Danger and usefulness are detected early in auditory lexical processing: evidence from electroencephalography

Tatiana Kryuchkova[a], Benjamin V. Tucker[a], Lee H. Wurm[b], R. Harald Baayen[a,c]

[a] *University of Alberta, Department of Linguistics, Assiniboia Hall 4-32, Edmonton, AB T6G 2E7, Canada.*
[b] *Wayne State University, Department of Psychology, 5057 Woodward Avenue (7th floor), Detroit, MI 48202, USA*
[c] *University of Tübingen, Seminar für Sprachwissenschaft, Wilhelmstr. 19, 72074 Tübingen, Germany*

Abstract

Visual emotionally charged stimuli have been shown to elicit early electrophysiological responses (e.g., Schupp et al., 2003; Stolarova et al., 2006; Ihssen et al., 2007). We presented isolated words to listeners, and observed, using generalized additive modeling, oscillations in the upper part of the delta range, the theta range (Bastiaansen and Hagoort, 2003), and the lower part of the alpha range related to degree of (rated) danger and usefulness (Wurm, 2007) starting around 150 ms and continuing to 350 ms post stimulus onset. A negative deflection in the oscillations tied to danger around 250-300 ms fits well with a similar negativity observed in the same time interval for visual emotion processing. Frequency and competitor effects emerged or reached maximal amplitude later, around or following the uniqueness point. The early effect of danger, long before the words' uniqueness points, is interpreted as evidence for the dual pathway theory of LeDoux (1996).

Keywords: danger, usefulness, theta oscillations, frequency, uniqueness point, auditory comprehension

---

Email addresses: `kryuchko@ualberta.ca` (Tatiana Kryuchkova), `benjamin.tucker@ualberta.ca` (Benjamin V. Tucker), `lee.wurm@wayne.edu` (Lee H. Wurm), `baayen@ualberta.ca` (R. Harald Baayen)

1. Introduction

Studies addressing emotion processing in healthy subject populations have observed that emotionally charged linguistic and non-linguistic stimuli may elicit very early responses in the brain. For example, using non-linguistic stimuli such as emotionally charged pictures, Schupp et al. (2003) and Schupp et al. (2008) observed an early posterior electrophysiological response (200–300 ms post stimulus onset) to emotionally arousing visual stimuli depicting pleasant, erotic, or violent scenes. This effect is referred to as the early posterior negativity (EPN) and is observed over the N1 and N2 time windows, showing greater temporal-occipital negativity in response to pleasant and unpleasant images, than to neutral images.

When affect-laden words are presented visually, they elicit an EPN at 200–300 ms post stimulus onset in silent reading (Herbert et al., 2009; Kissler et al., 2009; Herbert et al., 2008; Kissler et al., 2007) as well as in visual lexical decision (Scott et al., 2009; Hofmann et al., 2009; Palazova et al., 20011; Schacht and Sommer, 2009). Though the EPN has been consistently observed across studies, it may depend in part on the experimental paradigm (Rellecke et al., 2011). In a visual lexical decision task performed on emotion words, Palazova et al. (20011) observed that the effects of emotion in the ERP signal was preceded in time by effects of lexical frequency. Furthermore, the EPN emerged earlier for nouns and adjectives than for verbs.

Stolarova et al. (2006) reported even earlier brain activity associated with attention to affective pictorial stimuli, using a conditioned stimuli paradigm. An early negative modulation of the visual component C1 in response to unpleasant arousing pictures was observed 65–90 ms after stimulus onset. Early brain activity in response to emotional stimuli may be modified by the frequency with which a picture is presented in the course of the experiment. For example, Smith et al. (2003) observed smaller P1 ($<$ 120 ms) amplitudes associated with infrequently presented pictures with positive content.

Carretié et al. (2011), Carretié et al. (2009b), and Carretié et al. (2009a) reported that affective fearful and disgusting pictures inhibit participants' performance in cognitive tasks when used as distractors: Disgusting pictures elicited larger P2 amplitudes. Carretié et al. (2009b) observed that negative distractors elicited greater P1 amplitudes. Ihssen et al. (2007) reported a series of ERP experiments in which participants saw emotionally arousing pictures and then were requested to perform a visual lexical decision on neutral words. They observed that emotionally arousing images (erotica and mutulation) delay subsequent lexical processing as reflected by elongated responce latencies. Effects of emotional images on the subsequent cognitive task emerged as early as 200–264 ms after target word presentation and were expressed in smaller N1 amplitudes in response to words and nonwords following pleasant and unpleasant pictures, compared to a neutral baseline.

Scott et al. (2009) and Hofmann et al. (2009) reported effects of emotion at 80–120 ms post stimulus onset. According to Scott et al. (2009), this effect is modulated by lexical frequency (but see Hofmann et al., 2009). Both studies reported shorter response latencies for emotional, in particular negative, words, indicating facilitated processing of lexical emotion.

Only a limited number of studies is available on the processing of affect in the auditory modality. Bröckelmann et al. (2011), in a conditional learning experiment, observed neural activity in responce to ultra-quick tones, associated with emotional pictures through learning, as early as P1 (20–50 ms) and N1 (100–130 ms). Emotionally loaded images were also found to modulate the auditory evoked potential when listening to an unchanging emotionally neutral auditory stimulus (Wang et al., 2008). Wiethoff et al. (2008) showed that words spoken with an intonation expressing different emotions (happy, erotic, angry, fearful) elicited enhanced magnetic activity, compared to a neutral baseline, in the right mid superior temporal gyrus.

Paulmann and Kotz (2008a) reported that emotional prosody in speech can be identified by listeners as early as 200 ms post sentence onset, with emotional prosody eliciting smaller P2 amplitudes than emotionally neutral prosody. Paulmann and Kotz (2008b) also conducted an ERP experiment where participants listened to real sentences and pseudo-sentences spoken in an emotional way. Using a cross-splicing manipulation, they observed that a prosodic mismatch elicited a right-laterilized positivity at 350 ms after the onset of mismatch, whereas a combined prosodic-semantic mismatch elicited an early negativity at 110 ms post the onset of mismatch.

The present study investigates the time course of the processing of affect-laden spoken words using ERPs, following up on previous research by Wurm (2007), who proposed the orthogonal dimensions of Danger and Usefulness as predictors for lexical processing, replacing the standard dimensions of positive–negative, strong–weak, and high–low arousal (Osgood, 1969; Wurm, 2007). Wurm (2007) and Wurm and Seaman (2008), using auditory lexical decision and repetition tasks, observed faster response latencies for words with high danger or usefulness ratings independent of standard lexical distributional predictors such as word frequency (Rubenstein and Pollack, 1963). As Danger and Usefulness explained more variance (Wurm, 2007) in behavioural measures than the classical measures of Osgood, we have adopted these new measures for the present study. Of the two dimensions, Danger has the strongest semantic connection to emotional arousal.

This study extends previous research (Scott et al., 2009; Hofmann et al., 2009) on the processing of affect laden words by including additional lexical/distributional predictors. As in previous research, frequency of occurrence was included as a variable, but in addition we also include Morphological Family Size, Number of Synonyms, and Number of Competitors.

We expect words with high Danger ratings to give rise to an early negativity around 200–300 ms post stimulus onset, analogous to the early posterior negativity (EPN) observed, for example, by Schupp et al. (2003, 2006, 2008) for visual high-arousal stimuli. If our prediction is correct, the brain's electrophysiological response to danger will precede the uniqueness point, the moment in time at which the spoken word becomes uniquely identifiable (Marslen-Wilson and Welsh, 1978; Luce et al., 1984; Balling and Baayen, 2008), which (for our materials) is located on average 470 ms from stimulus onset.

Orthogonal to the dimension of Danger is the dimension of Usefulness. Wurm (2007) points out that the usefulness of an object is also important for an individual's survival. In other words, quickly grasping that a word is useful would be advantageous in a competitive environment with scarce resources. The emotion linked to words with high usefulness ratings might then be the wish to possess, or in the extreme case, greed. If this interpretation of the emotional valency of Usefulness is correct, we expect it to emerge co-temporal with Danger. If, however, Usefulness is emotionally neutral, it should emerge in the ERP signal after the uniqueness point.

