doi:10.1093/scan/nss003 SCAN (2013) 8, 333–340

Existential neuroscience: neurophysiological correlates of proximal defenses against death-related thoughts

Johannes Klackl,[1] Eva Jonas,[1] and Martin Kronbichler[1,2,3]

[1]Department of Psychology, University of Salzburg, Salzburg, Austria and [2]Center for Neurocognitive Research, University of Salzburg, Salzburg, Austria, [3]Neuroscience Institute, Christian-Doppler-Clinic, Paracelsus Private Medical University, Salzburg, Austria

A great deal of evidence suggests that reminders of mortality increase ingroup support and worldview defense, presumably in order to deal with the potential for anxiety that roots in the knowledge that death is inevitable. Interestingly, these effects are obtained solely when thoughts of death are not in the focus of consciousness. When conscious, death-related thoughts are usually defended against using proximal defenses, which entail distraction or suppression. The present study aimed at demonstrating neurophysiological correlates of proximal defenses. We focused on the late positive potential (LPP), which is thought to reflect an increased allocation of attention toward, and processing of, motivationally relevant stimuli. Our prediction was that the LPP should be increased for death-related relative to death-unrelated, but equally unpleasant stimulus words. In Experiment 1, this prediction was confirmed. This finding was replicated in Experiment 2, which used a target word detection task. In Experiment 2, both death-related and pleasant words elicited an enhanced LPP, presumably because during the less demanding task, people might have distracted themselves from the mortality reminders by focusing on pleasant words. To summarize, we were able to identify a plausible neurophysiological marker of proximal defenses in the form of an increased LPP to death-related words.

Keywords: terror management theory; mortality salience; proximal defenses; ERP

INTRODUCTION

We know that every life, including our own, will inevitably end one day. It is somewhat surprising that we are nevertheless able to live our daily lives without worrying too much about life's finiteness. Terror management theory (TMT), which is based on the writings of cultural anthropologist Ernest Becker (1973), proposes that people manage to do so by identifying with so-called cultural worldviews. Worldviews define an orderly and meaningful reality that persists beyond one's own existence and hence, provides symbolic immortality. To the extent that people regard themselves as satisfying the standards of value defined by the cultural worldview, they are able to attain self-esteem. Together, these two psychological structures, self-esteem and cultural worldviews, are the components of the so-called anxiety buffer (Solomon *et al.*, 1991) which protects the human mind from the existential terror of death to become conscious. This proposal of a joint terror management function of worldviews and self-esteem received considerable empirical support (Greenberg *et al.*, 1997; Pyszczynski *et al.*, 2004). For instance, reminding people of mortality increases their need for faith in their cultural worldviews, more positive evaluations of ingroup members and people who uphold cultural values and more negative evaluations of outgroup members and people who threaten their worldviews (for a meta-analysis, see Burke *et al.*, 2010). Interestingly, such defense of cultural worldviews can be obtained only after people have been distracted from conscious reminders of death or when death has been primed subliminally. In contrast, when participants are not distracted from a conscious mortality reminder, these effects usually do not occur (Greenberg *et al.*, 1994). In this study, having participants think more deeply about dying produced less worldview defense (preference for a pro-US author over an anti-US author) than a subtle reminder of mortality, indicating that strong conscious contemplation of death is less effective. Studies 2 and 3 showed that mortality salience (MS) did not produce worldview defense immediately after the MS manipulation—in order for it to occur, people had to be distracted from thoughts of mortality. Study 4 indicated that the availability of death-related thoughts also increased after people had been distracted from the MS manipulation.

In a recent event-related potential (ERP) study on the effects of MS (Henry *et al.*, 2010), white participants were shown photographs of white (ingroup) and black (outgroup) faces. The P2 (which was previously associated with threat perception) to ingroup faces was decreased by MS. This indicates that MS might lead to decreased perception of threat in ingroup faces, which in turn, might ease ingroup affiliation. In addition, MS lead to decreased N2 amplitudes to angry ingroup faces, which, based on findings that associate the N2 with conflict-eliciting stimuli, might reflect an increased desire for positive interactions with ingroup members. This latter study illustrates how ERPs can inform our understanding of MS-induced defensive reactions related to ingroup and outgroup perception.

Unlike this latter study, the present study focuses on what is happening during or shortly after conscious death ideation. Pyszczynski *et al.* (1999) addressed the differences between immediate and delayed reactions to reminders of mortality and proposed a dual-process model, which assumes two strategies for dealing with death-related concerns. 'Distal' defenses, such as worldview defense and ingroup support are assumed to increase the more death-related thoughts are accessible (as measured, for instance, by word-stem completion tasks), but still unconscious. If the accessibility of these thoughts increases to a level that reaches consciousness, 'proximal' defenses are initiated. Proximal defenses are characterized as threat-focused attempts to remove death-related thoughts from focal attention, 'either by suppressing such thoughts with distractions or by pushing the problem of death into the distant future by biasing rational inferential processes to deny one's vulnerability'. (Pyszczynski *et al.*, 1999, p. 837). Proximal defenses entail resource-demanding suppression, and might work similar to how Wegner's (1994) ironic process theory characterizes mental control processes. Ironic process theory posits that efforts to exert mental control involve an active operation process searching for thoughts that promote the desired mental state (e.g. death-unrelated

Received 17 May 2011; Accepted 9 January 2012
Advance Access publication 20 January 2012

Correspondence should be addressed to Johannes Klackl, Department of Psychology, University of Salzburg, Salzburg, Austria. E-mail: johannes.klackl@sbg.ac.at

thoughts) and an unconscious monitoring process that searches for contents that the individual is intending to suppress (e.g. thoughts of death). Ironically, because these processes aim at both suppressing and identifying the thoughts to be suppressed, recurrence is very likely. Indeed, evidence suggests that mental control can lead to rebound effects (Wegner *et al.*, 1987).

In the present ERP studies, we aimed at finding a candidate neuronal correlate of proximal defenses. To elicit conscious thoughts of death, we visually presented words that were either death-related (e.g. 'grave', 'funeral', 'death') or unpleasant, but death-unrelated (e.g. 'pain', 'accident', 'destroy') while recording ERPs. The main comparison of interest is between death-related and unpleasant words. According to previous work (Greenberg *et al.*, 1994; Arndt *et al.*, 1997; Pyszczynski *et al.*, 1999), proximal defensive strategies imply that death-related stimuli receive some attentional resources that other thoughts do not receive to the same degree. In the following, we argue that this process might be mirrored by the late positive potential (LPP) of the ERP.

Research on the LPP dates back to the 1960s. Researchers had identified a positive component peaking between 300 and 500 ms mainly at parietal sites (termed P300) which was sensitive to attended *vs* non-attended stimuli. A frequently used paradigm was (and still is) the oddball paradigm, in which participants are asked to count how many infrequent target stimuli are presented among frequent standard stimuli (Squires *et al.*, 1977; Johnson, 1984). Target stimuli consistently elicited a larger P300. This was taken to reflect an increased devotion of attention to the infrequent stimuli.

