectual coercion

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This ERP study investigates the electrophysiological cues of aspectual coercion, i.e., the process by which speakers adjust the apparent contradiction between the lexical or grammatical aspect of a predicate and rest of the sentence. The aim is to ascertain whether lexical aspect is projected or composed. We used Dowty's aspectual test to investigate whether n. 28 Italian native speakers project telicity top-down and treat it as a feature of the verb, or compose it bottom-up, as a function of the temporal frame following the verb. The *rationale* is that the prepositions *in* and *per* whch are featured in Dowty's aspectual diagnostics – given their frequency, skewed distribution, polysemy, entropy and semantic flexibility – do not just act as elements whose (in)compatibility with a given verb reveals whether that verb is telic or atelic. In contrast, they represent a reagent, that is, what forces a given verb to be interpreted as telic or atelic by speakers, the place where telicity is triggered, not the place where telicity is checked. Predictions were that the typical signatures of semantic violations (e.g. N400) are not expected. Rather, the correlates of a mechanism which integrates the linguistic input in the ongoing discourse representation, such as the Sustainer Anterior Negativity (SAN, Paczynski et al., 2014) is more likely to occur. We tested n. 28 right-handed Italian native speaker (Mean Age =24.46, Range=20-37) with ERPs. Sentence stimuli adapted from the Dowty's test had identical structure. The raw EEG acquired from 59 active electrodes placed on the scalp was pre-processed with BrainVision Analyzer 2 (filter: 0.15-35Hz; ICA correction of ocular artifacts; semi-automatic artifact rejection (9.17%)). The effects of the experimental factors [Acceptability and Telicity] and one topographical factor [Longitude (Frontal, Central and Parietal)] were tested at two word positions - prepositions and noun - with linear mixed models in R. We analyzed voltage amplitude in a time window spanning from 400 to 700ms to capture sustained anterior negativities. No effects were found either at the verb or at time-expressions. In contrast, a significant effect was found at the prepositions. A three-way interaction between Telicity, Acceptability (compatibility between verb and time expressions) and Longitude emerged [$F=7.79$, $p<.001$], showing that the effect of compatibility in frontal electrodes for atelic sentences (see distribution in Figure 2) surfaces the form of a larger negativity for allegedly incompatible ones [-0.78µV, $t=-2.03$, $p=.04$], while the effect was not robust for telic sentences. In sum: (A) The processing of atelic predicates in the 'unacceptable' condition affected the amplitude of the SAN, which is similar to other sustained anterior negativities previously reported in the literature on aspectual coercion. (B) In the 'unacceptable' condition, we did not find any signs of the N400, which is typically elicited by semantic violations, low transitional probabilities, and infrequent words; (C) the SAN was significantly modulated by the temporal propensity of the preposition: the less likely a verb-preposition pair occurred in temporal contexts in the Italian input, the stronger the negativity (D) such an effect only emerged only with 'acceptable' combinations involving telic predicates; (E) No difference within Telic predicates between achievements and accomplishments; (F) No effects at time expression (e.g. *per un mese* 'for one month' vs *per un secondo* 'for one second'). We suggest that our participants' brain probably reacted in order to integrate all the elements of the temporal frame, not to fix a violation. Participants probably did not establish that predicates were telic or atelic prior, but while reading the stimuli (no cues that telicity was 'projected' top-down). Reactions occurred at the preposition, neither at the V nor at the PP complement. Importantly, a distributional feature – the temporal propensity of prepositions or temporal ratio (TR) – played a role and modulated aspectual coercion. Our study introduces frequency and distribution of prepositions (the *ratio* of their temporal uses) as novel factors which enter the *aspectual calculus*. Indeed, at the preposition position, incompatible combinations with preposition *in* elicited a sustained negativity with atelic but not with telic verbs, possibly confirming that the amplitude of the effect linked to coercion is modulated by the distribution of temporal uses of the prepositions in the Italian input. Given the role played by a speaker's sensitivity to the distribution of prepositions in the Italian input, the adverbial test might actually be a telicity reagent, not a telicity diagnostics.

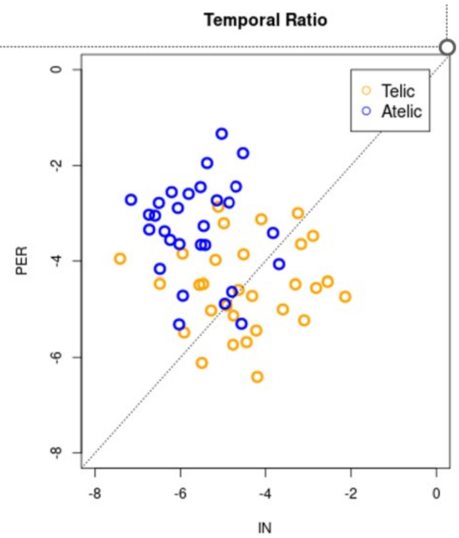

Figure 1. Telic verbs (yellow) – unlike atelic ones - are not skewed towards either prepositions when used in temporal expressions.

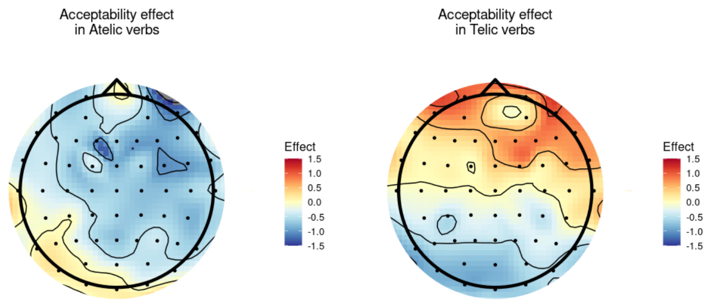

Figure2. Scalp distribution of the difference between Acceptable and Unacceptable sentences for atelic (on the left) and telic (on the right) sentences.

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Anchoring the self in mental space? *This* and *that* makes a difference in posterior parietal cortex.