In what follows we test these hypotheses using a regression design and statistical analysis with generalized additive modeling (described below) which allows us to investigate both standard ERP components as well as oscillations, often in the theta range, modulating these components.

2. Experiment

2.1. Materials

We selected 260 English nouns from the materials of Wurm (2007), Fischer (2007) and Wurm and Seaman (2008), for which ratings for Danger and Usefulness were available. These words are listed in the Appendix. Words were read aloud in a list format three times (to control for prosodic effects) by a female speaker of Western Canadian English, who was ignorant of the nature of the experiment. The productions were recorded to a single channel at a sampling frequency of 44.1 kHz and a 16 bit sampling rate. The second realization of each word was selected for stimulus presentation to control for list intonation. Stimuli were spliced out of the original recordings based on visual inspection of the waveform and spectrogram using PRAAT (Boersma and Weenink, 2010). Word onsets and offsets were determined by visible departure in the waveform from the preceding and following silence.

For each word the uniqueness point was determined by the following steps. First, uniqueness points were calculated on the basis of phonemic transcriptions available in the CELEX lexical database (Baayen et al., 1995), following Wurm (2007). Second, given the phoneme at which the word becomes unique, the acoustic uniqueness point was then determined as the mid-point of non-plosives or the onset of the burst release for plosives. The mean uniqueness point for these materials was 471 ms, their mean duration was 566 ms.

The ratings for Danger and Usefulness used in the present study were taken from the studies by Fischer (2007); Wurm (2007); Wurm and Seaman (2008). They asked their participants to rate words on an 8-point Likert scale as to how useful and how dangerous a word's referent is to human survival. Words with high danger ratings include *knife, plague, spear* and words with low danger ratings comprise *banana, dove, waltz.* On the Usefulness scale, words with high ratings such as *food, heart, land* contrast with words with low ratings such as *balloon, lint, dust.*

The following predictors were considered along with Danger and Usefulness. As a measure of Word Frequency we used the counts of the number of times a word occured in an 18-million word corpus of British English as available in the CELEX lexical database. A related measure is a word's Morphological Family size (Moscoso del Prado Martín et al., 2004; Schreuder and Baayen, 1997), the number of compound and derived words in which a word stem is found. For instance, *knife* has *knife-like* and *jack-knife* in its morphological family, which in all comprises 10 words. We also considered the morphological family frequency measure, the summed frequencies of all the words in the morphological family. As a measure of phonological similarity, included to gauge effects of lexical competition, we considered the Number of Competitors, i.e., the number of phonological neighbours. We defined phonological neighborhoods as those words that differ in one phoneme, e.g., *life* and *night* in the case of *knife* (Goldinger et al., 1992; Luce, 1985). This measure is expected to be predictive for the ERP signal around the uniqueness point. Finally, a word's number of Synonyms was extracted from Wordnet (Fellbaum, 1998; Miller et al., 1990). Frequency, Family Size and Number of Synonyms were log-transformed to remove the skew from their distributions. Correlations between predictors are illustrated in Table 1.

A further predictor, Concreteness, as available in the MRC database (Coltheart, 1981), was also considered, as concreteness can be correlated with frequency (Gernsbacher, 1984). Analyses of the correlations of Concreteness with the other predictors revealed a significant correlation with Frequency only ($r = 0.3, p < 0.01$). Thus in our discussion of frequency it is possible that the concreteness of the words may have contributed to some small extent (the correlation is small) to the effect of Frequency. In what follows, we do not examine Concreteness in further detail, as it does not enter into significant correlations with the primary predictors of this study, Danger and Usefulness.

	Usefulness	Danger	Family Size	Frequency	Competitors	Synonyms
Usefulness	1.000	-0.080	0.393	0.539	0.046	0.109
Danger	-0.080	1.000	-0.024	-0.036	-0.056	-0.072
Family Size	0.393	-0.024	1.000	0.677	0.104	0.462
Frequency	0.539	-0.036	0.677	1.000	-0.031	0.355
Competitors	0.046	-0.056	0.104	-0.031	1.000	0.023
Synonyms	0.109	-0.072	0.462	0.355	0.023	1.000

Table 1: Correlation table showing statistical relationships for all predictors in the analysis.

2.2. Participants

Twenty one native English speaking undergraduate students (14 women and 7 men) participated in the experiment and received course credit. None reported any hearing difficulties.

2.3. Procedure

Participants were seated in a sound-attenuated booth facing a computer screen and keyboard. The randomized stimuli were presented bi-aurally via ER-1 insert earphones (Etymotic Research, Inc.), which do not interfere with ERP registration. Participants were instructed to carefully attend to the stimuli. After approximately 10 to 15 stimuli, participants performed a simple calculation task (addition or subtraction, e.g., $50 - 35$), as quickly and accurately as possible to verify that they were paying attention. Participants always received positive feedback, "correct", to avoid possible frustration during the math task distracting participants during the following listening task. Analysis of the math task showed that participants correctly responded to the math task 93% of the time. (Most errors in the math task can be attributed to one single participant.) In post-experiment debriefing participants, did not express any confusion or frustration with regard to the math task. An inter-stimulus interval ranging from 500–1000 ms was used to allow the ERP signal to return to baseline. Participants were asked to keep their eyes on the fixation point in the middle of the computer screen during stimulus presentation. There were three short self-timed breaks during the experiment. E-Prime 1.0 (Schneider et al., 2002) was used for stimulus presentation and synchronization with the ERP registration system.

Participants wore a nylon BioSemi cap with 32 Ag/AgCl active electrodes (10/20 layout). Two further electrodes were placed at the left and right mastoids for off-line re-referencing. Four electrodes were placed at the outer canthi of the left and right eye and above and below the left eye for recording the vertical and horizontal electro-oculograms. The EEG signal was recorded using a BioSemi Active II digital amplification system with an input range of -262 μV to +262 μV per bit. The signal was band-pass filtered on-line from 0.01 to 100 Hz. For each stimulus the EEG signal was recorded starting 200 ms prior to stimulus onset for 1200 ms.

The digitized EEG signal was pre-processed with Brain Vision Analyzer software. The 32 channels were re-referenced to the left and right mastoid electrodes as a first step in removing noise from the signal. Subsequently, the signal was downsampled from a sampling rate of 8192 Hz to 128 Hz and band-pass filtered from 0.01 to 30 Hz using a Butterworth filter (time constant = 15.9155 sec) and DC-detrended based on the 100 ms interval preceeding the stimulus onset. Finally, the EEG signal was exported from Brain Vision Analyzer and further denoised using a combination of generalized additive regression modeling and wavelets to remove artifacts in the signal due to ocular movements and other muscular activity.

2.4. Generalized Additive Modeling

We used Generalized Additive Modelling (GAM, see Wood (2006)) to analyze the denoised EEG signal. As GAMs have not been used in this domain of inquiry (with the exception of Tremblay and Baayen (2010)), we provide a brief introduction to this method, developed specifically to analyse the ERP signal with numeric variables as predictors in regression designs. A detailed introduction to the present method of analysis can be found in Baayen et al. (2012).

The GAM model decomposes the ERP signal into a series of additive waveforms, as illustrated in Figure 1. The first panel presents the grand average waveform, obtained by applying a function that calculates the average microvoltage for all subjects and items for each timestep t. The grand average waveform reveals the familiar N2 and P3 components.

The second panel depicts the additive model adjustment (partial effect) to the grand average for one subject in our experiment. Voltages decreased over time in the 100–400 ms time epoch for this subject. The upper waveform in panel 3 presents the sum of the waveforms in panels 1 and 2. This waveform is the same as the average waveform for this subject, obtained by averaging the ERP signal over all items for each timestep t. An important property of our method of analysis is that this subject-average waveform is decomposed into a grand average waveform (panel 1) and a subject-specific waveform (panel 2).

The lower waveform in panel 3 shows the consequences of taking into account changes in the intercept associated with adding two additional regressors. In this example, adding adjustments to the intercept for item, *knife* in the present example, and trial produces a small negative shift in the waveform. For other items and other positions in the experimental list the adjustments may also be positive.