Theorists have argued that similar attentional processes might also be automatically recruited by stimuli which carry an intrinsic motivational significance and therefore automatically attract attentional resources (i.e. emotional pictures). This phenomenon has been termed 'motivated attention' (Lang *et al.*, 1997, 2004). Research has shown that not only emotional pictures, but also faces and words reliably elicit a P300-like parietal positivity (Chapman *et al.*, 1980; Schupp *et al.*, 2004a, 2004b; Dillon *et al.*, 2006; Fischler and Bradley, 2006; Hajcak *et al.*, 2007; Herbert *et al.*, 2008; Kissler *et al.*, 2009; Schacht and Sommer, 2009), which tends to last many hundred milliseconds or even seconds. This positivity has been referred to either as the P300 (Palomba *et al.*, 1997), or the late positive complex (LPC; Kissler *et al.*, 2009), but in the present article, we will refer to it as the late positive potential (LPP, Hajcak *et al.*, 2010). Also, high-arousal emotional stimuli (such as erotica or mutilation images) were found to elicit even greater LPPs compared to moderately arousing emotional stimuli (Cuthbert *et al.*, 2000; Schupp *et al.*, 2000), indicating that the LPP increases with increasing stimulus arousal.

Why are the P300 and the LPP plausible correlate of proximal defenses? If death-related words indeed elicit suppression and distraction, they are also likely to receive a greater amount of attentional resources during processing, compared to equally unpleasant, but death-unrelated words. Based on the notion that both reflect the allocation of attention to motivationally relevant stimuli, death-related words should elicit greater amplitudes. However, there are probably some functional differences between the earlier P300 and the somewhat later LPP. The P300 has been interpreted as a short-lived, phasic increase in attention to task-relevant stimuli (e.g. deviant tones in a classic oddball paradigm). In contrast, the LPP is probably better understood as reflecting a longer lasting, sustained increase in attention and processing of intrinsically motivating stimuli (Hajcak *et al.*, 2010). A recent experiment by König and Mecklinger (2008) supports this notion: emotional words enhanced both the P300 and the LPP, but only LPP amplitude was associated with subsequent memory. Thus, the LPP might be a better reflection of depth-of-processing than the P300. We therefore predict that proximal defenses should be more strongly related to the LPP rather than the P300.

Early ERP components such as the Early Posterior Negativity (EPN; Kissler *et al.*, 2007) at 200–300 ms or the P1/N1 complex (Bernat *et al.*, 2001; Ortigue *et al.*, 2004; Hofmann *et al.*, 2009; Scott *et al.*, 2009) have also been shown to be sensitive to visually presented emotional words, and their functional role might also be understood as early motivated attention toward emotional stimuli. Thus, we will also check whether death-related stimuli affect these components.

STUDY 1

Method

Participants

The sample consisted of 20 participants (13 female) with a mean age (s.d.) of 26.05 years (7.43) without any reported history of neurological disorders or prior head trauma. Eighteen participants were right-handed, two were left-handed. All participants gave written informed consent to participate in the study, which ostensibly investigated emotional word processing.

Stimuli

Ninety-six existing words were selected from the Berlin Affective Word List Reloaded (BAWL-R; Võ *et al.*, 2006). Four word categories were formed based on BAWL-R valence and arousal ratings: pleasant (e.g. 'happy', 'hero', 'party', 'applause', 'weekend'), neutral (e.g. 'line', 'margin', 'simple', 'blackboard', 'round'), unpleasant (e.g. 'pain', 'accident', 'torture', 'destroy') and death-related words (e.g. 'killer', 'funeral', 'grave', 'death'), each comprising 24 stimuli (see Table 1 for category means). Items in the pleasant, neutral and unpleasant categories were not immediately related to death. Altogether, the stimulus pool comprised 5 adjectives, 72 nouns and 19 verbs. The relative amount of these word types did not differ between word categories ($P = 0.29$, Fisher's exact test). Ninety-six non-words were created which matched the existing words in terms of word length and number of syllables. Analyses on the BAWL-R ratings suggested that the word categories differed with respect to Arousal, $F(3,92) = 220.48$; $P < 0.001$. Looking closely, neutral words were less arousing than

Table 1 Summary of emotional and lexical properties of the word categories used in Experiment 1

	Word category			
	Pleasant *M* (s.d.)	Neutral *M* (s.d.)	Unpleasant *M* (s.d.)	Death-related *M* (s.d.)
Valence[a]				
BAWL-R	2.19 (0.29)	0.05 (0.15)	−2.31 (0.22)	−2.35 (0.32)
Pretest	6.51 (0.33)	4.23 (0.38)	1.44 (0.29)	1.43 (0.44)
Arousal[b]				
BAWL-R	3.76 (0.32)	1.79 (0.12)	4.02 (0.39)	3.94 (0.47)
Pretest	5.99 (0.35)	3.47 (0.41)	5.11 (0.68)	5.13 (0.65)
Imageability	4.69 (0.89)	5.11 (0.95)	4.88 (0.68)	5.18 (0.81)
Death-relatedness	1.80 (0.52)	3.70 (0.47)	5.51 (0.79)	6.62 (0.58)
N letters	6.00 (1.74)	6.25 (1.29)	6.46 (1.14)	6.08 (1.72)
N phonemes	5.33 (1.52)	5.29 (1.04)	5.92 (1.32)	5.63 (1.58)
N syllables	2.00 (0.72)	2.04 (0.46)	2.13 (0.54)	2.04 (0.69)
Word frequency	31.89 (35.09)	21.07 (33.90)	27.16 (27.24)	25.96 (45.04)
N neighbors	1.79 (2.47)	2.33 (1.99)	1.04 (1.27)	2.08 (2.45)
Type bigram frequency	4206.92 (2349)	4594.81 (1830)	4076.16 (2160)	4731.67 (2990)

[a]The BAWL-R Valence scale ranges from −3 to 3, whereas the Pretest Valence scale ranges from 1 to 7.
[b]The BAWL-R Arousal scale ranges from 1 to 5, whereas the Pretest Arousal scale ranges from 1 to 7.

pleasant ($P < 0.001$), unpleasant ($P < 0.001$) and death-related words ($P < 0.001$). In addition, pleasant words were rated as less arousing compared to unpleasant ($P = 0.01$) and marginally less arousing compared to death-related words ($P = 0.071$). Death-related and unpleasant words did not differ ($P = 0.435$). Word categories also differed with respect to Valence, $F(3,92) = 1733.34$; $P < 0.001$. Pleasant words were rated as more positive than neutral, unpleasant and death-related words (all Ps < 0.001). Furthermore, death-related and unpleasant words were rated as less positive than neutral words (both Ps < 0.001), whereas they did not differ between each other ($P = 0.562$).

In order to test whether the selection of words from the BAWL-R based on valence and arousal ratings was sensible and to see whether death-related words were indeed rated as more descriptive of death than unpleasant words, we asked 22 (19 female; 22.14 ± 2.64 years) participants to rate the experimental stimuli using a paper-and-pencil test. In this pretest, all stimulus words were presented line-by-line in a questionnaire. The participants' task was to rate each item with respect to arousal, valence and death-relatedness using predefined 7-step Likert scales printed below each item. These values were subjected to ANOVAs with word category as single factor. Ratings of valence and arousal conformed with the BAWL-R: Word categories differed with respect to arousal; $F(3,92) = 90.50$, $P < 0.001$. Neutral items were rated as less arousing than pleasant, unpleasant and death-related words (all P's < 0.001), whereas unpleasant and death-related words did not differ ($P = 0.91$). However, in the pretest, pleasant words received higher arousal ratings than both unpleasant and death-related words (both P's < 0.001; see Table 1 for means). We did not find such a pattern in the BAWL-R ratings. Word categories also differed with respect to valence; $F(3,92) = 1101.62$, $P < 0.001$. Pleasant words were rated as more positive than neutral words ($P < 0.001$). Neutral words were rated as more positive than unpleasant and death-related words (both P's < 0.001). Death-related words were not rated differently from unpleasant words ($P = 0.93$; see Table 1 for means). Word categories also differed with respect to death-relatedness; $F(3,92) = 295.15$, $P < 0.001$ (see Table 1 for means). Importantly, death-related items were rated as more death-related than unpleasant items, which, in turn were more death-related than neutral items. Interestingly, neutral items were also rated as more death-related than pleasant items (all Ps < 0.001). Means and s.d.'s are given in Table 1.