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Introduction: Spatial demonstratives (in English *this* and *that*) are a prime example of the strong interdependence between language and extralinguistic cognition (Diessel & Coventry, 2020). Demonstratives are highly context-dependent, and prototypically used to distinguish peripersonal from extra-personal space. Comprehension of demonstratives within a narrative context has been found to correlate with activation of the posterior parietal cortex, including the precuneus (Rocca et al., 2020), in line with previous studies of spatial language (e.g. Wallentin, et al., 2008). Recent evidence based on the Demonstrative Choice Task (DCT) suggests that demonstrative forms are not only indicative of position in physical space, but also in semantic and psychological space. In a large DCT study, Rocca & Wallentin (2020) showed that, even in the absence of further context, participants consistently matched proximal vs. distal demonstratives with nouns according to semantic features of the stimuli indicating proximity to the self. The current fMRI study extends this work, investigating if the choice of "*this"* or "*that"* in the DCT is indicative of neural differences in semantic processing of the corresponding nouns and, if so, whether this distinction involves the same posterior parietal brain areas as spatial language. **Methods:** 69 participants (mean age = 24.82, SD=5.31, F = 51, M = 28) underwent fMRI scanning while completing a 303-item DCT. FMRI data were preprocessed using standard fMRIprep (Esteban et al., 2019) preprocessing pipelines. To model differences in processing of nouns associated to proximal vs. distal forms, we computed first-level T-contrasts between trials where participant chose each demonstrative form. Group-level inference was based on second-level intercept models, testing the average effect of the first-level contrasts (this>that and that>this) across participants. Non-parametric permutation tests tested the statistical significance of results (at $p<.05$). **Results:** The contrast between proximal and distal demonstrative trials (i.e., where participants matched the presented noun with *this* relative to *that*) was associated with increased BOLD response in the left precuneus, MNI peak coordinates [-4, -74, 37], cluster extent = 43 voxels, volume = 223.9 mm, $p<.05$ (Fig. 1). No significant effects were found for the distal-proximal demonstrative contrast. **Conclusion**: The present study provides evidence that the behavioral choice between proximal and distal demonstrative forms for nouns across a wide range of semantic dimensions, is accompanied by BOLD responses similar to those evoked by spatial language. Processing of nouns paired with a proximal demonstrative was characterized by increased activity in the posterior parietal cortex, compared to processing of nouns paired with a distal demonstrative. In addition to its key role in dorso-parietal visuospatial pathways (Kravitz et al., 2011), fMRI evidence also suggests that the precuneus is central in processing linguistic spatial information (Rocca et al., 2020). The precuneus is further considered a core node in the default mode network, perhaps due to a role in episodic memory (Traikapi et al., 2022) reflective self-awareness (Kjaer et al., 2002), and resting consciousness (Lou et al., 2004). These findings indicate that: a) choice of proximal and distal demonstrative forms involves some degree of spatial information processing, even in the absence of a physical spatial context; b) the precuneus may be central in establishing of a psychological space anchored around a *mental self*. Future work will investigate semantic characteristics of self-representation, and potential individual differences related to psychopathological symptom profiles altering representations of the self.

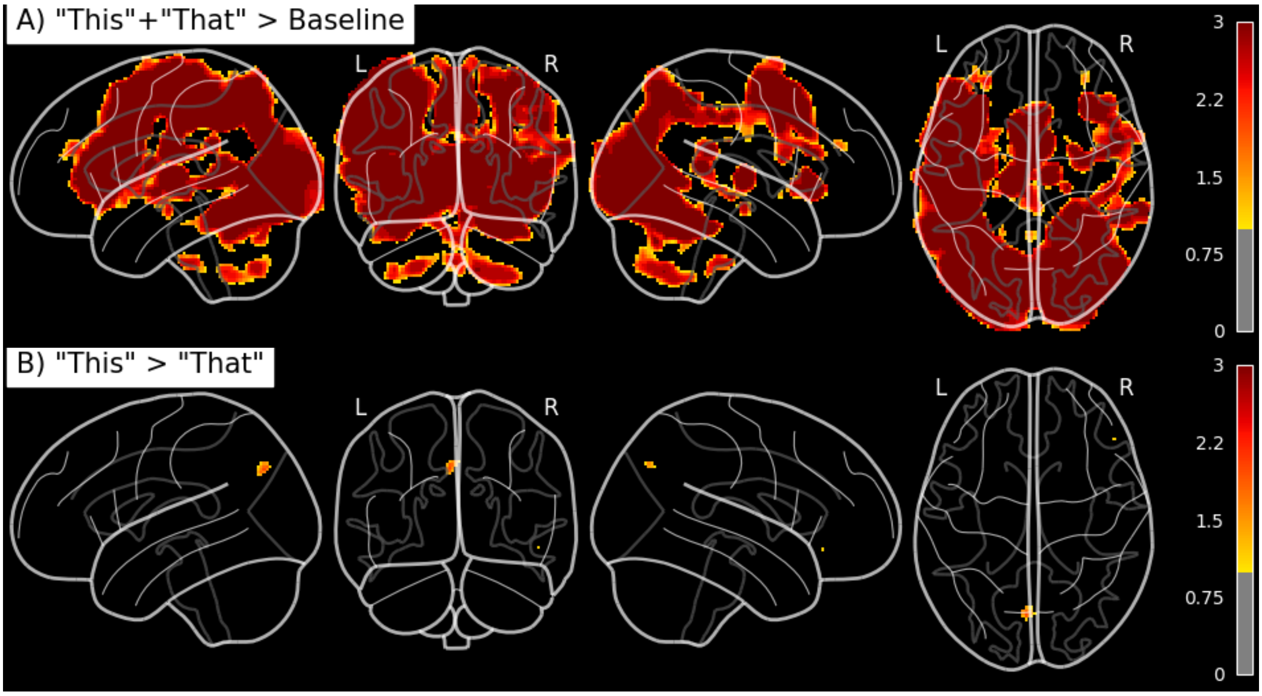

Figure 1. Group-level voxel-wise permutation test of significance ($p<0.05$) for contrasts A) trials with response "this" or "that" versus baseline and B) trials with response "this" versus "that". Values represent the negative log10 p-value with $p>1$ indicating statistical significance. Results suggest increased activity in precuneus for proximal demonstrative response trials, compared to distal demonstrative response trials.