The fourth panel visualizes a nonlinear interaction of time by Danger. As with the preceding panels, the horizontal axis represents time. The vertical axis represents the Danger ratings. Contour lines connect combinations of time and Danger for which the same microvoltage was observed. Larger negative microvoltages are coded with deeper shades of blue, more positive microvoltages are represented by darker shades of yellow. Green areas correspond to partial effects close to 0 microvoltage. Thus, the contour plot summarizes a wiggly microvoltage surface for each combination of time and Danger. The red horizontal line highlights the changes in the microvoltages for the word *knife*, which has a high danger rating. The waveform of these changes is traced separately in panel 5. When this partial effect of Danger is added to the lower waveform in panel 3, the expected waveform shown in panel 6 is obtained. It should be noted that the properties of a given

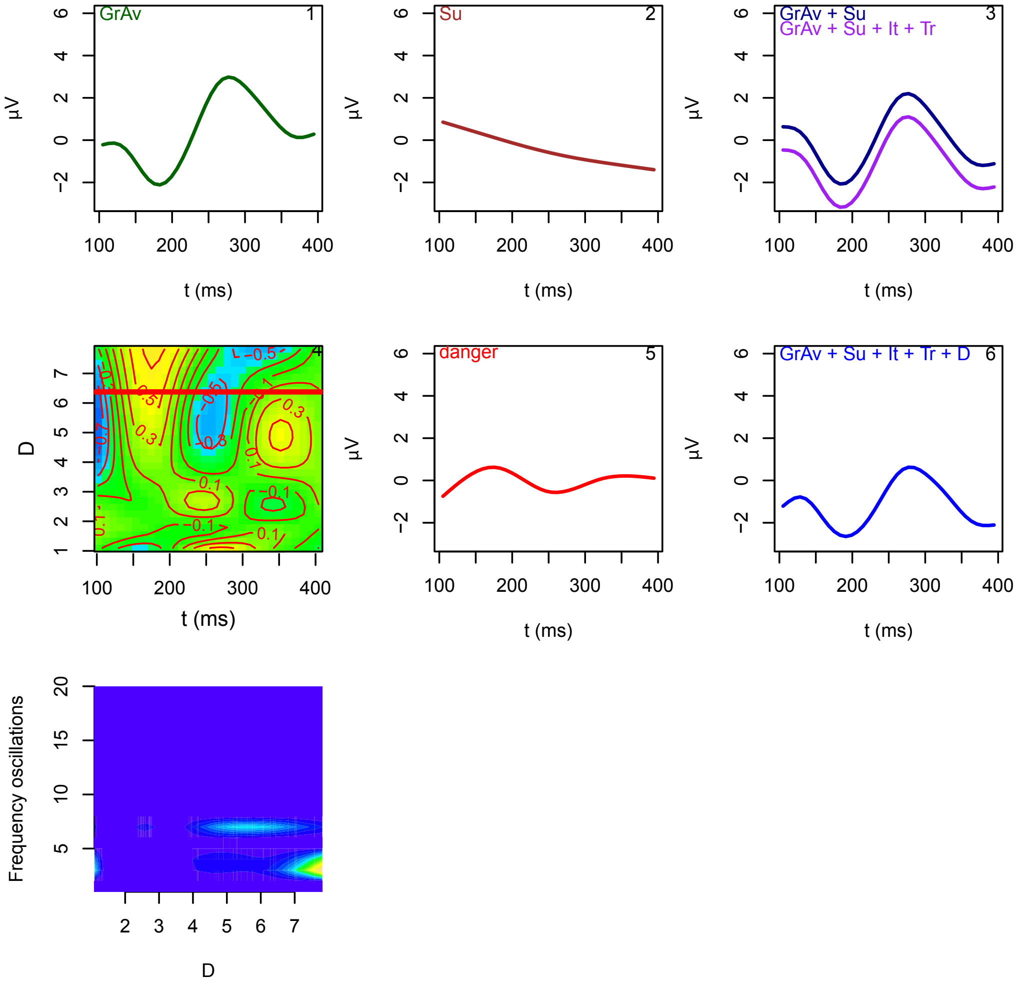

Figure 1: The components (GrAv: Grand Average; Su: Subject; It: Item; Tr: Trial: D: Danger) of the generalized additive model fit to the data for subject 10, item *knife* (D = 6.375), at electrode Fz. The red horizontal line in panel 4 highlights the changes in microvoltage for *knife* in the tensor surface for Time by Danger. The same waveform is visualized separately in panel 5. Panel 6 shows the sum of the 5 component waveforms. Panel 7 presents a predictor-frequency plot, brighter colors indicate higher-amplitude oscillations with the frequency in Hz on the vertical axis and the values of Danger for which these oscillations are observed on the horizontal axis.

item come into play in two different parts of model: on the one hand as an item specific adjustment to the intercept and on the other hand as an item specific waveform associated with its danger rating.

The period of the waveform for Danger in panel 5 is approximately 300 ms, which implies a frequency of 3.3 Hz. Using a fast Fourier transform, panel 7 plots the frequency in Hertz on the vertical axis against Danger on the horizontal axis with brighter colors to indicate greater amplitudes of the waveforms. In this way we can pair a time-predictor surface (panel 4) with a predictor-frequency surface (panel 7). For words with the highest danger ratings, high-amplitude oscillations are observed with a frequency of approximately 3.3 Hz. For intermediate values of Danger (4–6), a faster low amplitude oscillation of some 6.5 Hz is detected. In the data reported below, we observe oscillations in the range of 2–10 Hz, which includes the upper part of the delta range, the full theta range, and the lower part of the alpha range. Theta oscillations have been reported in several studies on language processing (Bastiaansen et al., 2005, 2008, e.g.), and are hypothesized to reflect memory demands (see also Bastiaansen and Hagoort, 2003, for comprehensive discussion).

In summary, we model the microVoltage at time t for a given subject, item, and position in the experimental list (trial), [V(t, participant, word, trial)] as the sum of a restricted cubic spline in time representing the grand average [s(t)], smooths in time for individual subjects [s(t, subject)], random intercepts for individual items [b(item)], a restricted cubic spline over the trials in the experiment [s(Trial)], and tensor products (Wood, 2006) for interactions of time by lexical distributional predictors [e.g., tensor(t, Danger)]:

$$
\begin{aligned}
V(t, \text{subject, item, trial}) &= \text{s}(t) + \\
&+ \text{s}(t, \text{subject}) + \\
&+ \text{b(item)} + \\
&+ \text{s(Trial)} + \\
&+ \text{tensor}(t, \text{Danger}) + \\
&+ \text{tensor}(t, \text{Usefulness}) + \\
&+ \text{tensor}(t, \text{Frequency}) + \\
&+ \text{tensor}(t, \text{Family size}) + \\
&+ \text{tensor}(t, \text{Number of synonyms}) + \\
&+ \text{tensor}(t, \text{Number of competitors}) +
\end{aligned}
$$

$$+ \quad \text{error} \tag{1}$$

Separate models were fitted to each electrode for four overlapping time intervals of 300 ms, as for larger time intervals smooths tend to loose precision. A hierarchical regression method was applied for the grand average waveform, the subject trends, the item random intercepts, and the effect of trial, which were added to the model sequentially in this order. The residuals of this baseline model were the response variable for separate models with tensor products for the lexical predictors (Danger, Usefulness, Frequency, Family Size, Number of Synonyms, and Number of Competitors). Similar results were obtained when the same predictors were entered hierarchically. We report the single-predictor models, as these models are independent of the order in which variables are entered. A hierarchical regression method was used for two computational reasons: the time required for fitting the model was reduced from a week to a few hours and, more importantly, fitting all terms in the model simultaneously turned out to be too complex an estimation problem leading to unstable and implausible estimates of the partial effects.

2.5. Results

Figure 2 summarizes the results obtained for Danger and Usefulness for channel FC2. The top panels present the grand average waveform for overlapping epochs of 300 ms each, together with (narrow) 95% confidence intervals. The familiar N2, P3 and N4 components are clearly visible, as well as a potential P1 around 120 ms post stimulus onset. These grand average waveforms are consistent across a wide range of electrodes, notably at central, left, right and posterior regions, as indicated by the inset heads.