In short, the pretest validated the BAWL-R valence and arousal ratings, except that in the pretest, pleasant words were rated as more arousing compared to death-related and unpleasant words. This divergence, however, does not affect the central hypothesis of the article, which focuses on the difference between death-related and negative words. Importantly, participants rated death-related words as more descriptive of death relative to unpleasant items, which was hitherto only assumed by the authors.

Because ERPs were shown to be sensitive to word length and lexical frequency (Assadollahi and Pulvermüller, 2003; Hauk and Pulvermüller, 2004; Hauk *et al.*, 2006), imageability (Swaab *et al.*, 2002) and orthographic neighborhood density (Taler and Phillips, 2007), we selected the stimulus words in a way which ensured that the word categories did not differ with respect to number of letters [$F(3,92) < 1$], number of phonemes [$F(3,92) = 1.06$, $P = 0.37$], number of neighbors [$F(3,92) = 1.70$; $P = 0.17$] word frequency [$F(3,92) < 1$], type bigram frequency [$F(3,92) < 1$] or word imageability [$F(3,92) = 1.69$, $P = 0.18$]. Table 1 shows means and s.d.'s for these measures.

Experimental task

Stimuli were presented in yellow 20 pt Times New Roman Font surrounded by a gray box, which remained on the screen throughout the experiment. We used a 17-inch CRT Monitor at 800×600 pixels resolution and 75 Hz refresh rate. Viewing distance was held constant at 1 m. Word presentation duration was 300 ms, preceded by a fixation period of either 700, 800, 900 or 1000 ms. Participants had to decide, for every word that appeared on the screen, whether it was an existing word or a pseudoword by pressing the left or right mouse button using their right index and middle finger as quickly as possible. Upon stimulus offset, a fixation cross appeared for 900 ms. In the subsequent intertrial period of 1200 ms, only the gray box remained on the screen. Two pseudorandomized stimulus orders were presented in a counterbalanced fashion. Each stimulus was presented twice in two successive sessions. In total, 192 pseudowords and 192 words (48 exemplars of each word category) were shown.

Procedure

Upon their arrival in the lab, participants were explained the experimental procedure and told that the study aim was to investigate emotional word processing in the brain. The experiment took place in a dimly lit, sound-attenuated room. Participants sat in a comfortable chair with armrests. Every 64 stimuli, stimulus presentation paused automatically and participants were offered to take a break to prevent them from getting drowsy. The experimenter continued the stimulus presentation as soon as participants indicated that they were ready to carry on with the task. At the end of the experiment, participants were thoroughly debriefed and explained the true purpose of the study. Furthermore, they were rewarded with research credits.

Electrophysiological recording and analysis

We used a BrainProducts BrainAmp MR amplifier at 250 Hz sampling rate. We mounted 32 AgCl electrodes according to the 10–20 system using an EasyCap electrode cap with an online reference on FCz. AFz served as ground. Scalp electrode positions were Fp1, Fp2, F3, F4, C3, C4, P3, P4, O1, O2, F7, F8, T7, T8, P7, P8, Fz, Cz, Pz, FC1, FC2, CP1, CP2, FC5, FC6, CP5 and CP6. In addition, we recorded signals from bilateral earlobe electrodes. Horizontal electrooculogram (EOG) was recorded using two electrodes placed next to the lateral canthi of both eyes. Vertical EOG was recorded using one electrode below the right eye. First, the data were re-referenced off-line to a computed average signal of left and right earlobe electrodes. Then, data epochs were filtered with an IIR filter (high-pass cutoff: 0.1 Hz, Slope: 12db/Oct; low-pass cutoff: 30 Hz, Slope: 12db/Oct). After that, epochs of 1200 ms were extracted from the continuous data. Independent Component Analysis (ICA) was used to correct eye movements. After eye movement correction, epochs were rejected if they exceeded 100 or $-100\ \mu V$ or contained signal differences of more than $100\ \mu V$ or both. Grand average ERPs were computed for each word condition separately. Participants contributed to these grand average ERPs with a mean (s.d.) numbers of 46.85 (1.90) pleasant epochs, 46.70 (1.90) neutral, 47.45 (1.36) unpleasant and 47.05 (1.15) death-related word epochs.

ERPs to pseudowords are irrelevant for the current study question and were therefore not analyzed. Visual inspection of grand average ERPs revealed P1 and N1 components, predominantly at occipital sites (Figure 1A, B). A P300 with a maximum at occipital and parietal sites emerged (Figure 1C) and was followed by a LPP which lasted until ~1 s after stimulus onset and had a more anterior scalp distribution with a maximum at parietal and centroparietal sites (Figure 1D).

For statistical analysis, we formed three electrode pools. The P1 and N1 were analyzed at electrodes O1, O2, P7 and P8. The P300 was analyzed at electrodes P3, Pz and P4. For the LPP, we used P3, Pz, P4, CP1, CPz, CP2, CP5 and CP6. The time windows of interest were set as follows: 80–140 ms for the P1, 140–200 ms for the N1, 250–400 ms for the P300, 400–800 ms for the LPP. An early posterior