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The neural infrastructure of interaction: Commonalities and asymmetries in conversational production and comprehension

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INTRODUCTION. The study of interactive language use is extremely rare in neuroimaging research. A key question within the field of neurolinguistics is to what extent production and comprehension processes share neural infrastructure [1–4] and recent accounts argue for one of two hypotheses: (A) a functional differentiation in the frontotemporal language network, where regions in the left inferior frontal gyrus (LIFG) support production-specific processes, while the left middle temporal gyrus (LMTG) support both production and comprehension processes [2, 3], or (B) production and comprehension share neural infrastructure, but production incurs a greater cost than comprehension for all regions within the frontotemporal language network [4]. We argue that interactive paradigms are crucial for neuroimaging research focused on answering questions about everyday language use, since the absence of its core features, e.g., turn-taking, will inevitably affect the nature of the underlying processes employed. Presumably, modality-specific processes (e.g., prediction in comprehension) require more cognitive resources during conversational turn-taking, as the expectations of providing timely conversational contributions are high [5, 6].

METHODS. We utilized a publicly available fMRI dataset [7] in which participants (N=24) engaged in unscripted conversations (12 min/participant) via an audio-video link with a confederate outside the scanner. The conversational events production and comprehension were extracted from orthographic transcriptions and defined from the participant's perspective. We ran two analyses. (1) Whole-brain analysis: Production and comprehension were modeled as two regressors and contrasted against the baseline (fixation cross) and each other. (2) ROI analysis: The mean beta values of each participant were extracted in SPM using anatomical ROIs from the automated anatomical labeling atlas AAL3 [8]. The choice of ROIs was based on a recent study [2] investigating the division of labor between recruitment of the LIFG and the LMTG during production and comprehension. Due to the different functions of subregions in the LIFG and LMTG, we conducted a more fine-grained analysis than in [2], by dividing them into the following subregions: the LIFG orbitalis, triangularis, and opercularis, the anterior LMTG, and the posterior LMTG.

RESULTS & DISCUSSION. In the whole-brain analysis, production and comprehension were associated with large overlapping clusters of activation in the frontotemporal language network. However, when contrasting production and comprehension, left inferior frontal activation was significantly stronger in production, while left middle temporal activation was stronger in comprehension. Additionally, we observed modality-specific activation outside the language network: production vs. baseline and production vs. comprehension was characterized by activation in medial frontal and posterior parietal cortices, possibly reflecting sociopragmatic processing subserved by intention processes [9] and attentional control [10]. When comprehension and production were contrasted against the baseline, larger aspects of the fusiform face area were activated for comprehension, possibly reflecting that hearers rely on the facial gestures of their interlocutor during speech perception. The ROI analysis showed that the BOLD signal change in each region was different from zero in production, except for the LIFG triangularis (which did not pass the Bonferroni correction for five tests, i.e., one per ROI). In comprehension, activation of the anterior and posterior LMTG was significant, but not the three LIFG regions. The differences between production and comprehension were significant (Bonferroni corrected) for all regions except the posterior MTG: production generated larger positive effects in the inferior frontal regions, while comprehension generated larger positive effects in the anterior MTG. Together, our results support the notion of a functional differentiation in the frontotemporal language network, in which the LIFG facilitates processes specific to production, and the posterior MTG facilitate both production and comprehension processes. The absence of frontal activation and increased anterior temporal activation in comprehension may reflect combinatorial semantic processes that allow for the circumvention of a full syntactic parse while processing the incoming signal [13]. Our results suggest that the mechanisms facilitating conversational comprehension are semantic rather than syntactic.

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ERP and oscillatory effects of Adjective-Noun and Verb-Noun composition in Norwegian

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The ability to compose word meanings into complex meanings lies at the core of human linguistic communication. However, due to limitations of current experimental paradigms (Călinescu et al., 2023), little progress has been made in uncovering the brain basis of this fundamental skill. On the other the hand, much progress has been made in describing composition on the theoretical level. Linguistic theory posits distinct combinatorial operations for predication (verb-noun) and modification (adjective-noun) structures. Previous work by Olstad et al. (2020) suggests that the two theoretical operations trigger different ERP responses. Moreover, lexico-semantic properties of words are also known to impact composition: intersective (e.g., 'grey'), subsective ('small') and privative ('fake') adjectives, when combined with a noun like elephant, differentially affect the meaning of the resulting phrase. While the denotation of a noun combined with an intersective adjective represents the intersection of the properties denoted by the noun and by the adjective, a noun modified by a subsective adjective results in a subset of the set denoted by the noun, but not necessarily also in a subset of the set denoted by the adjective. On the other hand, when combining with a privative adjective, the resulting noun phrase will not contain the denotation of the head noun. MEG and EEG work points to different processing profiles for the different classes, although with little consensus between studies (Fritz & Baggio, 2020; Schumacher et al., 2018, Ziegler et al., 2016).

The present study employed a novel paradigm to test whether syntactic and semantic properties of words impact the neural implementation of composition differently. The Cut-Compose paradigm compares full sentences (Compose) with sentences where composition is prevented by a naturalistic sentence boundary (Cut). This allows the comparison of the same element (a noun in our case) preceded by matched lexical material in combinatorial and non-combinatorial contexts. We conducted an EEG experiment asking whether the brain employs different mechanisms for combining nouns in predication (verb) vs. modification (adjective) contexts, as well as for combining nouns with different classes of adjectives.

We compared well-formed Norwegian sentences involving the composition of intersective (1), subsective (3) and privative (5) adjectives with a noun (modification), as well as composition between verbs and nouns (7) (predication) to corresponding baseline Cut conditions where the two words were part of different sentences and separated by punctuation. Sentences translated into English:

Modification

1. *Intersective-adj Compose:* Some birds must sit on grey **elephants** to clean them.
2. *Intersective-adj Cut:* Some birds have wings that are grey. **Elephants** are sometimes white.
3. *Subsective-adj Compose:* Both brown monkeys and small **elephants** life in Afrika.
4. *Subsective-adj Cut:* Monkeys are usually small. **Elephants** can step on them.
5. *Privative-adj Compose:* Animal-stories in children's books depict fictional **elephants** that fly.
6. *Privative-adj Cut:* Animal-stories for children are fictional. **Elephants** are real.

Predication

7. *Verb Compose:* In some countries people ride donkeys and feed **elephants** every day.
8. *Verb Cut:* At night people the horses feed. **Elephants** find food by themselves.