The contour plots in the second and third rows of Figure 2 present the partial effects of Danger and Usefulness respectively. The vertical distance between any two contour lines is 0.4 μV. Insets show the topographical distribution across the scalp. Red squares represent channels at which the same or a very similar tensor surface reaches significance. Orange squares represent channels where partially similar tensor surfaces reached significance. White squares represent channels that were not significant or where idiosyncratic tensor surfaces were found.

For Danger, a low frequency oscillation (3.3 Hz) begins to emerge for high-danger words in the first epoch, and is clearly present in the second epoch. In the second epoch, as clarified by the predictor-frequency plot shown in Figure 1, a second faster oscillation (6.5 Hz) is present for words

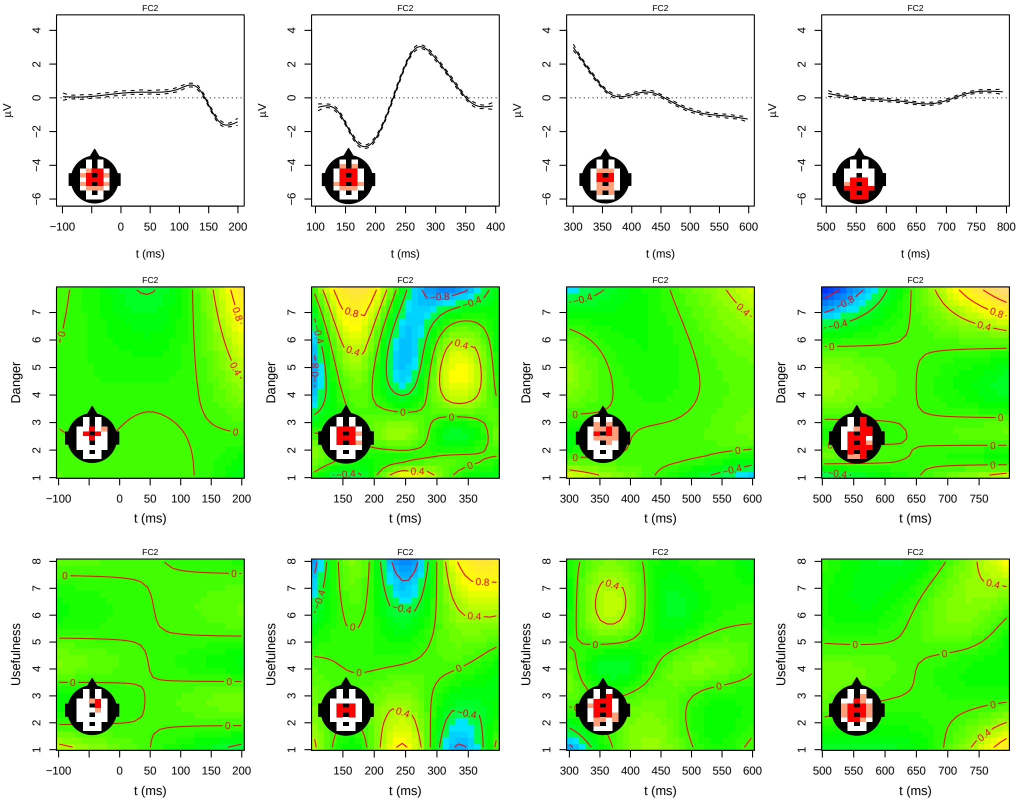

Figure 2: Partial effects of Danger and Usefulness at channel FC2. Top panels depict the grand average waveforms for four overlapping epochs. The central and lower panels present the tensor surfaces.

with danger ratings ranging from 4–6. Topographically less consistent, slow, and low-amplitude effects reached significance at several channels at the third epoch, in which the uniqueness point is located. After the uniqueness point, at the fourth epoch, a slow high-amplitude oscillation (1.25 Hz) emerged. The negativity in the higher frequency oscillations around 200–350 ms post stimulus onset is temporally consistent with the EPN, but in the present experiment, which addresses auditory comprehension, it is not posterior but frontal and central. Moreover, the effect of Danger emerges as inducing not only an early negativity, but also an earlier positivity, as well as further late modulations of the ERP waveform.

For Usefulness, theta oscillations (5 Hz) are present for both high and low usefulness, with a phase shift such that negative inflections for high usefulness are paired with positive inflections for low usefulness, and vice versa in the second epoch. Low-amplitude, lower frequency oscillations persist across the third and fourth epochs, that is, around and after the uniqueness point.

The oscillations for Danger and Usefulness in the second epoch are visible at frontal and central electrodes. At later epochs, significance is somewhat more widespread, with strong right-lateral support for Danger in the fourth epoch.

Figure 3 presents partial effects of Frequency and Number of Competitors. The top panels depict the grand average waveform, as in Figure 2. Theta oscillations linked to frequency arise in the second epoch and persist into the fourth epoch. It is noteworthy that the frequency effect emerges first for high-frequency words and is present for only some 200 ms, while the effect for low-frequency words spans 600 ms and emerges with its greatest amplitude in the fourth epoch, at which point it is to be found at right anterior and frontal channels. This pattern of results is consistent with the word frequency effect in behavioral studies, which report faster responses for high-frequency words.

For the Number of Competitors, there is a hint of a low-amplitude oscillation in the second epoch. In the third epoch, a high-amplitude but low-frequency oscillation occurs for words with many competitors. Compared to the second epoch, the significant channels are more centralized instead of anterior. The greater amplitude of the signal in the 300–600 ms time interval is consistent with the location of the uniqueness point for the present stimuli, at approximately 470 ms. It is around the uniqueness point that the cognitive system is engaged in discriminating the target word from

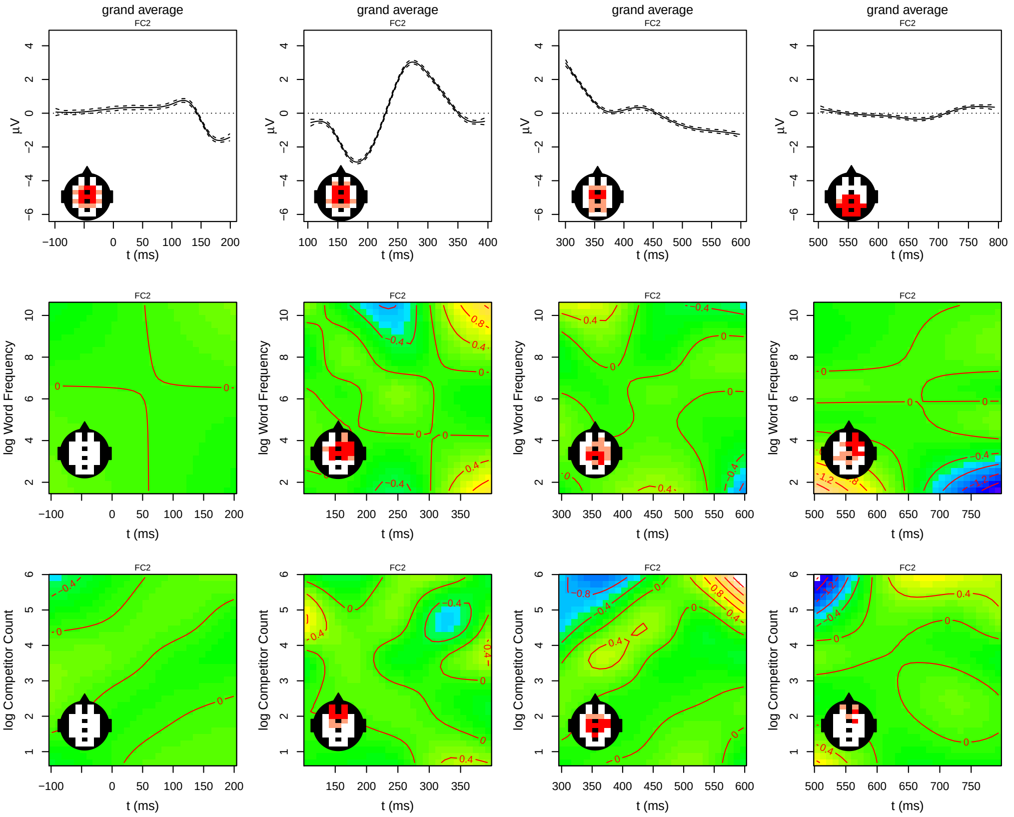

Figure 3: Partial effects of Frequency and Number of Competitors at FC2.

its strongest and semantically unrelated competitors.