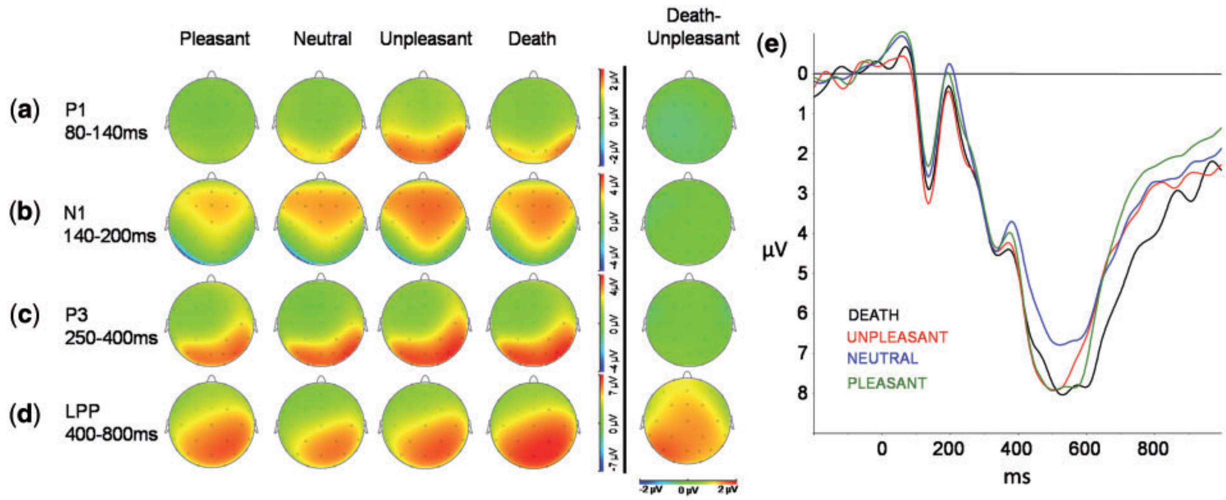

Fig. 1 Summary of the ERP results of Study 1. (**A**) The P1 was maximal at occipital recording sites. No effects of word category were present. (**B**) The N1 was also maximal at occipital sites. No effects of word category were present. (**C**) The P300 had a parieto-occipital maximum and exhibited no reliable word category effects. (**D**) The LPP was maximal at parietal sites and sensitive to word category. It was larger for death-related, unpleasant and pleasant words compared to neutral words. Also, it was more sensitive to death-related over both unpleasant and pleasant words. (**E**) Grand average ERPs at Pz illustrate the LPP effects. Note the stimulus offset effect at 300 ms, which coincides with the P300. The data were low-pass filtered (10 Hz, 24 db/Oct) for display purposes.

negativity (EPN; Schupp *et al*., 2003, 2004a, b) was not apparent in the grand average ERPs. This might have been due to poor electrode coverage of the occipital and occipitotemporal head regions. Mean amplitudes in the respective time windows were subjected to repeated measures ANOVAs with word category as the single factor.

Results

Behavioral results

In general, accuracy was high. On average, participants responded correctly in >96% of trials (see Table 2 for means). Accuracy differed marginally between stimulus categories, $F(3,57) = 2.47$, $P = 0.071$. It was lower for death-related words compared to neutral ($P = 0.017$) and pleasant words ($P = 0.046$). Death-related and unpleasant words, however, did not differ ($P = 0.186$). No other comparisons were significant or marginally significant.

Reaction times (Table 2) differed between stimulus categories, $F(3,57) = 3.83$, $P = 0.014$). Pleasant words received the fastest judgments. Reaction times to pleasant words were marginally shorter compared to neutral ($P = 0.096$), and significantly shorter compared to unpleasant ($P = 0.003$) and death-related words ($P = 0.002$). No other comparisons were significant or marginally significant.

ERP results

The P1 (Figure 1A) exhibited no reliable main effect of word category, $F(3,57) = 1.22$, $P = 0.311$. In the N1(140–200 ms; Figure 1B), no main effect of word category ($F(3,57) = 0.37$, $P = 0.775$) emerged. Also, the P300 (250–400 ms; Figure 1C, E) exhibited no effect of word category; $F(3,57) = 0.85$, $P = 0.474$.

In the LPP (400–800 ms; Figure 1D, E), amplitudes differed as a function of word category, $F(3,57) = 5.88$, $P = 0.001$. Pairwise comparisons indicated that pleasant, unpleasant and death-related words led to higher amplitudes relative to neutral words ($P = 0.040$, $P = 0.049$ and $P < 0.001$, respectively), indicating an effect of arousal in the LPP (Figure 1D, E). In addition, death-related words elicited greater amplitudes compared to neutral ($P < 0.001$), pleasant ($P = 0.049$) and unpleasant words ($P = 0.034$).

Table 2 Mean accuracy and reaction times for each word category

Word category	Percent correct (%) *M* (s.d.)	Reaction time (ms) *M* (s.d.)
Pleasant	97.80 (3.30)	595.99 (61.87)
Neutral	98.2 (2.75)	612.01 (67.80)
Unpleasant	97.2 (3.92)	620.32 (61.61)
Death	96 (3.89)	618.51 (70.80)

STUDY 2

The results of the Study 1 confirmed our prediction that the LPP is enhanced for death-related over unpleasant words. Apart from the LPP, none of the investigated ERP components (P1, N1, P300) were sensitive to word category. The task used in Study 1 (lexical decision) suffered from the problem that it required manual responses whose average latency coincided with the LPP. The manual responses might have influenced the ERP to a great extent by contaminating it with motor-related potentials. Another problem of Study 1 was that the words remained on the screen only for 300 ms, giving rise to stimulus offset effects in the ERP. In Study 2, we wanted to replicate the finding using a task in which ERPs were not affected by manual responses and stimulus offset effects. We also increased the number of stimuli in order to improve the quality of the ERPs. Thus, in Study 2, we used a target word detection task, in which participants were asked to press a response button whenever a word describing an animal was presented on the screen. The stimuli of interest (pleasant, neutral, unpleasant and death-related words) were randomly interspersed with these target words. We expected to replicate the key finding of Study 1, that is, a specific enhancement of the LPP for death-related words.

Method

Participants

The sample consisted of 28 healthy participants (18 female) with a mean age (s.d.) of 24.46 years (7.91). None reported neurological disorders or prior head trauma. All participants gave written informed consent to participate in the study, which ostensibly investigated emotional word processing.

Table 3 Summary of emotional and lexical properties of the word categories used in Experiment 2

	Word category			
	Pleasant ($n = 36$) M (s.d.)	Neutral ($n = 34$) M (s.d.)	Unpleasant ($n = 36$) M (s.d.)	Death-related ($n = 34$) M (s.d.)
Arousal	3.05 (0.38)	1.62 (0.03)	3.17 (0.35)	3.17 (0.44)
Valence	6.01 (0.38)	4.17 (0.37)	1.99 (0.37)	2.20 (0.67)
Imageability	5.75 (0.54)	5.75 (0.88)	5.19 (0.56)	5.23 (0.69)
Death-relatedness	1.13 (0.19)	1.23 (0.24)	2.57 (0.67)	4.49 (0.30)
N letters	6.85 (1.79)	7.58 (1.23)	7.32 (1.43)	7.08 (2.18)
N phonemes	6.06 (1.59)	6.58 (1.38)	6.59 (1.46)	6.64 (2.09)
N syllables	6.06 (1.59)	6.58 (1.38)	6.59 (1.46)	6.64 (2.09)
N neighbors	1.18 (2.07)	1.06 (1.72)	0.79 (1.70)	1.56 (2.22)
Word frequency[a]	32.25 (32.81)	27.00 (28.30)	29.28 (25.35)	21.89 (38.76)
Type bigram frequency	4129.91 (2195.17)	4500.35 (1841.27)	4531.50 (1822.99)	4887.17 (2686.32)

[a]We were unable to determine word frequency of two death-related words ('mortician' and 'crypt') because they were not present in the CELEX database. Thus, we had to exclude them during the calculation of mean word frequency.

Stimuli

By adding stimuli to the stimulus pool of Study 1, we arrived at 36 death-related, 32 negative, 36 neutral and 34 positive words. Most of the newly added stimuli were not part of the BAWL-R. Therefore, in order to check for between-category differences in relevant word characteristics, we conducted a pretest using an online survey tool (www.unipark.info). Seventeen participants [13 female; mean age (s.d.) 24.41 (4.77)] rated each stimulus with regard to arousal, valence, death-relatedness and imageability. Items were displayed one at a time in the browser window, subtended by a 7-point valence scale ranging from -3 to $+3$, a 7-point imageability scale ranging from 1 to 7, and arousal and death-relatedness scales ranging from 1 to 5.