We find different ERP responses involving modification and predication. All Compose–Cut contrasts modulate early components (N1-P2) but responses differ later on. Verb Compose vs. Cut results in a larger N400 amplitude at the noun, while modification Compose–Cut do not significantly differ in the N400 time-window for any adjective class (Fig 2). Additionally, the processing of privative adjectives reliably modulates the N400 compared to that of intersective and subsective adjectives (Fig 1). Time frequency analysis reveals that composition in predication and modification environments modulate power in alpha/beta bands around 400 ms for all Compose-Cut comparisons. We also observe additional early effects in the alpha band for subsective and privative Compose-Cut comparisons, starting around 200 ms prior to noun onset until 200 ms post-noun onset (Fig 3).

Our results show that the composition of words as neurally implemented is impacted differently by different syntactic and semantic environments, with processing costs in the ERP domain incurred by obligatory argument saturation as well as by composition with privative adjectives that substantially alter the original denotation of the noun. We also consider potentially alpha/beta as a signature of composition that applies to all structures.

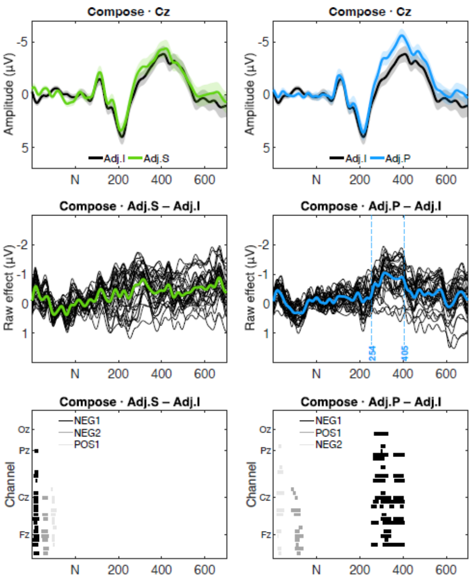

Figure 1. Comparison between Compose conditions involving subsective vs intersective (left) and privative vs intersective (right) semantic environments.

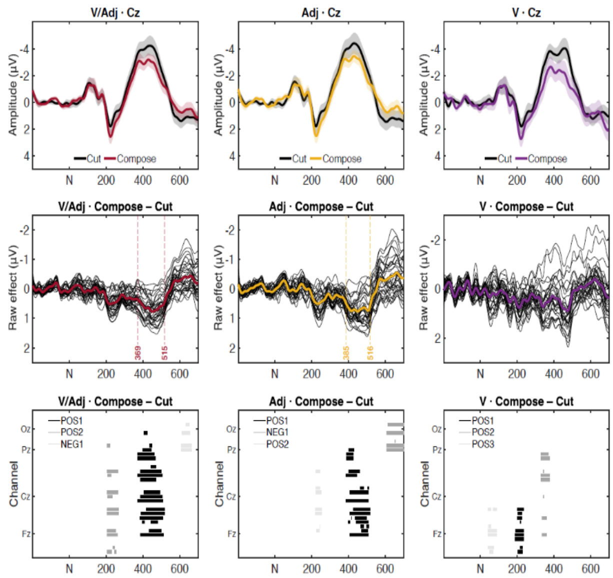

Figure 2. Compose-Cut contrasts for predication (right) and modification (center) syntactic environments.

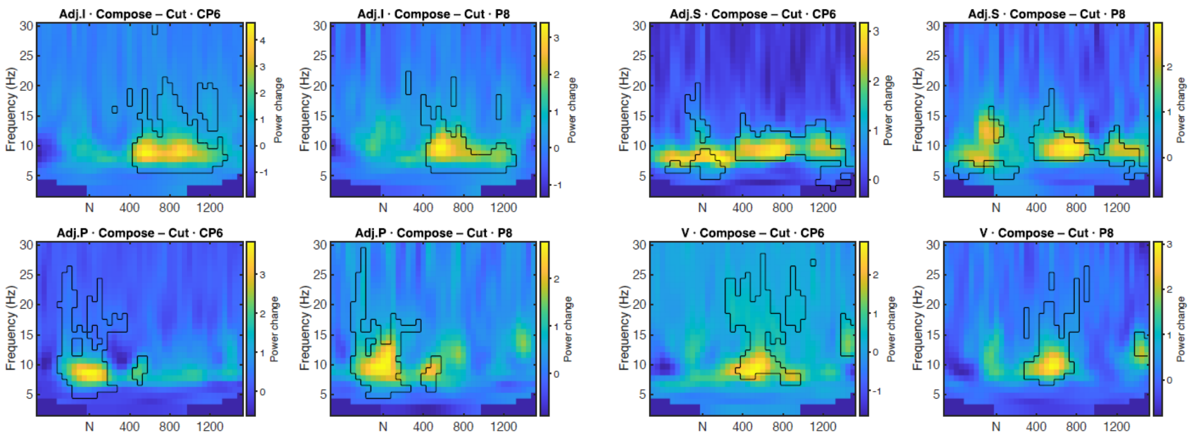

Figure 3. TFR results for selected channels for each Cut-Compose comparisons.

Neural correlates of movement vs. composition: An MEG study of Danish verb and argument movement in rapid parallel presentation

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One of the classic findings in neurolinguistics is the sensitivity of the LIFG to syntactic movement. However, despite nearly three decades of neuroimaging research on this topic, starting with Stromswold et al.'s classic 1996 study, our understanding of the exact role of the LIFG in language processing remains elusive. Here we take advantage of the syntactic properties of Danish to construct a situation in which movement occurs without posing any load to working memory, whose contribution to movement effects in the LIFG has been difficult to disentangle. We achieve this by manipulating the interrogative force of declarative sentences (Subject-Verb), which in Danish become yes/no questions via a word order swap (Verb-Subject?). Further, we employ Rapid Parallel Visual Presentation (RPVP, Snell & Grainger 2017) as the stimulus delivery method during a magnetoencephalography (MEG) recording, flashing the sentences for 300ms in a simple matching task (Figure 1). The critical stimuli were Sentences (declarative vs. interrogative) and the control stimuli two-verb Lists (see Table 1). As a further manipulation, we varied the argument structure of the verbs to include verbs that have been hypothesized to trigger argument-movement (unaccusatives and alternating unaccusatives; Perlmutter, 1978), and ones that do not involve movement (unergatives). This gave us the additional possibility to compare the effects of two different types of movement, verb and argument movement.