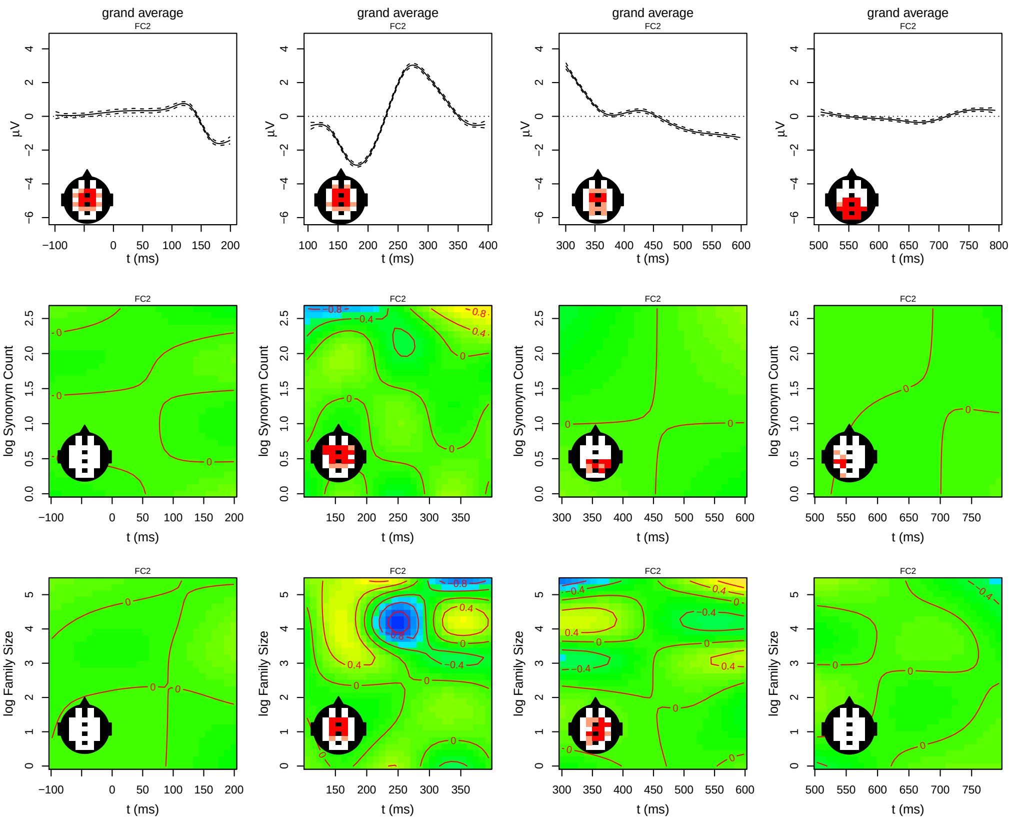

Figure 4: Partial effects of Number of Synonyms and Morphological Family Size at FC2.

Figure 4 presents the partial effects of Number of Synonyms and Family Size. An effect for Number of Synonyms is visible in the second epoch, where it is widespread over frontal and central channels, with a higher-amplitude oscillation for words with many synonyms. Sporadic oscillations persist through later epochs.

Partial effects of Family Size are significant in the second epoch at central and frontal electrodes. The theta oscillations for words with large morphological families persist into the third epoch.

Scattered effects of family frequency (not shown) were visible for a few electrodes in the second epoch. More consistent effects began to emerge at right anterior and frontal channels in the second epoch, and spread to left frontal, as well as central channels in the fourth epoch.

Number of Synonyms and Family Size are well correlated ($r = 0.46$)

suggesting that these two predictors might possibly tap into the same underlying processes. There are two important differences arguing against this possibility. First, the theta oscillations for Synonyms and Family Size have different frequencies at the second epoch. Second, only the oscillations of Family Size persist into the third epoch.

3. Discussion

The pattern of results for Danger emerging from this experiment is as follows. Some 150 ms post stimulus onset, a positivity in the ERP signal arises for words with high danger ratings, peaking around 175 ms, at frontal and central channels. This positivity attenuates the N2 component. Of all predictors considered in the present study, Danger is the only one for which an effect is already significant and topographically consistent at the end of the first epoch.

This positivity is followed by a negative deflection, attenuating the P3, starting around 200 ms and, for the words with the highest danger ratings, continuing up to 350 ms post stimulus onset. A fast Fourier transform indicated the presence of both a slow oscillation (3.3 Hz) as well as a faster theta oscillation (6.5 Hz). The former oscillation (for the words with the highest danger ratings) is time-locked with the grand average waveform, attenuating both the N2 and P3. The 6.5 Hz oscillation, for words with lower but above-average danger ratings, modulates the grand average waveform independently. Although weak effects of Danger persisted in the third epoch, a higher-amplitude oscillation re-emerged late, in the 500–800 ms time window, for 75% of the words post stimulus-offset, at many central and right-lateral sites.

The negativity visible in the contour plot for Danger in the second epoch around 225–300 ms post stimulus onset is remeniscent of the EPN reported by, e.g., Schupp et al. (2003, 2006, 2008), albeit at central rather than posterior channels. In our data, however, this negativity is part of an oscillatory process that emerges earlier in the ERP signal.

The early effects of Danger precede the words' uniqueness points. This presents a problem to the standard interpretation of the uniqueness point as the point in time where the lexical competition process has run its course and the meaning carried by the auditory stimulus has become available. The uniqueness point would characterize the moment in time at which the listener would become aware of the word referring to a dangerous object, and hence the point at which the listener would be able take action (flight or fight), if so required. In other words, a response to a word with a potentially dangerous referent, such as *knife*, would then be initiated only after the uniqueness point. Our experiment, however, indicates that the processing system begins to respond to the danger meaning of the word already some 150 ms after stimulus onset.

However, it is preferable to conceptualize the uniqueness point as the moment in time at which uncertainty as to a word's meaning has been substantially reduced, rather than as the point of recognition, as it has been shown that lexical competitors in the cohort of candidates for recognition activate their meanings (Salverda et al., 2003). It might therefore be argued that the danger meaning can already be accessed long before the uniqueness point is actually reached. One assumption here is that any competitor in the cohort of lexical candidates compatible with the acoustic information available at a given point in time will be activating its semantics, including its emotional shades of meaning.

This explanation would be strengthened if independent evidence supporting very early activation of competitors would be available. However, the Number of Competitors measure fails to be predictive for the first epoch. It is predictive at the second epoch, but here its effects are weak and irregular, and supported at a small number of anterior channels. It is only around the uniqueness point that a high-amplitude oscillation emerges with strong topographical support. These considerations suggest that it is unlikely that lexical competition is taking place already around 150 ms post stimulus onset, the time at which the effect of Danger begins to emerge. As a consequence, it is also unlikely that at this time the word would be sufficiently activated in its cohort of lexical competitors to activate its semantics and the dangerousness of its referent.

This conclusion receives further support from the late emergence of the word frequency effect. The word frequency effect emerges around 200 ms post stimulus onset, but only for high-frequency words. For the lower-frequency words, oscillations with non-negligible amplitude are possibly arising around 300 ms post onset, with large amplitudes only in the fourth epoch, post word offset. If word frequency is used as a diagnostic for lexical access, then, given the absence of a correlation of Danger and Frequency ($r = -0.04, p > 0.55$) and the relative scarcity of high-frequency words (most words have low frequencies), lexical access cannot be a prerequisite for the effect of Danger to arise for a large majority of high-danger words.

