Brain & Language 122 (2012) 81–91

Contents lists available at SciVerse ScienceDirect

Brain & Language

journal homepage: www.elsevier.com/locate/b&l

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, Canada T6G 2E7
[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

ARTICLE INFO

Article history:
Accepted 19 May 2012
Available online 21 June 2012

Keywords:
Danger
Usefulness
Theta oscillations
Frequency
Uniqueness point
Auditory comprehension

ABSTRACT

Visual emotionally charged stimuli have been shown to elicit early electrophysiological responses (e.g., Ihssen, Heim, & Keil, 2007; Schupp, Junghöfer, Weike, & Hamm, 2003; Stolarova, Keil, & Moratti, 2006). 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 & 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).

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, 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, Junghöfer, & Kissler, 2008; Herbert et al., 2009; Kissler, Herbert, Peyk, & Junghöfer, 2007; Kissler, Herbert, Winkler, & Junghöfer, 2009) as well as in visual lexical decision (Hofmann, Kuchinke, Tamm, Võ, & Jacobs, 2009; Palazova, Mantwill, Sommer, & Schacht, 2011; Scott, O'Donnell, Leuthold, & Sereno, 2009; Schacht & Sommer, 2009). Though the EPN has been consistently observed across studies, it may depend in part on the experimental paradigm (Rellecke, Palazova, Sommer, & Schacht, 2011). In a visual lexical decision task performed on emotion words, Palazova et al. (2011) 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, Cacioppo, Larsen, and Chartrand (2003) observed smaller P1 (<120 ms) amplitudes associated with infrequently presented pictures with positive content.

Carretié, Albert, López-Martín, and Tapia (2009a), Carretié, Hinojosa, López-Martín, Albert, and Pozo (2009b), Carretié, Ruiz-Padial, López-Martín, and Albert (2011) 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 response

* Corresponding authors. Fax: +1 780 492 0806.
E-mail addresses: kryuchko@ualberta.ca (T. Kryuchkova), benjamin.tucker@ualberta.ca (B.V. Tucker), lee.wurm@wayne.edu (L.H. Wurm), baayen@ualberta.ca (R.H. Baayen).

0093-934X/$ - see front matter © 2012 Elsevier Inc. All rights reserved.
http://dx.doi.org/10.1016/j.bandl.2012.05.005

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.

Hofmann et al. (2009) and Scott 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, Nicol, Skoe, Sams, & Kraus, 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 & Pollack, 1963). As Danger and Usefulness explained more variance (Wurm, 2007) in behavioral 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 (Hofmann et al., 2009; Scott 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), Schupp, Flaisch, Stockburger, and Junghöfer (2006), Schupp et al. (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 (Balling & Baayen, 2008; Luce, Pisoni, & Manous, 1984; Marslen-Wilson & Welsh, 1978), 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 Fischer (2007), Wurm (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 & 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, Piepenbrock, & Gulikers, 1995), following Wurm (2007). Second, given the phoneme at which the word becomes unique, the acoustic uniqueness point was then determined as the midpoint 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 Martın, Bertram, Häikiö, Schreuder, & Baayen, 2004; Schreuder & 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