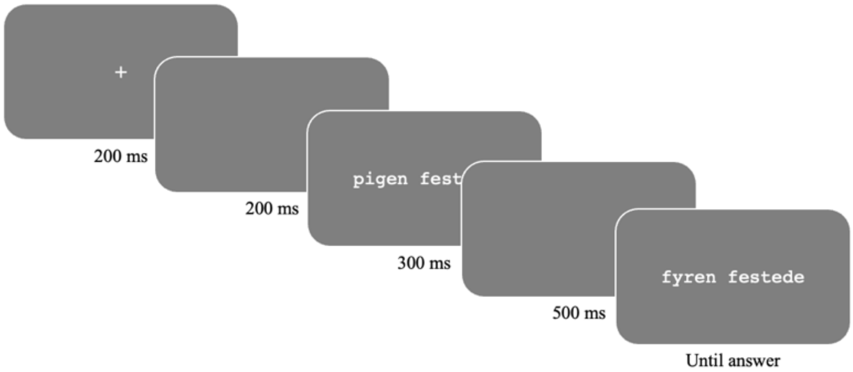

Figure 4: Trial structure of experiment.

Table 1: Stimulus design table with factors composability, syntactic frame, and argument structure.

Composability	Syntactic frame	Argument structure	Stimuli	English gloss
Sentence	Declarative	Unergative	`pigen festede`	The girl partied
Sentence	Interrogative	Unergative	`festede pigen`	Did the girl party
List	Decl. control	Unergative	`udgav festede`	published partied
List	Intr. control	Unergative	`festede udgav`	partied published
Sentence	Declarative	Unaccusative	`pigen vågnede`	The girl awoke
Sentence	Interrogative	Unaccusative	`vågnede pigen`	Did the girl awake
List	Decl. control	Unaccusative	`udgav vågnede`	published awoke
List	Intr. control	Unaccusative	`vågnede udgav`	awoke published
Sentence	Declarative	Alt. unaccusative	`pigen drejede`	The girl turned
Sentence	Interrogative	Alt. unaccusative	`drejede pigen`	Did the girl turn
List	Decl. control	Alt. unaccusative	`udgav drejede`	published turned
List	Intr. control	Alt. unaccusative	`drejede udgav`	turned published

Our main regions of interest were the LIFG, motivated by the prior movement literature, and the posterior temporal lobe (PTL), motivated by a growing body of literature implicating it for syntactic composition (Matchin & Hickock 2020; Rodd et al. 2015; Walenski et al. 2019). Over the years, linguistic theories have differed in whether movement is simply an instance of composition (or "Merge") or a computation distinct from Merge. The former predicts that effects of movement should pattern similarly to effects of composition, here diagnosed via the Sentence vs. List contrast, while the latter predicts that movement effects should be distinct from effects of basic composition. While analysis is ongoing, the behavioral data reveal consistently faster Match-judgements for Sentences than for Lists, yielding an instance of the Sentence Superiority Effect (SSE) reported in prior RPVP literature. This is mirrored by a clear neural SSE localizing in the anterior and middle temporal cortex, with higher activity for Sentences than Lists at 490-640ms after stimulus onset (Figure 2). In addition to these behavioral and neural SSEs, our behavioral data indicate differential processing of sentences with and without movement, showing faster reaction times to declaratives over interrogatives as well as unergatives over unaccusatives and alternating unaccusatives.

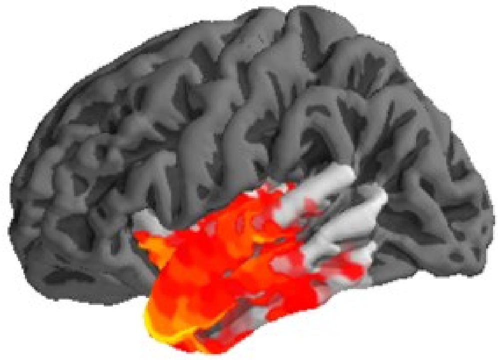

Figure 5: Sentence Superiority Effect localizing in left mid-anterior temporal lobe between 490-640ms post-stimulus onset.

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Seriality surpasses hierarchy when children process sentences and picture sequences

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Opposing perspectives of language processing either emphasize serial order or hierarchal structure (Frank et al., 2012; Yang et al., 2017), while a third perspective unifies seriality and hierarchy in the view that hierarchical organizations emerge from simultaneous serial activity on different time scales just as in other domains (Langacker, 2020). With the aim to contribute to these discussions, we replicated and extended an earlier study (Cohn et al., 2014) with adults in which ERPs patterned with the hierarchical structure of picture sequences (comic strips) and not with their serial order. In the present ERP study with children, we used both Cohn et al.'s picture paradigm and a novel verbal paradigm (so far not used with adults) that was constructed to correspond to the picture paradigm. More specifically, interruptions (prolonged silent pauses) were inserted within or between clauses of auditorily presented sentences to correspond to interruptions (blank panels) within or between constituents of picture sequences. Preliminary results for 10-12-year-old children ($N = 15$) revealed an expected anterior negativity (500-700 ms) that varied with placement of interruptions of picture sequences but the previously reported effect of this manipulation on the P600 amplitude was not replicated. Importantly, however, the amplitude of the anterior effect varied with the serial order of the interruptions, in contrast to previous results for adults where the amplitude varied with the hierarchical structure (i.e., an increased anterior negativity, 500-700 ms, to within constituent interruptions compared to between constituent interruptions). This pattern of results was identical in the novel verbal paradigm. That is, in children, interruptions of sentences elicited an anterior negativity that varied in amplitude with the serial order of the interruptions rather than with the hierarchical structure, while the P600 amplitude was not affected by placement of interruption. These combined results suggest that children's processing relies on seriality rather than hierarchy in both sentences and picture sequences. This is in line with domain general perspectives of language processing that regard serial order as fundamental and hierarchical structures as emerging organization. We suggest further investigations to answer when in development hierarchical processing emerges in both domains.