We think that the early response to the danger stimuli is best explained by the dual pathways framework of (LeDoux, 1996). When danger words are learned, a short sub-cortical route to the amygdala would be established, allowing information important for survival to reach the amygdala faster than it would via the standard cortical pathway. The functionality of this short subcortical route would then be to allow a fast flight or fight response.

Do the remaining three lexical-distributional predictors support this interpretation?

First, consider the effect of Family Size, a measure that, although uncorrelated with Danger ($r = -0.02, p > 0.65$), shows two oscillations, both a slow oscillation for the words with the highest numbers of morphological family members, and a theta oscillation for words with log family size in the range of 3–5, that are remarkably similar to those observed for Danger. Recall that the family size measure represents the count of complex words containing a given word. In the case of the high-danger word *knife*, this count includes family members such as *pocketknife, jackknife, carving-knife, sheath-knife, flick-knife, pruning-knife, table-knife*, and *penknife*. We can therefore conceptualize the family size effect as a measure of the degree to which a high-level concept such as *knife* has specialized hyponyms. Words with many hyponyms occur in many different contexts (for *knife*, gardening, eating, preparation of food, and violence), which afford enhanced opportunities for learning (see also Baayen et al., 2011).

These considerations suggest that the effect of Danger should be especially large for words with large morphological families, as those are the words that are most important in the speech community and for which the strongest subcortical connections are acquired. In other words, an interaction of Danger by Family Size by Time is predicted. Such an interaction can be modeled by means of a three-way tensor product. A model with such a three-way tensor provides a significant improvement in goodness of fit compared to a model with two separate two-way tensor products (one for Time by Danger and one for Time by Family Size) according to an analysis of deviance test ($p < 0.0001$, reduction in AIC: 267). This three-way interaction is visualized in Figure 5, which plots the $Time$ by D microvoltage surface for the second, third and fourth quartiles of Family Size in the second epoch. For the second quartile and median Family Size (the left and center panels), a theta oscillation with a frequency of approximately 6 Hz characterizes the higher danger words. For the fourth quartile of Family Size, a slower oscillation (approximately 4 Hz) is found, with greater amplitude (right panel).

Recall that a fast Fourier transform detected oscillations at two frequencies for the Time by Danger tensor surface of Figure 1. We can now link these two separate oscillations to different ranges of the Family Size measure. The slower, higher amplitude oscillation originates with high-danger words with many hyponyms. The faster, lower-amplitude oscillation arises for words with few hyponyms, which are more difficult to learn, which are culturally less important, and for which, as expected, the effect of Danger is somewhat reduced.

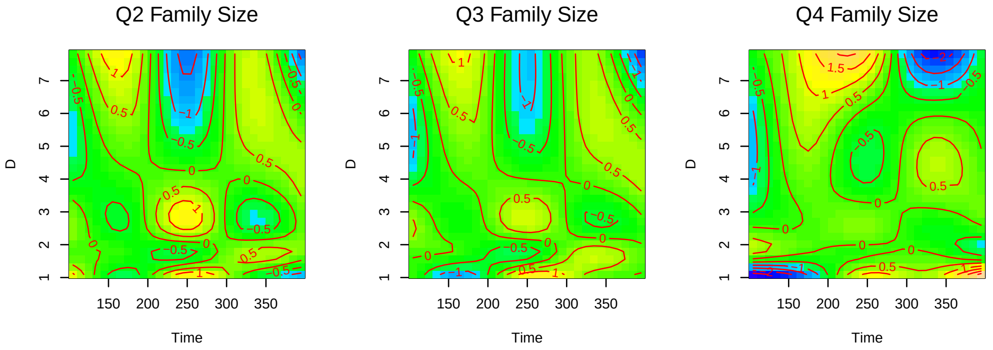

Figure 5: Visualization of the three-way interaction of Time by Danger by Family Size: The microvoltage surface is shown for the second (0.25%), third (median), and fourth (0.75%) quartiles of Family Size.

The second predictor, Number of Synonyms, captures the extent to which the same concept can be expressed by different words (for *knife*: *(switch) blade, dagger, lancet, scalpel, stiletto, machete*). Like Family Size, this measure taps into the number of (co-)hyponyms a word has, and like Family Size, Number of Synonyms enters into an interaction with Time and Danger ($p < 0.0001$, with a reduction in AIC of 137 compared to a baseline model including separate tensors for Time by Danger and Time by Number of Synonyms). Figure 6 clarifies that Number of Synonyms modifies only the slow oscillation for Danger, which reaches its greatest amplitude for words with a Number of Synonyms equal to or exceeding the median.

Finally consider Usefulness. Usefulness is characterized by Wurm (2007) as a dimension orthogonal to Danger but nevertheless also important for an individual's survival. Its emotional valence would then be that of the desire of having, using, or consuming the object. Interestingly, oscillations in the theta range are present in the second epoch, the epoch for which the strongest effects for Danger emerged as well. The effect of Usefulness,

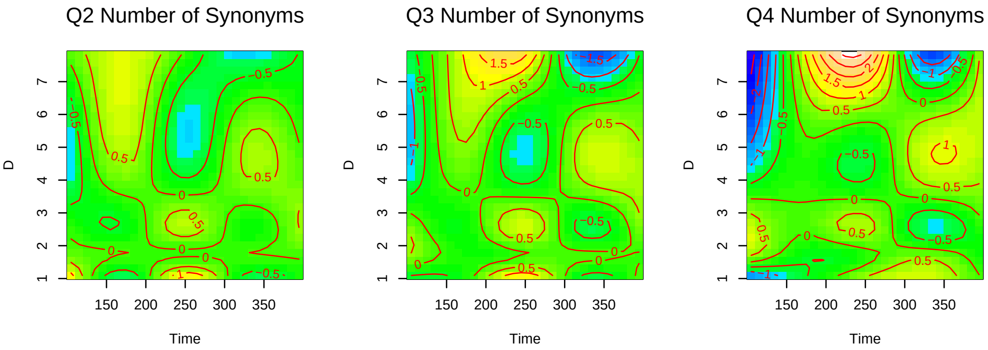

Figure 6: Visualization of the three-way interaction of Time by Danger by Number of Synonyms: The microvoltage surface is shown for the second (0.25%), third (median), and fourth (0.75%) quartiles of Number of Synonyms.

however, is qualitatively different in that it emerges not only at the high end of the rating scale, but also at the low end, albeit with a shift in phase. For the most useful words, a negative inflection modulating the P3 is present that coincides with the negative inflection for Danger. As the effect of Usefulness is found at central channels, as is the case for Danger, it is possible that the effect of Usefulness also arises through the subcortical pathway.

An alternative explanation is possible, however. Usefulness enters into a significant positive correlation with Family Size ($r = 0.39, p < 0.0001$) and a marginally significant positive correlation with Number of Synonyms ($r = 0.11, p = 0.0797$, two-tailed tests). These positive correlations make sense, as words refering to more useful objects will come with more morphologically related words, as well as more synonyms for denoting ‘subspecies’ of these objects as used across the many different situations in which these objects are used. As a consequence, the theta oscillations for highly-useful words might reflect, just as Family Size and Number of Synsets, the strength of the association with the amygdala of the words specifying danger.

Both interpretations of the effect of Usefulness are, at first sight, challenged by the appearance of oscillations not only for high but also for low values of Usefulness. However, the observed pattern of (phase-shifted) oscillations may reflect not sensitivity to Usefulness per se, but rather sensitivity to the probability of the degree of usefulness: Both low and high values of Usefulness are rare, and we may therefore be witnessing the brain investing processing effort for handling words with low-probability usefulness. Furthermore, the phase shift between the oscillations for useful and useless words may indicate that when highly useful words are active, useless words are suppressed, and vice versa. If this understanding of the tensor surface of Usefulness is on the right track, it remains possible to argue that it is the highly useful words that are driving the effect, in which case both of the above explanations remain viable.