Mean ratings for each stimulus word for each measure were calculated and subjected to separate univariate ANOVAs with word category as a single factor. There was a main effect of word category for arousal, $F(3,136) = 146.75$, $P < 0.001$. Arousal was greater for death-related, unpleasant and pleasant, compared to neutral words (all P's < 0.001). Means are given in Table 3. Valence also differed between categories, $F(3,136) = 564.61$, $P < 0.001$. Positive words were rated as more positive than neutral, unpleasant and death-related words (P's < 0.001). Neutral words were rated as more positive than both unpleasant and death-related words (P's < 0.001). Unpleasant words were marginally more negatively valenced than death-related words ($P = 0.067$). See Table 3 for means. Word categories differed with respect to imageability, $F(3,136) = 7.19$; $P < 0.001$. This effect was due to higher ratings of imageability for pleasant and neutral words than for the death-related and unpleasant word categories (all P's < 0.002). Pleasant and neutral words, however, did not differ from each other ($P = 0.995$). Neither did death-related and negative words ($P = 0.804$).

The word categories differed greatly with regard to death-relatedness, $F(3,136) = 555.48$, $P < 0.001$. Pleasant and neutral words were rated least death-related, but did not differ ($P = 0.274$). Unpleasant words were rated as more death-related compared to neutral ($P < 0.001$) and pleasant words ($P < 0.001$). Death-related words were rated as more death-related than unpleasant words ($P < 0.001$). Importantly, death-related words were rated as about twice as death-related compared to negative words (4.49 *vs* 2.57).

To summarize, the word categories met our basic requirements regarding differential levels of valence, arousal and death-relatedness. All emotional stimulus categories exhibited higher arousal than neutral words and did not differ from each other. Both unpleasant and death-related words were more negatively valenced compared to neutral and pleasant words, although the unpleasant words tended to be more negative than death-related words.

Finally, to check for differences in lexical parameters, we extracted data from the CELEX lexical database (Baayen *et al.*, 1993). The word categories did not differ with respect to number of letters, $F(3,136) = 1.20$, $P = 0.314$, number of phonemes, $F(3,136) = 0.94$, $P = 0.425$, number of syllables, $F(3,136) = 0.11$, $P = 0.952$, number of neighbors, $F(3,136) = 0.93$, $P = 0.426$, word frequency, $F(3,134) = 0.65$, $P = 0.585$, or type bigram frequency, $F(3,136) = 0.71$, $P = 0.547$ (see Table 3 for means).

Experimental task

For Study 2, we used the same presentation hardware as in Study 1. Word presentation duration was raised to 1000 ms. The experimental task was to press the left button whenever the presented word described an animal. As in Study 1, each stimulus was presented twice in two successive sequences. Both stimulus sequences were completely randomized for each participant. In sum, each participant read 72 death-related, 64 unpleasant, 72 neutral and 68 pleasant words. In addition, 10 target words which all described animals were shown during each experimental session. This resulted in a total number of 296 experimental trials. Trials in which participants erroneously responded to non-target words were excluded from the analysis.

Procedure

The procedure closely resembled that of Study 1, except that no pauses were included during recording. Also, participants received 15 € in addition to research credits as a reward for participation. Grand average ERPs were computed for each word condition separately. ERPs to animal target items are not relevant for the current study question and were therefore not analyzed.

Electrophysiological recording and analysis

Both the recording hardware and the analysis strategy were identical to those used in Study 1. Due to technical problems, marker information of three participants in the second experimental session was lost. For these participants, only data from the first session were entered into the analysis. After trials containing artifacts and false alarms were rejected, we arrived at a mean number (s.d.) of 56.21 pleasant word epochs (12.69), 56.11 neutral word epochs (13.70), 56.39 unpleasant word epochs (13.56) and 59.75 death-related word epochs (14.65) per participant. The large standard deviations are mostly due to the three participants from whom second-session data were not available.[1] Visual inspection of grand average ERPs revealed reliable P1, N1, P300 and LPP, see Figure 2E. As in Study 1, no early posterior negativity (EPN) was apparent in the data. The P1 and N1 were most prominent at occipital leads. P300 and LPP were especially pronounced at parietal leads. Compared to the P300, the LPP had a broader scalp distribution, extending more toward central sites. As in Study 1, electrodes were collapsed into three distinct electrode pools and analyzed using a repeated measures ANOVA with the factor word category. The same electrode pools and time windows as in Study 1 were used.

[1]When excluding the three participants from which only partial data were available, the main effect of word category on the amplitude of the LPP remained significant, $F(3,72) = 4.28$, $P = 0.008$. Also, the death-related > unpleasant effect remained significant, $P = 0.037$. Thus, the inclusion of these potentially less reliable data did not affect the significance of the key effects.

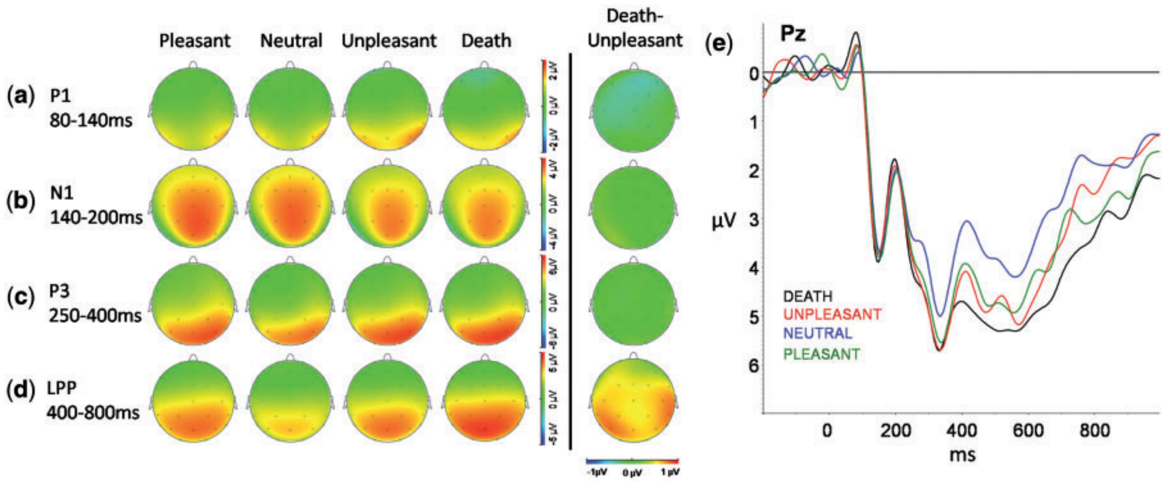

Fig. 2 Summary of the ERP results of Study 2. (**A**) The P1 was maximal at occipital sites. (**B**) The N1 also exhibited bilateral occipital maxima, but was not differentially sensitive to the word categories. (**C**) A clear parietooccipital P300 emerged, but was not influenced by word category. (**D**) The distribution of the LPP was somewhat more anterior compared to the P300. The LPP was sensitive to arousal in general: death-related, unpleasant and pleasant words elicited greater amplitudes. As in Experiment 1, it was also more sensitive to death-related over both neutral and unpleasant words. Unlike in Experiment 1, death-related and pleasant words did not differ. (**E**) Grand average ERPs at Pz. The data were low-pass filtered (10 Hz, 24 db/Oct) for display purposes.

Results

No main effect of word category was present in the P1 [$F(3,81) = 0.17$, $P = 0.917$], the N1 ($F(3,81) = 0.33$, $P = 0.329$) or the P300 [$F(3,81) = 1.78$, $P = 0.157$].