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Beyond description: Predictive coding provides a biologically plausible account of predictive language comprehension

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It is no longer controversial to state that we engage in prediction during language comprehension. Indeed, one of the strongest predictors of behavior and neural activity during sentence processing is the lexico-semantic predictability of each incoming word in relation to its prior context. Several different architectures and algorithms can account for these lexical prediction effects, ranging from recent models of the N400 event-related potential, to OpenAI's GPT series of large language models. However, I will argue that it is not sufficient for a model to show that lexical predictability influences behavior or brain activity. Instead, a deep understanding of how the brain comprehends language requires us to develop models that incorporate insights from decades of research on (a) the neurobiology of the human cortex, especially the prevalence of feedback connections; (b) the interactive nature of real-time language processing, particularly the influences of lower-level linguistic information, like phonology/orthography on lexical prediction. By integrating these biological and psychological constraints, our models should not only be capable of *describing* the effects of lexical predictability during processing, but they should also provide an explanation for *why* and *how* these predictions influence neural activity and behavior.

I will then propose that predictive coding—a computational architecture and algorithm that has been proposed to approximate Bayesian inference in the brain—satisfies many of these biological and cognitive constraints. I will outline an implemented predictive coding model of lexico-semantic processing, emphasizing several key features that differentiate predictive coding from other predictive processing frameworks. I will then show that this model is able to successfully simulate both univariate and multivariate effects from a series of experiments that combine MEG/EEG, fMRI, and intracranial recordings with event-related analyses and representational similarity analyses to study language processing. Together, these findings provide compelling evidence that the brain employs predictive coding to infer meaning from the linguistic form of incoming words during incremental language comprehension.

Poster presentations – Day 2

Individual differences in auditory-motor synchronization to speech: extending results from English- and German- to a Norwegian-speaking population

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It has previously been found that the ability to synchronize one's own speech to a string of syllables at the average cross-language rate of 4.5 syllables/sec, is not uniformly distributed[1] in the population. In fact, when performing a simple 1-minute test, participants' ability to synchronize to the speech-proxy seems to be bimodally distributed, rendering participants as members of one out of two groups (so-called high or low synchronizers). High synchronizers better align their utterances to the stimulus as compared to lows, measured as phase-locking between the perceived and produced signals. Interestingly, high synchronizers display increased neural synchrony between motor and sensory regions of the language network in the brain, as compared to low synchronizers. The functional differences between the groups are likely to be supported by the underlying neural structure(s), namely increased white matter in areas connecting these two regions[1]. Importantly, the individual neural differences associated with the high and low synchronizers are also evident in ecologically relevant behavioral tasks, such as statistical word-learning[1], syllable detection[2] and rate discrimination[3].

As these neural differences in auditory-motor coupling, relevant for language processing and learning, can be assessed by a short and simple behavioral test (the spontaneous synchronization to speech, SSS, - test), exploring the limits of the test and, thus, its usefulness as an experimental tool, is of importance. Up to this point, the bimodal distribution in synchronization ability has only been observed for native English[1,4–6]- and German-speakers[2,3,7].

Given the opportunity, we will present a poster with evidence for similar results in terms of speech-to-speech synchronization ability for a Norwegian-speaking population (Fig 1). The results not only replicate the previously observed bimodal distribution, but also generalize the findings to a population of speakers of a bitonal language, as compared to the ones previously tested. We hope to also present preliminary results on potential group differences in terms of neural statistical word-learning as measured with EEG, by estimating the degree of inter-trial phase coherence to words over syllables, while participants are listening to a stream of pseudo-words[8]. The latter evidence thus extends the observed bimodal distribution to the neural differences between the groups, potentially contributing to their differences in statistical word-learning ability.

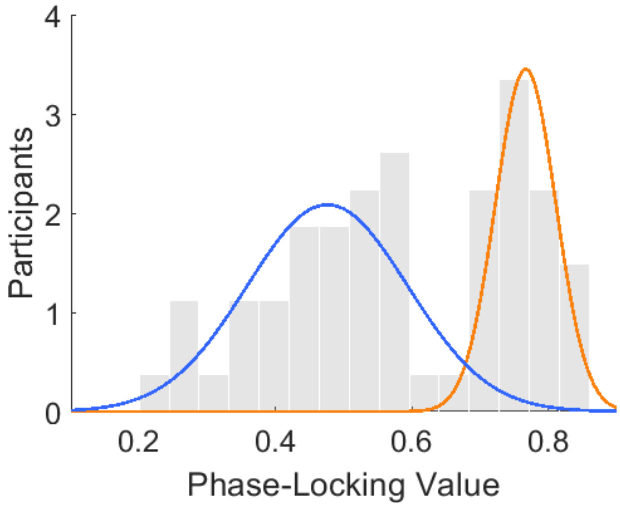

Figure 1. Distribution of speech-to-speech synchronization ability for Norwegian-speaking population (N=61), displaying two peaks. Blue and orange lines indicate the groups of low and high synchronizers, respectively.

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The role of tone in Swedish speech segmentation

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Introduction. In speech, there are no blank spaces to signal boundaries between words as there is in written language, but listeners can nevertheless recognise individual words rapidly. Without these blank spaces or commas, listeners have to divide up – segment – the continuous speech stream into discrete words using other means. This study aimed to investigate the tonal cues important for speech segmentation in Swedish. We know that that different languages use different cues in speech segmentation, such as stress (Norris, McQueen, & Cutler, 1995), syllable weight (Cutler & Norris, 1988) and vowel harmony (Suomi, McQueen, & Cutler, 1997), but we do not yet know the extent to which phonological cues are used in speech segmentation. In English, stressed and metrically strong syllables are heard as more reliable word onsets, leading the parser to initiate a lexical access attempt at these points. Accurate segmentation is crucial since words can always be embedded in larger words, and these spurious embedded words are activated in memory (Luce & Cluff, 1998): the phrase *start writing* potentially includes *star*, *trite*, *try*, *rye* and so on (Cutler, 2012). However, no study has yet investigated speech segmentation in languages like Swedish, where prosody systematically combines with morphology. This will allow us to more fully understand universal drivers behind speech segmentation.

In Swedish, every word or word stem has a lexical tone known as a *word accent*, in addition to stress. In Central Swedish, this tone is either low (accent 1) or high (accent 2). All monosyllabic words have accent 1, and the majority of polysyllabic words – such as compounds – have accent 2 on the word stem, especially trochees. There is also an interaction between prosody and morphology, so that stem word accent is also determined by suffixation: the word stem *båt* ('boat') has accent 1 preceding the singular suffix *-en* (*båt*$_1$*-en*) but accent 2 preceding the plural suffix *-ar* (*båt*$_2$*-ar)*. With regard to word embeddings, a frequent accent 2 word with a plural suffix like *möten*$_2$ ('meetings') potentially contains *mö* ('maiden') and *tenn* ('tin'), and the accent 2 on the word stem ensures it can also be heard as the compound *mö-tenn* ('maiden tin'). However, the string *möten*$_1$ with accent 1 can only be heard as two words, as in the phrase *möt en ko* ('meet a cow'). Accent 2 has thus been proposed to be 'connective' (Elert, 1970; Malmberg, 1959): it signals that more syllables will follow, belonging to the same lexical item. A string with accent 2 can thus always contain other words, perhaps more so than accent 1, which might make it more difficult to segment – especially in the case of monosyllabic targets – than accent 1 strings.