In summary, surprisingly, simple words, read aloud by an untrained and uninformed speaker, and presented to naive undergraduate listeners without context in a psycholinguistics laboratory, nevertheless elicit a clear and early response in the ERP signal. Our stimuli are not emotionally arousing pictures, as in the studies of Schupp et al. (2003); Smith et al. (2003); Stolarova et al. (2006); Schupp et al. (2008); Bröckelmann et al. (2011), nor are they spoken with emotional intonation, as in Wiethoff et al. (2008); Paulmann and Kotz (2008a,b). Instead, they are simple sequences of harmless speech sounds, and yet effects of danger and usefulness emerge around 150 ms post stimulus onset

The response to Danger comprises two oscillations. The first, a large-amplitude slow oscillation modifying the N2 and P3 of the grand average waveform, is enhanced for words with large morphological families and/or large numbers of synonyms. The second oscillation, which falls into the theta range (6.5 Hz), is typical for words with average or below-average family sizes. We hypothesize that the effects of Family Size and Number of Synonyms reflect the strength of the subcortical pathway, and should not be interpreted as indicators of cortical lexical access to the words' meanings. This hypothesis is supported by two observations. First, measures traditionally viewed as indicators of lexical access, such as Word Frequency and Number of Competitors, emerge with strong effects long after Danger, and also Usefulness, have shown their highest-amplitude effects. Second, Family Size and Number of Synonyms enter into three-way interactions with Time and Danger. We have interpreted these interactions as reflecting that the dangerousness of objects is better learned when these objects are socio-culturally important. Deeper learning would then lead to a stronger subcortical pathway, and hence higher-amplitude oscillations in the ERP signal. By contrast, it is difficult to see why, under a standard cortical lexical access account, socio-culturally central concepts would trigger privileged early processes as opposed to other aspects meaning.

Two questions remain to be answered. First, do the oscillations observed for Danger reflect processing along the subcortical pathway and in the amygdala? Given that the ERP signal is registered at the scalp and typically captures cortical rather than subcortical processing, this question must be answered in the negative. The proper way of understanding these oscillations is that they reflect cortical processes that have been initiated by activation coming from the subcortical route. As a consequence, the moment at which the subcortical route itself becomes active must precede the moment at which the present (cortical) oscillations are observed.

Second, there must be information in the acoustic signal that selectively activates the subcortical route. As emotional intonation has been shown to play a role in the recognition of words (Paulmann and Kotz, 2008b,a; Wiethoff et al., 2008), it is conceivable that Danger is encoded in our stimulus materials by differences in F0 contours. However, analyses of the intonation contours of our stimuli, using both generalized additive modeling and functional data analysis, did not reveal any reliable differences in the F0 contour that might be due to differences in Danger. Furthermore, the stimulus materials were constructed in such a way that intonational differences were minimized. Interestingly, acoustic duration turns out to be a more likely phonetic correlate of Danger: Words with higher danger ratings tended to have slightly longer durations ($r = 0.16, p = 0.0088$, two-tailed test). This positive correlation fits well with the smooth signal redundancy hypothesis of Aylett and Turk (2004), according to which linguistic units that carry more information are articulated with longer acoustic durations. However, more research is necessary before any claims can be made regarding the precise phonetic cues that activate the subcortical route for words expressing danger.

We conclude with a methodological consideration. We have made use of generalized additive modeling to understand the quantitative structure of the ERP signal. This methodology offers new opportunities for studying the contributions of numerical predictors, while staying close conceptually to the current standards of ERP analysis which are grounded in the analysis of grand average waveforms. This method allows us to extend the previous literature by looking not only at either ERP components or at oscillations in the EEG signal: It allows us to consider both simulataneously. One noteworthy finding, which awaits further replication, is that temporary restricted oscillations linked to linguistic properties of the stimuli can be found not only in the theta or gamma range (Pulvermüller et al., 1995; Bastiaansen and Hagoort, 2003), but also in the delta and alpha ranges.

Acknowledgments

We are grateful to Antoine Tremblay for his help in processing and analyzing the data. We also thank members of the Centre for Comparative Psycholingusitics and three anonymous reviewers for their insightful comments on earlier versions of this research.

References

Aylett, M., Turk, A., 2004. The smooth signal redundancy hypothesis: a functional explanation for relationships between redundancy, prosodic prominence, and duration in spontaneous speech. Language and Speech 47, 31–56.

Baayen, R. H., Milin, P., Filipovic Durdjevic, D., Hendrix, P., Marelli, M., 2011. An amorphous model for morphological processing in visual comprehension based on naive discriminative learning. Psychological Review 118 (3), 438–481.

Baayen, R. H., Piepenbrock, R., Gulikers, L., 1995. The CELEX lexical database, Release 2 (CD-ROM). Philadelphia, Pennsylvania.

Baayen, R. H., Tremblay, A., Hendrix, P., 2012. An introduction to analyzing the ERP signal with generalized additive modeling using the gam-erp package, vignette for the GAM-eRp package for R, vignette and package in preparation.

Balling, L., Baayen, R., 2008. Morphological effects in auditory word recognition: Evidence from Danish. Language and Cognitive Processes 23 (7-8), 1159–1190.

Bastiaansen, M., Hagoort, P., 2003. Event-induced theta-responses as a window on the dynamics of memory. Cortex 39, 967–992.

Bastiaansen, M., Oostenveld, R., Jensen, O., Hagoort, P., 2008. I see what you mean: theta power increases are involved in the retrieval of lexical semantic information. Brain and Language 106, 15–28.

Bastiaansen, M., Van Der Linden, M., Ter Keurs, M., Dijkstra, T., Hagoort, P., 2005. Theta responses are involved in lexical-semantic retrieval during language processing. Journal of Cognitive Neuroscience 17, 530–541.

Boersma, P., Weenink, D., March 2010. Praat: Doing phonetics by computer (Version 5.1.29) [Computer program].
URL `http://www.praat.org/`

Bröckelmann, A.-K., Steinberg, C., Elling, L., Zwanzger, P., Pantev, C., Junghöfer, M., 2011. Emotion-associated tones attract enhanced attention at early auditory processing: Magnetoencephalographic correlates. The Journal of Neuroscience 31, 7801–7810.

Carretié, L., Albert, J., López-Martín, S., Tapia, M., 2009a. Negative brain: An integrative review on the neural processes activated by unpleasant stimuli. International Journal of Psychophysiology 71, 57–63.

Carretié, L., Hinojosa, J. A., López-Martín, S., Albert, J., Pozo, M. A., 2009b. Danger is worse when it moves: Neural and behavioral indicies of enhanced attentional capture by dynamic threatening stimuli. Neuropsychologia 47, 364–369.

Carretié, L., Ruiz-Padial, E., López-Martín, S., Albert, J., 2011. Decomposing unpleasantness: Differential exogenous attention to disgusting and fearful stimuli. Biological Psychology 86, 247–253.

Coltheart, M., 1981. The MRC Psycholinguistic Database. Quarterly Journal of Experimental Psychology 33A, 497–505.

Fellbaum, C. e., 1998. WordNet: An electronic database. The MIT Press, Cambridge, MA.

Fischer, K., 2007. Constituent usefulness effects on the recognition of compound words, Honours thesis, Wayne State University.

Gernsbacher, M. A., 1984. Resolving 20 years of inconsistent interactions between lexical familiarity and orthography, concreteness, and polysemy. Journal of Experimental Psychology: General 113, 256–281.

Goldinger, S. D., Luce, P. A., Pisoni, D. B., Marcario, J. K., 1992. Form-based priming in spoken word recognition: The roles of competition and bias. Journal of Experimental Psychology: Learning, Memory and Cognition 18, 1211–1238.

Herbert, C., Ethofer, T., Anders, S., Junghöfer, M., Wildgruber, D., Grodd, W., Kissler, J., 2009. Amygdala activation during reading of emotional adjectives — an advantage for pleasant conotent. SCAN 4, 35–49.

Herbert, C., Junghöfer, M., Kissler, J., 2008. Event related potentials to emotional adjectives during reading. Psychophysiology 45, 487–498.

Hofmann, M., Kuchinke, L., Tamm, S., Võ, M. L.-H., Jacobs, A. M., 2009. Affective processing within 1/10th of a second: high arousal is necessary for early facilitative processing of negative but not positive words. Cognitive, Affective, and Behavioral Neuroscience 9, 389–397.

