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Are there similarities between emotional and familiarity-based processing in visual word recognition?

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ABSTRACT

Previous ERP research revealed emotion effects on visual word processing in early time windows (P1) and during later evaluative processing (LPC). In both time windows interactions with word familiarity measures have been reported.

Using an evaluative conditioning paradigm participants learned to associate meaningless pseudowords with neutral or negative valence. In addition, one set of pseudowords was learned three times as often as the others in order to manipulate familiarity.

Behavioral results confirmed that evaluative conditioning was effective. Small effects of emotion on P1 and of overall conditioning on the LPC were visible, while familiarity only modulated later ERP amplitudes (> 300ms). Exploratory analyses demonstrated a functional relationship between P1 and LPC emotion effects but not for familiarity. Post-hoc examinations illustrated that good learners showed effects of emotion and familiarity on LPC amplitudes which were not evident in participants performing below average. These results are discussed in light of questions regarding the representation and processing of valence and familiarity that are of interest for theoretical models of visual word recognition.

1. Introduction

Neuroscientific examinations in emotion word recognition that mainly relied on the event-related potentials (ERP) method have revealed emotional effects at different levels of processing. Evidence exists that such effects can be visible already at very early stages of word processing approximately 100–140 ms after a word is displayed (P1 and/or N1 components of the ERP, see Hofmann, Kuchinke, Tamm, Võ, & Jacobs, 2009; Scott, O'Donnell, Leuthold, & Sereno, 2009; Kissler & Herbert, 2013; Palazova, Mantwill, Sommer, & Schacht, 2011). Additionally, later controlled processing stages often visible as a late positive deflection of the ERP (the LPC) around 400–600 ms have been found to be modulated by the words' emotional connotations (see Citron, 2012, for a review). LPC modulations have been interpreted to indicate that the subsequent access to the words' emotional and semantic features and meanings trigger additional explicit evaluative processing.

We have recently been able to show that to some extent the early effects can be explained by a contextual learning hypothesis (Fritsch & Kuchinke, 2013; Kuchinke, Fritsch, & Mueller, 2015; Kuchinke, Krause, Fritsch, & Briesemeister, 2014) where verbal and emotional information are interconnected based on previous learning episodes. This hypothesis states that it are not the emotional features themselves that trigger the early emotion effects in visual word recognition, but learned associations between lexical representations, their physical attributes and valence. In these studies previously meaningless letter strings are presented together with unconditioned emotional pictures during different conditioning sessions. Thereby affective associations are established that associate

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a letter string with the valence category of the pictures (so-called evaluative conditioning, e.g. Fritsch & Kuchinke, 2013). In visual word recognition such learned affective associations likely signal emotional significance very early during the word recognition process and are thought to shift attention to these affective features and towards faster (Kissler & Herbert, 2013) and more elaborated processing of emotional words (Kuchinke et al., 2015).

Such early emotional modulations (100–140 ms after a word is displayed) occur temporarily in parallel to the so-called lexical access, i.e. the point in time when a word is identified. One way to infer the time window of lexical access is to examine word frequency effects in visual word recognition. A manipulation of (objective) word frequency in word recognition aims at the familiarity with which a stimulus word is processed, assuming that high frequency words are accessed faster compared to low frequency words (Sereno & Rayner, 2003). Earliest effects of word frequency are visible before 140 ms (Sereno, Rayner, & Posner, 1998), but also later effects have been reported often visible as a frontal N400 component (FN400) and at the level of the LPC (e.g. Hauk & Pulvermüller, 2004; also; Dufau, Grainger, Midgley, & Holcomb, 2015; Laszlo & Federmeier, 2014). Such later effects are discussed to reflect post-lexical processing or the re-processing of word information (Hauk & Pulvermüller, 2004).