As in Study 1, the LPP showed a main effect of word category, $F(3,81) = 4.22$, $P = 0.008$. The LPP responded more to death-related over neutral ($P = 0.002$), unpleasant over neutral ($P = 0.035$) and pleasant over neutral words ($P = 0.042$). Pleasant words did not differ from death-related or unpleasant words ($P = 0.341$ and $P = 0.546$, respectively). Death-related words led to higher amplitudes compared to unpleasant ($P = 0.047$) and neutral words ($P = 0.002$). To summarize, the LPP was again more sensitive to death-related over unpleasant words, but also showed a similar degree of sensitivity to pleasant words, an effect that was absent in Experiment 1.

GENERAL DISCUSSION

Decades of research on Terror management theory have shown that priming people with thoughts of mortality reliably leads to an upvaluation of cultural values and ingroups (for a recent meta-analysis, see Burke *et al.*, 2010). These effects, however, arise only when thoughts of death are at the fringes of consciousness, but not when they are in current focal attention. When in focal attention, so-called proximal defenses are engaged which aim at removing these thoughts from consciousness through suppression or distraction (Arndt *et al.*, 1997; Pyszczynski *et al.*, 1999). In the present investigation, we aimed at identifying neurophysiological correlates of proximal defenses. We have presented two experiments in which participants were confronted with death-related thoughts in the form of written words. Based on findings that link the LPP of the ERP to attention allocation to motivationally relevant stimuli, we predicted an increased LPP for death-related compared to unpleasant death-unrelated words. In both experiments, this prediction was confirmed.

Visual inspection of grand average ERPs reveal that in Experiment 1, the LPP elicted by death-related words was more prolonged compared to pleasant, neutral and unpleasant words (Figure 1). This might indicate that during Experiment 1, death-related words captured participants' attention for a sustained period of time compared to the other word types. In Experiment 2, however, differences between death-related and unpleasant words were found across the entire LPP time window. One possible reason for this divergence is that in contrast to the less demanding target detection task of Experiment 2, the lexical decision task used in Experiment 1 (which demanded a response on each trial) might have led to a limited availability of cognitive resources to engage in proximal defenses. Consistent with this idea, differences in Experiment 1 started to emerge at the mean response latency (~600 ms). At this time, lexical decisions were completed and resources for suppression efforts might have subsequently become available again. An interesting effect emerged in Study 2: although death-related words elicited a larger LPP compared to unpleasant words, LPPs to death-related and pleasant words did not differ reliably. One possible explanation for this rests on work by DeWall and Baumeister (2007), who found that reminders of death lead to automatic and unconscious tuning to positive affective information. In fact, focusing on pleasant thoughts has been identified as a defensive strategy to cope with the exposure to unpleasant affective material (Boden and Baumeister, 1997). Thus, in Experiment 2, participants might have taken advantage of the availability of pleasant stimulus words in the experimental material and used them to distract themselves from the thoughts of mortality elicited by the death-related stimulus words. Consistent with this idea, dual-process theory proposes distraction (i.e. pursuing positive thoughts as a means of avoiding death-related thoughts) as one form of proximal defenses (Pyszczynski *et al.*, 1999).

An alternative explanation of the death-related > unpleasant word effect in the LPP in terms of stimulus emotionality is unlikely because these two word categories were not different with respect to valence or arousal. This is important because the amplitude of the LPP is tightly linked to stimulus arousal (Cuthbert *et al.*, 2000; Schupp *et al.*, 2000).

Although the present study is the first ERP study to explicitly investigate proximal defenses, we are aware of two functional magnetic resonance imaging (fMRI) studies that systematically contrasted death-related and unpleasant stimuli, but did not explicitly link their results to proximal defenses. First, a study by Han *et al.* (2010) found that death-related words elicited less activity in the insula and anterior cingulate cortex compared to unpleasant words. A negative correlation between the subjectively rated death-relatedness of the stimulus words and insula activation suggested that insula activity decreased the more death-related the words were rated. Furthermore, insula activity correlated negatively with the judged negative emotionality of death-related words. The authors interpreted their finding in terms of a decreased activation of the sentient self during death-related word processing. Another study (Quirin *et al.*, 2012) found the right amygdala, the anterior cingulate cortex (ACC) and caudate nucleus to be more active when participants answered questions about death *vs* when they answered questions about dental pain. Their interpretation was that the amygdala and rostral ACC effects reflect unconscious markers of threat that were aroused in the MS condition. These two fMRI studies revealed inconsistent findings. First, Han and colleagues found decreased ACC activity for death-related stimuli, whereas Quirin and colleagues reported an increase. Second, Quirin and colleagues found some activations in subcortical regions, whereas Han and colleagues reported insula deactivation for death-related words.

How can these inconsistencies be explained? First, between-culture differences in how people deal with death must be considered as a relevant factor. Second, Quirin and co-workers only investigated male participants, whereas the Han study only investigated female participants. Third, Quirin and colleagues used sentences from a death anxiety questionnaire, which might have led to a different, and perhaps deeper contemplation of death than the single-word stimuli used in both the present study and by Han and co-workers. Fourth, Quirin and colleagues did not check whether their death-related and negative conditions were different with respect to valence or arousal, whereas in the Han and colleagues study, death-related words were more arousing than unpleasant non-death words. We recommend that future neuroimaging studies on this topic should address these potential sources of variation in neuronal reactions toward death reminders.

One interesting possibility (which corresponds to the interpretation of Quirin *et al.*, 2011) is that the observed heightened LPP for death-related words in the present study reflects subtle unconscious emotion. Indeed, there is evidence that the subliminal presentation of the word 'death' *vs* 'pain' elicits increased corrugator activity (a facial muscle involved in sad facial expressions), but no changes in self-reported affect (Arndt *et al.*, 2001), indicating that unconscious emotional processes might be involved at least during subliminal death priming. Also, recent evidence suggests that emotion can be elicited in the absence of awareness, remain inaccessible to introspection and nevertheless influence behavior (Winkielman and Berridge, 2004). For instance, subliminally presented happy, neutral and angry faces did not influence conscious affect, but influenced the evaluation and consumption of a drink (Winkielman *et al.*, 2005). However, this possibility is highly speculative because evidence to date suggests that the LPP requires conscious recognition. We are aware of one study that compared overt and covert processing of fearful and neutral faces and found that responses ~300–450 ms were sensitive to overt, but not covert fearful faces (Williams *et al.*, 2007), speaking against the notion that the LPP might be sensitive to unconscious emotion. Thus, an interpretation of the present results in terms of unconscious emotion must remain highly speculative.

Across both the studies presented in this article, other ERP components (P1, N1, P300) were insensitive to word category. It has to be noted that P1 effects of emotion in words are rare and studies that found these effects have provided inconsistent results. Both Hofmann and colleagues (2009) and Scott and colleagues (2009) reported P1 decreases for pleasant and unpleasant relative to neutral words. In contrast, Bernat *et al.* (2001) reported a P1 increase rather than a decrease for unpleasant relative to pleasant words. Thus, it is not clear what to expect from this early time window. Enhanced N1 responses toward pain-related words have been found in chronic and prechronic pain patients (Flor *et al.*, 1997; Knost *et al.*, 1997). The authors of these studies interpreted the effect in terms of these patients' more elaborate pain memories, which facilitate recognition of pain-related cues at an early stage of processing. Applying the same reasoning to the present data, one could argue that the inevitability of death is a universal human problem and that reminding humans of death is somewhat similar to reminding chronic pain patients of their disease. This does not seem to be the case. The present results do not indicate that death-related words affect early components such as the P1 or N1. It was somewhat surprising that the P300 was not differentially sensitive to the word categories under investigation, because previous studies using emotional adjectives found such effects (Naumann *et al.*, 1992; Herbert *et al.*, 2006) However, we are aware of one study that reported an explicit absence of a P300 effect for emotional words (Scott *et al.*, 2009), suggesting that emotional modulation of the P300 does not always occur.