Ihssen, N., Heim, S., Keil, A., December 2007. The costs of emotional attention: Affective processing inhibits subsequent lexico-semantic analysis. Journal of Cognitive Neuroscience 19 (12), 1932–1949.

Kissler, J., Herbert, C., Peyk, P., Junghöfer, M., 2007. Buzzwords. early cortical responses to emotional words during reading. Psychological Science 18, 475–480.

Kissler, J., Herbert, C., Winkler, I., Junghöfer, M., 2009. Emotional and attention in visual word processing — an ERP study. Biological Psychology 80, 75–83.

LeDoux, J., 1996. The Emotional Brain. Simon and Schuster, New York.

Luce, P., 1985. Structural distinctions between high and low frequency words in auditory word recognition. PhD dissertation, Indiana University.

Luce, P. A., Pisoni, D. B., Manous, L. M., 1984. Isolation points and frequency effects in the gating paradigm: Predictions from an online data-base. Research in Speech Perception 10, 303–310.

Marslen-Wilson, W. D., Welsh, A., 1978. Processing interactions and lexical access during word recognition in continuous speech. Cognitive Psychology 10, 29–63.

Miller, G. A., Beckwith, R., Fellbaum, C., Gross, D., Miller, K. J., 1990. Introduction to wordnet: An on-line lexical database. International Journal of Lexicography 3, 235–244.

Moscoso del Prado Martín, F., Bertram, R., Häikiö, T., Schreuder, R., Baayen, R. H., 2004. Morphological family size in a morphologically rich language: The case of Finnish compared with Dutch and Hebrew. Journal of Experimental Psychology: Learning, Memory, and Cognition 30, 1271–1278.

Osgood, C. E., 1969. On the whys and wherefores of e, p, and a. Journal of Personality and Social Psychology 12, 194–199.

Palazova, M., Mantwill, K., Sommer, W., Schacht, A., 20011. Are effects of emotion in single words non-lexical? evidence from even-related brain potentials. Neuropsychologia 49, 2766–2775.

Paulmann, S., Kotz, S. A., 2008a. Early emotional prosody perception based on different speaker voices. NeuroReport 19, 209–213.

Paulmann, S., Kotz, S. A., 2008b. An ERP investigation on the temporal dynamics of emotional prosody and emotional semantics in pseudo- and lexical-sentence context. Brain and Language 105, 59–69.

Pulvermüller, F., Lutzenberger, W., Preißl, H., Birbaumer, N., 1995. Spectral responses in the gamma-band physiological signs of higher cognitive processes? Neuroreport: An International Journal for the Rapid Communication of Research in Neuroscience.

Rellecke, J., Palazova, M., Sommer, W., Schacht, A., 2011. On the automaticity of emotion processing in words and faces: event-related brain potentials evidence from a superficial task. Brain and Cognition 77, 23–32.

Rubenstein, H., Pollack, I., 1963. Word predictability and intelligibility. Journal of Verbal Learning and Verbal Behavior 2, 147–158.

Salverda, A., Dahan, D., McQueen, J., 2003. The role of prosodic boundaries in the resolution of lexical embedding in speech comprehension. Cognition 90, 51–89.

Schacht, A., Sommer, W., 2009. Emotions in word and face processing: early and late cortical responses. Brain and Cognition 69, 538–550.

Schneider, W., Eschman, A., Zuccolotto, A., 2002. E-Prime 1.0. PA: Psychological Software Tools.

Schreuder, R., Baayen, R., 1997. How complex simplex words can be. Journal of Memory and Language 37, 118–139.

Schupp, H. T., Flaisch, T., Stockburger, J., Junghöfer, M., 2006. Emotion and attention: event-related brain potential studies. Progress in Brain Research 156, 31–51.

Schupp, H. T., Junghöfer, M., Weike, A. I., Hamm, A. O., 2003. Attention and emotion: an ERP analysis of facilitated emotional stimulus processing. NeuroReport 14 (8), 1107–1110.

Schupp, H. T., Stockburger, J., Bublatzky, F., Junghöfer, M., Weike, A. I., Hamm, A. O., 2008. The selective processing of emotional visual stimuli while detecting auditory targets: an ERP analysis. Brain Research 1230, 168–176.

Scott, G. G., O'Donnell, P. J., Leuthold, H., Sereno, S. C., 2009. Early emotion word processing: evidence from event-related potentials. Biological Psychology 80, 95–104.

Smith, N. K., Cacioppo, J. T., Larsen, J. T., Chartrand, T. L., 2003. May i have your attention, please: electrocortical responses to positive and negative stimuli. Neuropsychologia 41, 171–183.

Stolarova, M., Keil, A., Moratti, S., 2006. Modulation of the c1 visual event-related component by conditioned stimuli: Evidence for sensory plasticity in early affective perception. Cereb Cortex 16, 876–887.

Tremblay, A., Baayen, R. H., 2010. Holistic processing of regular four-word sequences: A behavioral and ERP study of the effects of structure, frequency, and probability on immediate free recall. In: Wood, D. (Ed.), Perspectives on Formulaic Language: Acquisition and communication. The Continuum International Publishing Group, London, pp. 151–173.

Wang, J., Nicol, T., Skoe, E., Sams, M., Kraus, N., 2008. Emotion modulates early auditory response to speech. Journal of Cognitive Neuroscience 21 (11), 2121–2128.

Wiethoff, S., Wildgruber, D., Kreifelts, B., Becker, H., Herbert, C., Grodd, W., Ethofer, T., 2008. Cerebral processing of emotional prosody — influence of acoustic parameters and arousal. NeuroImage 39, 885–893.

Wood, S. N., 2006. Generalized Additive Models: An Introduction with R. Chapman and Hall.

Wurm, L. H., 2007. Danger and usefulness: an alternative framework for understanding rapid evaluation effects in perception? Psychonomic Bulletin & Review 14 (6), 1218–1225.

Wurm, L. H., Seaman, S. R., 2008. Semantic effects in naming and perceptual identification but not in delayed naming: implications for models and tasks. Journal of Experimental Psychology 34 (2), 381–398.

Appendix

Words used in the experiment: *back, bag, balloon, banana, basin, basket, bean, bed, blade, blanket, boat, bolt, book, booth, bottle, brass, bread, breath, buffalo, cake, canteen, canyon, car, carrot, chicken, club, coffee, cork, craft, crime, deceit, desk, diamond, dove, dragon, dust, eagle, echo, elephant, elm, finch, fire, flag, flake, food, forest, fraud, friend, frog, fruit, girl, globe, glove, grape, ground, gun, hand, head, heap, hero, herring, hog, honey, horn, hospital, hotel, house, hurricane, insect, joke, juice, kettle, kitten, knife, lady, land, lava, leaf, lemon, lid, lily, linen, lint, lion, loss, magazine, meal, method, minnow, moment, money, moon, moose, mountain, mouse, movie, mud, mule, music, nail, napkin, needle, noun, nut, ocean, ointment, oven, owl, palace, parent, parsley, peach, pigeon, point, poison, potato, pox, priest, print, problem, rabbit, sardine, sequel, shawl, ship, shot, skin, skunk, sleeve, snake, soil, song, spear, spoon, steeple, stone, stool, storm, stove, strap, string, suit, syringe, tarantula, theft, thief, thorn, threat, time, toad, tobacco, tomb, tornado, town, trout, tub, tunic, twig, umbrella, uncle, vase, village, wagon, waltz, web, wheat, window, woman, wood, yard, year, youth, ant, apple, area, arrow, ash, ball, bird, bomb, bone, boy, brick, bug, bulb, bull, cannon, cap, card, course, crow, desert, dial, dog, doll, door, egg, fish, fly, folk, fork, germ, guard, gull, heart, hill, hole, hook, horse, lad, lamp, law, line, man, mare, mile, mill, neck, oak, opera, organ, pan, piece, pin, pit, plague, pond, port, post, rat, ring, rink, room, root, rug, screw, seed, shell, shoe, side, sight, stead, steak, stick, straw, stream, sty, style, sword, tail, tide, ton, trance, tree, verb, way, week, weight, wheel, wool.*