In visual word recognition behavioral and neuroscientific data have revealed an interaction between emotional valence and word frequency (a measure of a words' familiarity; e.g. Kuchinke, Võ, Hofmann, & Jacobs, 2007; Mendez-Bertolo, Pozo, & Hinojosa, 2011a; Palazova et al., 2011; Scott et al., 2009, Scott, O'Donnell & Sereno, 2012). The observation of emotion*frequency interactions in ERPs before 150 ms (e.g. Scott et al., 2009) thus shed light on encoding processes early in visual word recognition that are commonly affected by emotional features of a word and by its frequency of occurrence. In the study by Scott et al. (2009) for example, early emotion effects were only visible for high-frequency words. Additionally, emotion*frequency interactions have been observed to influence the LPC. Mendez-Bertolo et al. (2011a) for example reported reduced LPC amplitudes for neutral compared to negative nouns but only for low and not high frequency words. Taken together, emotion*frequency interactions in these ERP studies point to word recognition processes that are triggered by both of these word characteristics in a comparable fashion or to common functions of these variables visible in at least two time windows.

Of interest for the present study is the direction these effects elicited by emotion and frequency have: In the behavioral data both variables, higher values of emotion (i.e., more extreme positive or negative valence or higher arousal of a word) and higher values of word frequency/familiarity, lead to faster response times (Kuchinke et al., 2007). At the neurophysiological level, higher values of emotion and higher values of frequency seem to have opposing effects. Regarding the emotion variables the behavioral assumption is still right that higher values lead to larger effects visible as larger deflections in the ERP components at N1/P1 and the LPC (see Citron, 2012; Hofmann et al., 2009; Mendez-Bertolo et al., 2011a). In general, larger ERP amplitudes are interpreted as a relatively larger recruitment of, for example, attentional resources during early processing or more elaborate processing at late processing stages. Regarding word frequency and familiarity, it are the lower values, i.e. low-frequency, unfamiliar words, that attract attention and demand additional controlled processing (again reflected in larger early and/or later ERP deflections; Sereno et al., 1998; Hauk & Pulvermüller, 2004; Scott et al., 2009).

Studies on immediate repetition priming, which more directly modulates the familiarity of a word stimulus, have revealed that emotion variables interact with the effect of stimulus repetition at multiple stages of word processing, namely the early P1/N1 complex, P300 and N500 (e.g. Mendez-Bertolo, Pozo, & Hinojosa, 2011b). Specifically, although repetition priming operates at a short temporal interval during which the feeling of familiarity is established by presenting the target word twice in a row, first as a prime and directly afterwards as a target, the results seem comparable with the above reported frequency manipulations. Again, these authors discussed that higher amplitudes at early processing stages reflect attentional shifts to repeated (vs. unrepeated) words that are only visible for negative words (Mendez-Bertolo et al., 2011b). This seems comparable to what is found in Scott et al. (2009) where only the familiar, high-frequency words triggered effects of the P1.

This parallelism in behavioral data and the opposition in the direction of the neurophysiological effects is often neglected. While higher values of emotion are thought to attract attention and to facilitate lexical access (e.g. Kissler & Herbert, 2013), it is assumed that word frequency operates on the familiarity dimension of a word stimulus. More familiar words are processed faster but with less attentional processing. As a consequence faster lexical access for familiar words goes along with less attentional demands. At the theoretical level this is also considered: familiarity enhances the overall activation level in the hypothetical mental lexicon. Hence it are the unfamiliar stimuli that demand additional processing to gain a similar activation level necessary to trigger word identification (cf. Grainger & Jacobs, 1996; Kuchinke et al., 2007). This additional effort is assumed to account for higher amplitudes at post-lexical evaluative processing stages for unfamiliar words.