How does this research contribute to understanding terror management processes? First, the data suggest that sustained motivated attention toward death-related information might be considered as the starting point in the psychodynamics of terror management. This brings us another step closer to understanding how exactly proximal defenses can be understood in neuronal terms. Second, existing research on proximal defenses was able to only indirectly infer that participants have used suppression and distraction after Mortality Salience, for instance, by blocking necessary cognitive capacities or measuring worldview defense immediately after MS, thereby preventing participants from engaging in proximal defenses (Pyszczynski *et al.*, 1999). The LPP might prove to be a more direct measure of these defenses. Also, our results have some important implications for emotion research that on the LPP: because death-related words enhanced the LPP despite any differences in valence or arousal, death-relatedness seems to be an additional, independent contributor to the LPP. Research on the LPP clearly benefits from knowing about the effects of death reminders. For instance, the inclusion of death-related stimuli in a negative stimulus pool might boost the LPP in a way that is unwanted by investigators.

It would be premature to conclude that the enhanced LPP 'directly' reflects proximal defenses. For instance, devoting more attention to death-related stimuli might also promote the use of proximal defenses at some time point after an initial encounter with a reminder of death. The current experimental designs only allowed us to look at the first second after stimulus onset, whereas proximal defenses are usually assumed to happen within the time course of many seconds or minutes after subtle death reminders. Thus, a comprehensive investigation of proximal defenses must also take these later time stages into account. In Experiment 2, we found evidence for one particularly interesting form of proximal defenses which did not happen in the very moment of confrontation with reminders of death: LPPs to pleasant and death-related words did not differ. Hence, participants might have distracted themselves by attending more to pleasant stimulus words.

Future studies should check whether the increased LPP to death-related and/or pleasant stimuli indeed reflect proximal defenses, for instance, by limiting processing capacity through cognitive load. This should hamper the use of proximal strategies and to a reduction of the LPP to death-related words. Furthermore, it would be interesting to study the role of self-esteem on the LPP to death-related words. This is because dispositionally high or experimentally increased self-esteem was found to reduce self-reported anxiety, physiological arousal and the use of proximal defenses (measured as the tendency to deny one's vulnerability to an early death when exposed to strong reminders of mortality, Greenberg, *et al.*, 1992). Thus, low self-esteem might relate to an increased use of proximal defenses. Furthermore, it would be informative to correlate the individual amplitude of the LPP to the degree of death-thought accessibility and the use of distal defenses after mortality priming. The idea is if large LPPs to death-related stimuli indeed reflect successful death-thought suppression, LPP amplitude to death-related words should be positively related to distal defenses and death-thought accessibility because these are greatest when thoughts of death were successfully suppressed from focal consciousness. A similar argument can be made when measuring the LPP elicited by pleasant stimuli as a measure of distraction after conscious reminders of mortality. Thus, the present ERP findings generate some exciting research questions that can be addressed in future studies.

Conflict of Interest

None declared.

REFERENCES

Arndt, J., Allen, J., Greenberg, J. (2001). Traces of terror: subliminal death primes and facial electromyograoguc indices of affect. *Motivation and Emotion*, *25*(3), 253–77.

Arndt, J., Greenberg, J., Solomon, S., Pyszczynski, T., Simon, L. (1997). Suppression, accessibility of death-related thoughts, and cultural worldview defense: exploring the psychodynamics of terror management. *Journal of Personality and Social Psychology*, *73*(1), 5–18.

Assadollahi, R., Pulvermüller, F. (2003). Early influences of word length and frequency: a group study using MEG. *Neuroreport*, *14*(8), 1183–7.

Baayen, R.H., Piepenbrock, R., Rijn, (1993). *The CELEX lexical data base on CD-ROM*. Linguistic Data Consortium.

Becker, E. (1973). *The Denial of Death*. New York: Free Press.

Bernat, E., Bunce, S., Shevrin, H. (2001). Event-related brain potentials differentiate positive and negative mood adjectives during both supraliminal and subliminal visual processing. *International Journal of Psychophysiology*, *42*(1), 11–34.

Boden, J.M., Baumeister, R.F. (1997). Repressive coping: distraction using pleasant thoughts and memories. *Journal of Personality and Social Psychology*, *73*(1), 45–62.

Burke, B.L., Martens, A., Faucher, E.H. (2010). Two decades of terror management theory: a meta-analysis of mortality salience research. *Personality and Social Psychology Review*, *14*(2), 155–95.

Chapman, R.M., McCrary, J.W., Chapman, J.A., Martin, J.K. (1980). Behavioral and neural analyses of connotative meaning: word classes and rating scales. *Brain and Language*, *11*(2), 319–39.

Cuthbert, B.N., Schupp, H.T., Bradley, M.M., Birbaumer, N., Lang, P.J. (2000). Brain potentials in affective picture processing: covariation with autonomic arousal and affective report. *Biological Psychology*, *52*(2), 95–111.

DeWall, C.N., Baumeister, R.F. (2007). From terror to joy: automatic tuning to positive affective information following mortality salience. *Psychological Science*, *18*(11), 984–90.

Dillon, D.G., Cooper, J.J., Grent-'t-Jong, T., Woldorff, M.G., LaBar, K.S. (2006). Dissociation of event-related potentials indexing arousal and semantic cohesion during emotional word encoding. *Brain and Cognition*, *62*(1), 43–57.

Fischler, I., Bradley, M. (2006). Event-related potential studies of language and emotion: words, phrases, and task effects. *Progress in Brain Research*, *156*, 185–203.

Flor, H., Knost, B., Birbaumer, N. (1997). Processing of pain- and body-related verbal material in chronic pain patients: central and peripheral correlates. *Pain*, *73*(3), 413–21.

Greenberg, J., Pyszczynski, T., Burling, J., et al. (1992). Why do people need self-esteem - converging evidence that self-esteem serves an anxiety-buffering function. *Journal of Personality and Social Psychology*, *63*(6), 913–22.

Greenberg, J., Pyszczynski, T., Solomon, S., Simon, L., Breus, M. (1994). Role of consciousness and accessibility of death-related thoughts in mortality salience effects. *Journal of Personality and Social Psychology*, *67*(4), 627–37.

Greenberg, J., Solomon, S., Pyszczynski, T. (1997). Terror management theory of self-esteem and social behavior: empirical assessments and conceptual refinements. In: Zanna, M.P., editor. *Advances in Experimental Social Psychology*, Vol. 29, New York: Academic Press, pp. 61–139.

Hajcak, G., Dunning, J.P., Foti, D. (2007). Neural response to emotional pictures is unaffected by concurrent task difficulty: an event-related potential study. *Behavioral Neuroscience*, *121*(6), 1156–62.