This study used a word spotting paradigm to investigate the segmentation of Swedish words embedded in non-word frames to determine how prosody and syllable structure interact to affect word spotting performance.

Methods. Native speakers of Swedish listened to auditory stimuli – trisyllabic non-word frames – recorded by a native speaker of Central Swedish. They were asked to press a button when they heard a Swedish word at the beginning of a string, entering the word using the computer keyboard. Each participant heard 15 monosyllabic target words embedded in accent 1 frames (***bal****-ädi*$_1$ 'ball'), 15 monosyllabic words in accent 2 frames (***bal****-ädi*$_2$), 15 disyllabic words in accent 2 frames (***bagge****-pi*$_2$ 'ram') and 15 disyllabic words in accent 1 frames (***bagge****-pi*$_1$). All target items were matched for word frequency. Word accent pairs were counterbalanced across subjects. There were 60 fillers, containing no possible Swedish words.

For response times, only trials where participants spotted and typed in the correct word were included, whereas all trials were included in the accuracy analysis.

Data analysis and results. Response times were analysed using a generalised linear mixed-effects model with an inverse Gaussian function and identity link using the lme4 package in R (Bates, Mächler, Bolker, & Walker, 2015). Word accent and number of target syllables were included as deviation-coded fixed effects with participant and item as random effects. The fastest response times were found for disyllabic words (e.g. *bagge*) in accent 2 frames, significantly faster than for monosyllabic words (e.g. *bal*) in accent 2 frames. Response accuracy was analysed using an identical model structure to response times but using a binomial function and logit link. An interaction between accent and number of target syllables showed that disyllabic words were spotted more successfully than monosyllabic words in accent 2 frames.

Discussion. Monosyllabic targets were more difficult to spot in accent 2 strings, as shown by both response time and accuracy. This can possibly be explained by the fact that accent 2 strings can always contain other words, slowing down speech segmentation and recognition. It is also possible that the word accent triggers inappropriate syllabification, so that *bal* in ***bal**-ädi*$_2$ is heard as the non-word *ba* (*****ba**-lädi*), similarly to strong syllables signalling a segmentation point and prompting syllabification in English (Cutler & Norris, 1988).

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Morphosyntax predictions in second language listeners

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In languages where prosody interacts with morphosyntax, listeners use prosodic cues to predict morphosyntactic properties. This has been demonstrated for stress in Spanish, pitch in Swedish, and voice quality in Danish (Hjortdal et al., 2022; Roll et al., 2011; Roll, 2022; Sagarra & Casillas, 2018). Danish listeners, for instance, predict the definite singular suffix *-en* but not the plural suffix *-e* when they hear the word *bold* 'ball' produced with creaky voice. Second language (L2) listeners, in comparison, use the target language's predictive prosodic cues considerably less. Beginner learners seem not to predict word structure at all whereas highly proficient L2 speakers do to some extent (Gosselke Berthelsen et al., 2018; Hed et al., 2019; Lozano-Argüelles et al., 2019; Sagarra & Casillas, 2018).

At NLS, I would like to present data from a study aimed at investigating the onset and progression of prosody-based predictions of morphosyntactic structure during L2 acquisition. In a cross-sectional study, 40 adult L2 learners of Danish were recruited who self-assessed their listening skills as beginner (10), lower intermediate (10), upper intermediate (10), or advanced (10). They participated in an online response time study where they were tasked with quickly identifying features of words related to grammatical suffixes which were either validly or invalidly cued by the prosody. Results revealed that prosodic cue validity had no effect on the response times at group level suggesting that L2 learners of Danish overall make no use of prosodic cues to predict related suffixes. Surprisingly, there were no interactions with listening skills or correlations with any factors related to Danish proficiency despite the advanced learners having lived in Denmark for up to 10.5 years ($M = 4$). In contrast to previous studies on different prosodic cues, these findings indicates that the predictive creaky voice feature of Danish is not readily used by advanced second language learners. This may be due to the feature's crosslinguistic rarity or due to intra- and inter-speaker variation in its realisation.

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“*Keine*” doppelte Verneinigung mit *Kein*

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This study investigates the double negation with kein in L1 data of children acquiring German.
1. Background: German is a Double Negation language that uses the negative marker nicht and also Negative Quantifiers (NQs) to express sentential negation. Whenever more than one negative elements occur together in a clause, they both yield their own negation and give an interpretation of an affirmation. Zeijlstra(2004, et seq.) argues that the presence of a clear 1:1 mapping between the negative form and meaning guides young children to assume the same in their grammar of negation.

2. Motivation for the study: Recently, there have been studies using imitation, elicitation, and other experimental techniques investigating the comprehension of DN sentences by young children acquiring German that argue that children assign single negation reading to doubly negated sentences (Nicolae, et al. 2022). The presence of double negation in the production data has been reported less. In this study, we will investigate the naturalistic spoken data of children acquiring German as their L1 to see if they use more than one negative element per clause to express a single negation.

3. Hypothesis: The presence of a 1:1 relation between negative form and meaning in the caregivers' provided input will be reflected in children's grammar.

4. Methodology: Naturalistic spoken speech of children acquiring German and that of their caregivers' is retrieved from CHILDES (http://talkbank.org/CHILDES). Negative sentences for children and their caregivers, per month, were searched containing the negative quantifier *kein* with all of its subject and adjectivespecific endings, as shown in (1).

a. Es komt *kein* Ball Mama.
b. In *keinem* Feuerwehrhaus.
c. Ich mochte *keine* Sachen.
d. I mag aber *keinen* Fisch.
e. Hier ist *keiner*.
f. Hast du *keines*?