At present, no theoretical or computational model of word recognition exists that is able to incorporate and explain emotional effects at early processing stages (for a review see Hofmann & Jacobs, 2014). While familiarity is represented as higher levels of resting activity based on previous encounters with a word (e.g. Grainger & Jacobs, 1996), no such prediction is made for emotional features. The present study will contribute to this literature by applying an evaluative conditioning (EC) paradigm adapted from Fritsch and Kuchinke (2013, also Kuchinke et al., 2014) and examining the effects of emotion and familiarity manipulations at the level of electrophysiological responses. Since emotion and familiarity variables are known to correlate already at the database level (i.e. more positive words have higher familiarity levels, see Citron, Weekes, & Ferstl, 2014), it seemed advantageous to manipulate these variables using a-priori meaningless stimulus material: Evaluative conditioning refers to an association learning paradigm to establish an emotional connotation for meaningless pseudowords while at the same time avoiding a one-to-one mapping or identity learning. Thus, following multiple repetitions of learning trials with random pairings of pseudowords with emotional (or in the neutral condition neutral) pictures one can show that these items now possess an emotional valence (e.g. Hofmann, de Houwer, Perugini, Baeyens, & Crombez, 2010). It should be noted that we observed large interindividual differences in our previous evaluative conditioning ERP studies (Fritsch & Kuchinke, 2013; Kuchinke et al., 2015). The performance measures of the evaluative conditioning were shown to correlate with the ERP effects. Such results likely indicate that only participants with above average valence conditioning performance also reveal larger effects at the level of ERP responses, which will therefore additionally be examined in the present study.

In addition to a manipulation of the emotionality of these pseudowords, the present study also targets the familiarity of the previously unknown items. Therefore a third of the pseudowords were studied three times more often than the others, but also each time paired with a different neutral picture. Thus, this study was designed to directly manipulate the mental representations of previously meaningless pseudowords along either the valence or the familiarity dimension. In a subsequent test phase the effects that valence and familiarity have on the processing of pseudowords were measured using ERPs. Both variables were expected to facilitate processing of pseudowords. With such a design we are able to examine the electrophysiological effects of valence and familiarity manipulations in pseudowords and compare them to the theoretical assumptions in visual word recognition research regarding the processing and mental representation of emotional words. If the proposed similarities between valence and familiarity are evident at the representational level, comparable effects on early and late ERP components would be expected in pseudoword processing. Given the above considerations of differences in the directions of early and late ERP effects elicited by emotion compared to familiarity, additional exploratory analyses will be conducted. Correlations between early and late stages of processing could indicate functional similarities (Portella et al., 2012). Thus, any differences and/or size of the directions of such correlations between the emotion and familiarity manipulations would support the assumption of fundamental differences between these conditions.

2. Materials and methods

2.1. Participants

Twenty-six students (4 male) of the Ruhr-University Bochum took part in this study for course credit. Their informed consent was obtained prior to the first study session. The study was conducted in accordance with the declaration of Helsinki and approved by the local ethics committee of the Faculty of Psychology at Ruhr-University Bochum. All participants reported to be right-handed, neurologically healthy and having normal or corrected-to normal vision. Participants' mean age was 22.12 years (SD = 4.35), ranging from 18 to 35.

