Independence of valence and reward in emotional word processing

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Background

Emotional stimuli are special: They are processed faster and in a more elaborate manner. For instance, angry versus neutral faces lead to a faster and stronger event-related potential (ERP) response around 200 ms after face presentation [1]. Similarly, emotional words ('murder', 'love') elicit markedly different brain responses than more neutral words. Previous electrophysiological work on word processing shows that emotional word content can enhance word processing at all stages from pre-lexical encoding and semantic access, up to contextual integration, evaluation and memory encoding [for review 2]. This processing advantage is explained by the intrinsic relevance and salience of emotional stimuli for the human organism [3].

In this study we investigate whether the privileged processing of emotional stimuli (words) is influenced by another potent and primary regulator of cognition, namely the expectancy of reward. A wealth of recent work shows that the expectation of reward or loss modulates cognitive processing such as spatial attention [4], working memory [5], spatial localization or target detection [for review 6]. Here we investigated whether emotional processing is similarly open to modulation from reward, or whether it is immune to the effects of reward expectancy.

We measured EEG from healthy participants while they performed a semantic categorization task (abstract – concrete) on words with different valence (positive, negative, neutral). Importantly, performance on each trial had a direct consequence for the participant: participants could either win money, lose money, or none of both (reward, punish, zero). The presence or absence of reward was signaled by a cue presented 1 second before the word. Our working hypothesis was that if emotional valence and reward expectation interact via a common mechanism, we should observe interaction effects in specific components of the ERP.

Methods

Stimuli:

Words were selected from the database of Affective Norms for English Words (ANEW) [7] which provides a set of normative emotional ratings (valence, arousal, dominance). In order to obtain concrete and abstract words, a rating experiment was conducted prior to the main study in which 1760 positive, negative and neutral words from the ANEW database were evaluated on a 5-point concreteness scale by 42 students (18 male). The final sample consisted of 300 English nouns which differed significantly in terms of valence and arousal, but were controlled for word frequency, word length and concreteness.

Variable	*Positive*	*Neutral*	*Negative*
Valence	7.53 (.43)	5.24 (.52)	2.42 (.38)
Arousal	5.56 (.91)	4.68 (.82)	5.64 (.84)
Concreteness	3.14 (1.48)	3.29 (1.48)	3.17 (1.36)
Word length (letters)	6.56 (2.03)	6.27 (1.85)	6.51 (2.26)
Word frequency (per million)	17.31 (27.46)	16.39 (28.83)	18.26 (35.96)

Table 1: Characteristics of word stimuli

The cue stimuli consisted of '+5', '-5' and '0' in the rewarded, punished and zero condition respectively. Participants were paid according to performance after the experiment.

Participants and EEG-recording: EEG was measured from 64 electrodes in 18 healthy native speakers (9 female, mean age 21).

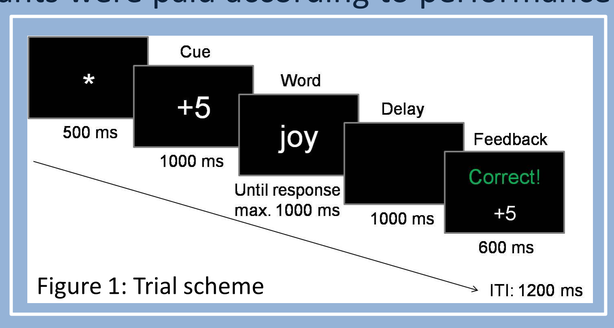

Figure 1: Trial scheme

Artifact precautions: prototypical blinks were corrected using BESA; remaining artifacts were removed with a common automatic algorithm

Analysis: ANOVAs with Huynh-Feld correction on mean amplitude in 100 ms epochs, α = .05, included Reward, Valence, Concreteness (and Electrode)

Results and Discussion

Behavioral data:

90.68% (SD 4.07) of all words were correctly categorized (RT mean=627.29 ms (SD 45.49)). Repeated measures ANOVAs revealed significant effects of reward and concreteness on RT (concreteness < abstract; reward < punish & zero) and accuracy (concreteness > abstract; reward > punish & zero) (all p<.05). In both behavioral measures valence interacted significantly with concreteness (p<.05) but not with reward (p>.05).