To estimate the effect of independent variables on the dependent variable, a GLMM (Baayen, 2008) with a Poisson error structure and the log link function (McCullagh & Nelder, 1989) was used. Full null model comparison was significant. The main effect of individual fixed effects was tested using the drop1 function (Dobson, 2002).

5. Results: In this section, three levels of results will be presented.

5.1 Empirical Results: Our empirical results show that no sentences containing an NQ and nicht or two NQs were found in children's or caregivers' sentences. The bare form of the NQ kein (1a) was the most frequent in children's and caregivers' sentences. Kein appeared at the age of 20 months, keine at 19th, keiner at 22nd, keines at 26, and keinem at 36th months of age. All of these forms of NQs were present in caregivers' data from the child age 19 months.

5.2 Inferential Results: In the preliminary results, we found that caregivers' input for NQs (LRT: x2 (1)=36.9, $p < 0.001$) and age as a continuous predictor variable (LRT: x2 (1)=68.59, $p < 0.0001$) both show a statistically highly positive significant effect on children's acquisition of NQs.

5.3 Post hoc multiple age-group comparisons: We conducted the post hoc multiple age-group comparisons to see at what age point children acquire a particular form of kein. We found that after the age of 36 months, children were exhibiting a similar estimated average use of NQ kein in its bare form kein but they were still exhibiting a statistically significant difference in the estimated average use of other forms of NQ kein.

6. Conclusion: We conclude that the clear presence of 1:1 mapping between caregivers' provided language input is reflected in children's grammar, and children establish the acquisition of NQs quite early i.e., soon after their 3rd birthday.

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Pre-activation negativity in language brain potentials

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The pre-activation negativity (PrAN) is an event-related potential (ERP) component indexing how constraining phonological cues are. It has an early phase (136-200 ms), with sources in the left auditory cortices, and a late phase (200 ms onwards), with sources in Broca's area. The PrAN has been found for segmental and prosodic cues increasing the certainty about upcoming words, morphemes, grammatical structures, or lexicality. The phonological cues investigated have been Central Swedish, South Swedish, Danish, and English segmental phonemes, Central and South Swedish lexical tone accents, Danish stød, and Central Swedish boundary tones and left-edge boundary tones/initiality accents.

Neural Asymmetry in the Perception of South Swedish Word Accents - Evidence from Mismatch Negativity

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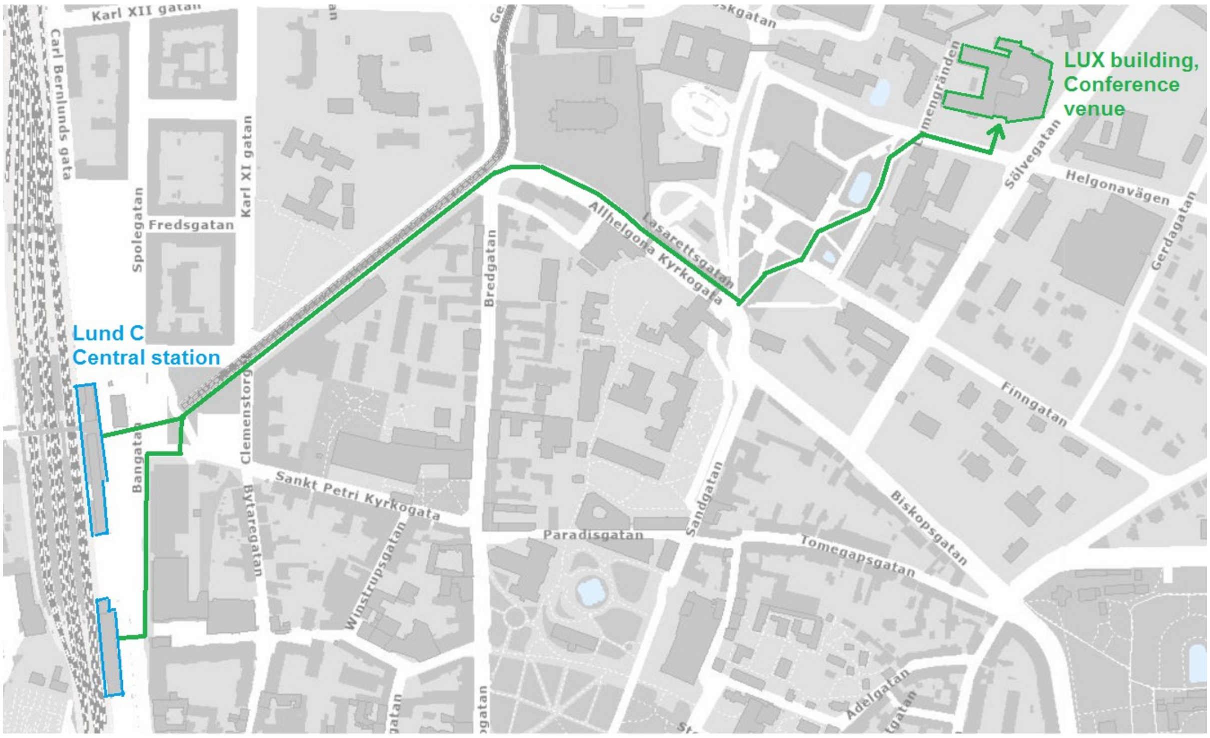
South Swedish, as a dialect of modern Swedish, has two tonal word accents, accent 1 and accent 2. Regarding these two word accents, there are three groups of opinion on which on is more lexically specified. The first group believes that accent 2 is more specified and accent 1 is default shaped by intonation, whereas the second group deems that accent 1 is lexically specified and accent 2 is the default accent. The third group, however, holds the opinion that both word accents are specified. In order to find evidence from brain level to support one of those opinions, a mismatch negativity (MMN) study under the passive oddball paradigm was conducted in the present study. Results show that in South Swedish accent 1 elicited significant early MMN while accent 2 elicited significant and robust late MMN. The asymmetry in temporal and amplitude domain suggests that accent 2 has more linguistics information encoded, which suggests that accent 2 in South Swedish has a more specific memory trace in native speakers' mental phonology. According to the underspecification theory, the more specified structure has more specific memory representation than underspecified features. In conclusion, the results of the present study support the first group's opinion, which is that accent 2 is more lexically specified than accent 1 in South Swedish.

Venue and navigation

The conference will take place at LUX building, Helgonavägen 3, Lund:



How to get to the conference rooms (ground floor):