2.2. Materials and procedure

The tasks consisted of five study sessions and one experimental session. The study sessions were conducted on five consecutive days leading up to the experimental session on the sixth day. Participants were able to conduct each of the five study sessions on their personal computer using PXLab (Irtel, 2007). In each study session they completed 800 trials. After each block of 200 trials a memory test of 30 test trials was implemented to ensure the participants' compliance. On a normal study trial, participants saw a pseudoword (CS) together with a picture (US). Pseudowords were pronounceable letter strings of 4–7 letter length that were randomly assigned to one of four experimental conditions for each participant. Pictures were taken from the International Affective Picture System (IAPS; Lang, Bradley, & Cuthbert, 2008) and were attributable to the valence categories "negative" and "neutral" (Mean valence: negative = 3.25; neutral = 5.09), that additionally differed regarding their arousal ratings (mean arousal: negative = 5.33; neutral = 3.67). 40 pseudowords were paired only with negative IAPS pictures. Each of these 40 pseudowords was presented four times during each study session and paired with a different negative picture for each of the four presentations, such that an affective association was learned but not a specific pseudoword meaning. 80 negative pictures were used of which each was shown twice per study session but never paired with the same pseudoword. Apart from the negative conditioned pseudowords, there were two different categories of neutrally conditioned pseudowords. Analogue to the negative category, one neutral category consisted of 40 pseudowords that were each shown four times in a study session and always presented with neutral pictures out of a pool of 80 neutral pictures. Each of these pictures was shown twice paired with pseudowords of this category. A second neutral category was learned more frequently than words of the other categories. The corresponding 40 pseudowords were presented 12 times in each study session, again together with neutral IAPS pictures out of a pool of 240 pictures, so that again as in the other categories, each picture was shown twice but never together with the same pseudoword. Therefore the 800 trials (US-CS pairs) in each study session consisted of 4×40 negative conditioned pseudowords (Ng; summing up to 160 trials), 4×40 neutrally conditioned pseudowords (Nu; 160 trials) and 12×40 more frequently neutrally conditioned pseudowords (FNu; 480 trials). During the test trials that were always shown after 200 study trials, participants were presented 30 picture-pseudoword pairings and were asked to indicate via button press whether the pairing was old (already seen) or new (never seen together). Completion of a study session took approximately an hour. After completing five of these study sessions with 800 trials each, participant came to the laboratory to take part in the ERP experiment. It is important to note that the assignments of pseudowords to emotion and familiarity categories were randomized across participants. Therefore, for each participant a different set of pseudowords was conditioned negatively or neutrally.

2.3. Experimental session

The experimental session consisted of three different parts. In the first part, participants were shown 240 pseudowords of which 120 were the old, conditioned pseudowords (CS) and the other 120 were new but equal in their properties. A randomized sequence of these 240 pseudowords was presented to each participant who had the task to indicate via button press on a confidence scale from 1 (sure old) to 6 (sure new) whether they had seen the respective pseudoword during the study sessions or whether it was a new pseudoword. Participants were given the opportunity to rest for a self-paced period of time after 80 and after 160 trials. Each trial started with the presentation of a fixation cross for a jittered amount of time between 300 and 700 ms followed by the presentation of a pseudoword for 1000 ms. Only afterwards participants were shown the scale from 1 to 6 and thereby given the opportunity to indicate their answer for 3 s. During this part of the experimental session EEG was recorded from 64 electrode sites. Afterwards the EEG cap was taken off and participants completed two further rating tasks.

EC success is examined with two standard measures, an evaluation task (where participants provide valence evaluations of the conditioned pseudowords) and an awareness check to examine the explicit awareness of the contingency between the pseudoword and the conditioned stimulus category (e.g. De Houwer, Thomas, & Baeyens, 2001). In the first rating task, the 120 conditioned pseudowords were one by one presented in the center of the screen and using a cursor participants had to indicate the learned, associated valence of the presented pseudoword on a 7 point Likert scale from −3 (negative) to +3 (positive) that was presented below the pseudowords. Participants were given as much time as they needed to rate the pseudowords.

In the second rating task, the awareness check, all conditioned pseudowords were once more presented one by one and participants had to indicate whether the displayed pseudoword had been associated to negative, or to neutral pictures during the study sessions. To give their answer, participants used the cursor to click on the respective category (negative or neutral) that were displayed below the pseudoword. Again participants were given as much time as they needed to rate each pseudoword. All paradigms were programmed and presented using Presentation software (Neurobehavioral Systems Inc. Canada). Completion of all three parts of the experimental test session took approximately 60 min.

2.4. EEG recordings

The experiment took place in a dimly-lit sound-and electrically shielded laboratory. During the first part of the experimental session, continuous EEG data were recorded using 64 active electrodes (actiCap system, Brain Products, Germany) that were placed on the scalp according to the international 10–20 system using an Easycap. The signal was DC-amplified using a 64 channel amplifier (Brainamp, Brain Products, Germany) at a sampling rate of 500 Hz. Impedances were kept below 10 kΩ. Electrodes were referenced to the right mastoid and one electrode was applied to the left mastoid for later re-referencing. 4 of the 64 electrodes were placed above and below the right eye to capture eye blinks, as well as on both outer canthi to capture horizontal eye movements.