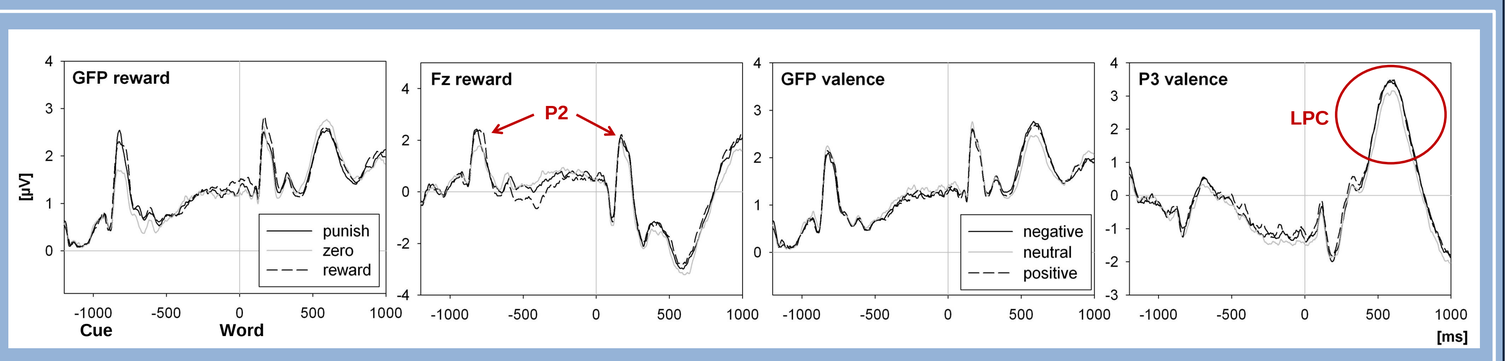

Figure 3: Effects of reward and valence on ERPs in cue (-1000 to 0 ms) and word interval (0 to 1000 ms)

ERP-Data:

Reward expectancy lead to a significantly amplified P2 amplitude in the cue (p=0.01, η_p^2=0.13) and word interval (p=0.00, η_p^2=0.14), possibly resulting from reflex-like visual attention to task-relevant stimuli [8]. In line with previous studies [9], emotional words elicited a significantly enhanced late positive complex (LPC) (400-700 ms from word) compared to neutral words (positive: p=0.01, η_p^2=0.12; negative: p=0.01, η_p^2=0.15), reflecting a more elaborate processing of the emotional words [10], and concreteness modulated the N400 (p=0.00, η_p^2=0.22). Furthermore valence interacted with concreteness in the LPC time window (p=0.00, η_p^2=0.13). Neither in the omnibus ANOVAs on 100 ms epochs, nor in peak amplitude analyses we found an interaction between reward and valence (all p>.05).

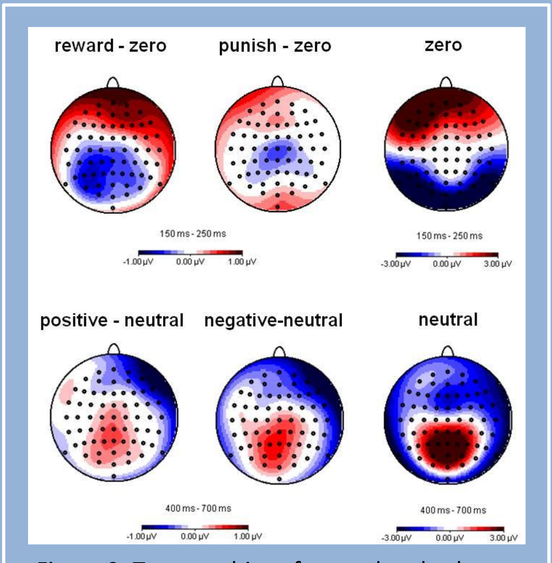

Figure 2: Topographies of reward and valence effect in word interval

Emotion-related and reward-related effects occur in different time windows, do not interact, and show different topographies (map dissimilarity analysis). This speaks for an independence of reward expectancy and the processing of emotion as a word-inherent feature. Emotional semantics might be related to automatic reactions that are not prone to be affected by short term information of monetary gain or loss.

Future research on reward expectancy should be extended to other emotional domains such as pictures, face expressions and possibly sound.

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