Hajcak, G., MacNamara, A., Olvet, D.M. (2010). Event-related potentials, emotion, and emotion regulation: an integrative review. *Developmental Neuropsychology*, *35*(2), 129–55.

Han, S., Qin, J., Ma, Y. (2010). Neurocognitive processes of linguistic cues related to death. *Neuropsychologia*, *48*(12), 3436–42.

Hauk, O., Davis, M.H., Ford, M., Pulvermüller, F., Marslen-Wilson, W.D. (2006). The time course of visual word recognition as revealed by linear regression analysis of ERP data. *NeuroImage*, *30*(4), 1383–400.

Hauk, O., Pulvermüller, F. (2004). Effects of word length and frequency on the human event-related potential. *Clinical Neurophysiology*, *115*(5), 1090–103.

Henry, E.A., Bartholow, B.D., Arndt, J. (2010). Death on the brain: effects of mortality salience on the neural correlates of ingroup and outgroup categorization. *Social Cognitive and Affective Neuroscience*, *5*(1), 77–87.

Herbert, C., Junghöfer, M., Kissler, J. (2008). Event related potentials to emotional adjectives during reading. *Psychophysiology*, *45*(3), 487–98.

Herbert, C., Kissler, J., Junghöfer, M., Peyk, P., Rockstroh, B. (2006). Processing of emotional adjectives: evidence from startle EMG and ERPs. *Psychophysiology*, *43*(2), 197–206.

Hofmann, M.J., Kuchinke, L., Tamm, S., Vo, 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*(4), 389–97.

Johnson, R. (1984). P300 - a model of the variables controlling its amplitude. *Annals of the New York Academy of Sciences*, *425*(Jun), 223–9.

Kissler, J., Herbert, C., Peyk, P., Junghofer, M. (2007). Buzzwords. Early cortical responses to emotional words during reading. *Psychological Science*, *18*(6), 475–80.

Kissler, J., Herbert, C., Winkler, I., Junghofer, M. (2009). Emotion and attention in visual word processing: An ERP study. *Biological Psychology*, *80*(1), 75–83.

Knost, B., Flor, H., Braun, C., Birbaumer, N. (1997). Cerebral processing of words and the development of chronic pain. *Psychophysiology*, *34*(4), 474–81.

König, S., Mecklinger, A. (2008). Electrophysiological correlates of encoding and retrieving emotional events. *Emotion*, *8*(2), 162–73.

Lang, A., Sparks, J.V., Bradley, S.D., Lee, S.K., Wang, Z. (2004). Processing arousing information: psychophysiological predictors of motivated attention. *Psychophysiology*, *41*, S61–S61.

Lang, P.J., Bradley, M.M., Cuthbert, B.N. (1997). Motivated attention: affect, activation, and action. In: Lang, P.J., Simons, R.F., Balaban, M., editors. *Attention and Orienting: Sensory and Motivational Processes,* pp. 97–135.

Naumann, E., Bartussek, D., Diedrich, O., Laufer, M. (1992). Assessing cognitive and affective information processing functions of the brain by means of the late positive complex of the event-related potential. *Journal of Psychophysiology*, *6*, 285–98.

Ortigue, S., Michel, C.M., Murray, M.M., Mohr, C., Carbonnel, S., Landis, T. (2004). Electrical neuroimaging reveals early generator modulation to emotional words. *NeuroImage*, *21*(4), 1242–51.

Palomba, D., Angrilli, A., Mini, A. (1997). Visual evoked potentials, heart rate responses and memory to emotional pictorial stimuli. *International Journal of Psychophysiology*, *27*(1), 55–67.

Pyszczynski, T., Greenberg, J., Solomon, S. (1999). A dual-process model of defense against conscious and unconscious death-related thoughts: an extension of terror management theory. *Psychological Review*, *106*(4), 835–45.

Pyszczynski, T., Greenberg, J., Solomon, S., Arndt, J., Schimel, J. (2004). Why do people need self-esteem? A theoretical and empirical review. *Psychological Bulletin*, *130*(3), 435–68.

Quirin, M., Loktyushin, A., Arndt, J., et al. (2012). Existential neuroscience: a functional magnetic resonance imaging investigation of neural responses to reminders of one's mortality. *Social Cognitive and Affective Neuroscience*, *7*(2), 193–8.

Schacht, A., Sommer, W. (2009). Emotions in word and face processing: early and late cortical responses. *Brain and Cognition*, *69*(3), 538–50.

Schupp, H.T., Cuthbert, B.N., Bradley, M.M., Cacioppo, J.T., Ito, T., Lang, P.J. (2000). Affective picture processing: the late positive potential is modulated by motivational relevance. *Psychophysiology*, *37*, 257–61.

Schupp, H.T., Junghofer, M., Weike, A.I., Hamm, A.O. (2003). Attention and emotion: an ERP analysis of facilitated emotional stimulus processing. *Neuroreport*, *14*(8), 1107–10.

Schupp, H.T., Junghofer, M., Weike, A.I., Hamm, A.O. (2004a). The selective processing of briefly presented affective pictures: an ERP analysis. *Psychophysiology*, *41*(3), 441–9.

Schupp, H.T., Öhman, A., Junghofer, M., Weike, A.I., Stockburger, J., Hamm, A.O. (2004b). The facilitated processing of threatening faces: an ERP analysis. *Emotion*, *4*(2), 189–200.

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*(1), 95–104.

Solomon, S., Greenberg, J., Pyszczynski, T. (1991). A terror management theory of social behavior: the psychological functions of self-esteem and cultural worldviews. In: Zanna, M.P., editor. *Advances in Experimental Social Psychology*, Vol. 24, San Diego: Academic Press, pp. 91–159.

Squires, K.C., Donchin, E., Herning, R.I., McCarthy, G. (1977). On the influence of task relevance and stimulus probability on event-related-potential components. *Electroencephalography and Clinical Neurophysiology*, *42*(1), 1–14.

Swaab, T.Y., Baynes, K., Knight, R.T. (2002). Separable effects of priming and imageability on word processing: an ERP study. *Cognitive Brain Research*, *15*(1), 99–103.

Taler, V., Phillips, N.A. (2007). Event-related brain potential evidence for early effects of neighborhood density in word recognition. *Neuroreport*, *18*(18), 1957–61.

Võ, M.L.-H., Jacobs, A.M., Conrad, M. (2006). Cross-validating the Berlin affective word list. *Behavior Research Methods*, *38*(4), 606–9.

Wegner, D.M. (1994). Ironic processes of mental control. *Psychological Review*, *101*(1), 34–52.

Wegner, D.M., Schneider, D.J., Carter, S.R., White, T.L. (1987). Paradoxical effects of thought suppression. *Journal of Personality and Social Psychology*, *53*(1), 5–13.

Williams, L.M., Kemp, A.H., Felmingham, K., Liddell, B.J., Palmer, D.M., Bryant, R.A. (2007). Neural biases to covert and overt signals of fear: dissociation by trait anxiety and depression. *Journal of Cognitive Neuroscience*, *19*(10), 1595–608.

Winkielman, P., Berridge, K.C. (2004). Unconscious emotion. *Current Directions in Psychological Science*, *13*(3), 120–3.

Winkielman, P., Berridge, K.C., Wilbarger, J.L. (2005). Unconscious affective reactions to masked happy versus angry faces influence consumption behavior and judgments of value. *Personality and Social Psychology Bulletin*, *31*(1), 121–35.