2.5. Data preparation

EEG raw data were analyzed using Brain Vision Analyzer software (Brain Products, Germany). A low-cutoff filter of 0.01 Hz was applied and in addition a 40 Hz high-cutoff filter. Data were re-referenced to linked mastoids. After performing a manual raw data inspection to eliminate muscular artefacts, an ocular correction independent component analysis (ICA) was carried out to correct for eye movements. Subsequently an automatic raw data inspection was carried out that eliminated all intervals with amplitudes above 90 µV and below −90 µV. Data were segmented into intervals of −200 to 800 ms relative to stimulus onset and baseline corrected to the pre-stimulus interval. Based on these segments, averages were computed for each participant and each experimental condition, i.e. negative (Ng), neutral (Nu), frequent neutral (FNu) and new pseudowords. Grand averages were computed separately for the 4 experimental conditions in order to identify relevant time windows for further analysis. Considering previous results (Fritsch & Kuchinke, 2013) and the grand averages across participants, peak detections were carried out over a time window between 100 and 160 ms for the P1 ERP component and between 170 and 220 ms for the N1 ERP component on averaged data, separately for participants and experimental conditions. Peak informations were exported ± 20 ms surrounding each peak (see Fritsch & Kuchinke, 2013). Additionally, area information of the late positive complex (LPC) was exported of the time interval between 500 and 600 ms after stimulus onset. Because visual inspection also indicated a mid-frontal effect with negative going amplitudes of familiarity in a time window 350–400 ms after stimulus onset, area information was also extracted for this time window for all four conditions.

2.6. Data analyses

2.6.1. Behavioral data

During the experiment, participants were asked to state on a 6 point scale whether each pseudoword was surely old (1) or surely new (6). Answers from 1 to 3 were considered stating the letter string was old and answers from 4 to 6 were considered as "new"-answers. Correct trials were aggregated for each participant across experimental conditions (Ng, Nu, FNu) and transformed into a score of percentage of correctly classified stimuli. A repeated measures ANOVA was computed to analyze performance differences between experimental conditions. Subsequently, mean valence scores of the first rating and scores of correctly identified valence categories from the second rating were computed per participant and category each and submitted to oneway repeated measures ANOVAs. Reported are Bonferroni-corrected results of post-hoc pairwise comparisons. Significance of simple *t*-test and correlation analyses are reported based on confidence intervals resulting from $n = 1000$ bootstrapping samples.

2.6.2. ERP analyses

Data of P1 and N1 peak amplitudes and latencies of electrodes P7, PO7, P8 and PO8 for the four categories (Ng, Nu, FNu, new) were submitted to 4 × 2 x 2 repeated measures ANOVAs (category x hemisphere x electrode). For the LPC electrode clusters were computed separately for each of the four categories (Ng, Nu, FNu, new) over electrodes CP1, CP2, CPz, P3, P4, Pz, PO3, PO4, POz

Table 1
Behavioral data.

	Ng		Nu		FNu	
	M	SD	M	SD	M	SD
Performance	0.82	.17	.82	.15	.93	.10
Rating 1	-.35	.46	+.12	.37	+.26	.41
Rating 2	.52	.18	.68	.16	.68	.12

Ng = negative, Nu = neutral, FNu = frequent neutral condition.

during the time window between 500 and 600 ms after stimulus onset similar to Kuchinke et al. (2015). To examine the frontal negativity between 350 and 400 ms average amplitudes of a fronto-central electrode cluster (F1, F2, F3, F4 and Fz) were computed. Both time windows were analyzed based on oneway repeated measures ANOVAs that compare the mean amplitudes in response to the four categories. Only main effects and interactions including the factor category will be reported in the results section. Greenhouse-Geisser correction was applied when the assumption of sphericity was violated. Results of post-hoc pairwise comparisons are reported based on Bonferroni-corrected p-values. Exploratory correlation analyses were computed based on amplitude or latency differences that were computed based on the amplitude and latency measures of the P1 and LPC. For the valence data difference values of amplitudes/latencies of negative minus that of neutral amplitudes were computed. For the familiarity data difference values of amplitudes/latencies of frequent neutral minus that of neutral amplitudes/latencies were computed. To reduce the number of computed correlations, averages for the P1 amplitudes and latencies were computed for left and right hemispheres (summarizing P07 and P7 or PO8 and P8 data).

3. Results

3.1. Behavioral

An oneway repeated measures ANOVA with the within-subjects factor category (Ng, Nu, FNu) on performance during the experiment revealed a main effect of pseudoword category F (2, 50) = 26.06; $p < .001$; $\eta^2 = 0.510$. Best results were achieved for pseudowords of the frequent neutral stimuli followed by neutral and negative (see Table 1). Bonferroni corrected pairwise comparisons showed that while frequent neutral pseudowords were classified significantly better than pseudowords of both other categories ($ps < .001$), the latter two did not differ between each other ($p > .999$).

3.1.1. Rating 1 (valence rating)

A repeated measures ANOVA with the within-subjects factor category (Ng, Nu, FNu) on valence ratings of the pseudowords on a scale from −3 to + 3 revealed a significant effect of category F (2, 50) = 27.48; $p < .001$; $\eta^2 = 0.524$. Bonferroni corrected pairwise comparisons revealed that negatively conditioned pseudowords were also rated as being more negative compared to both other types of neutrally conditioned pseudowords ($ps < .001$) that did not differ significantly from each other ($p = .118$). Additional t-tests were carried out in order to explore whether the ratings differed not only from each other but also from 0. This was true for negative conditioned pseudowords (T (25) = −3.82; $p = .001$) as well as for frequently presented neutral words (T (25) = 3.27; $p = .013$) but not for pseudowords of the neutral category (T (25) = 1.62; $p > .05$).

3.1.2. Rating 2 (explicit awareness check)

For the second rating, the percentages of correctly as negative or neutral identified pseudowords were used as dependent variable. A repeated measures ANOVA with the within-subjects factor category (Ng, Nu, FNu) on this variable revealed a main effect of category F (2, 50) = 8.80; $p = .001$; $\eta^2 = 0.260$. Negative conditioned pseudowords were correctly classified significantly less often compared to both neutral categories ($ps < .022$) while the latter did not differ ($p > .999$). To examine whether these classifications were above the chance level of 50% simple t-tests were computed. Negative classifications were not significantly above chance level ($p = .551$), while neutral (T (25) = 5.56; $p = .001$) and frequent neutral pseudowords (T (25) = 7.23; $p = .001$) were significant above the 50% level.

3.2. ERP Data

3.2.1. P1

3.2.1.1. P1 latency. A 4 × 2 × 2 repeated measures ANOVA with the within-subjects factors category (Ng, Nu, FNu, new), hemisphere (left, right) and electrode site (posterior, posterior-occipital) was carried out on latency values of the P1 ERP component. Results revealed a significant category*hemisphere interaction F (3, 75) = 2.91; $p = .040$; $\eta^2 = 0.104$. Splitting up the 2-way interaction for hemisphere revealed a significant main effect of category on the left hemisphere's latency values F (3, 75) = 3.44; $p = .021$; $\eta^2 = 0.121$ with largest latencies for negative pseudowords ($M = 130.0$) which differed significantly from neutrally conditioned pseudowords ($M = 122.2$; $p = .027$) while all other categories did not differ from each other ($ps > .153$; see Fig. 1). On the right hemisphere, no significant main effect was evident ($p = .604$).

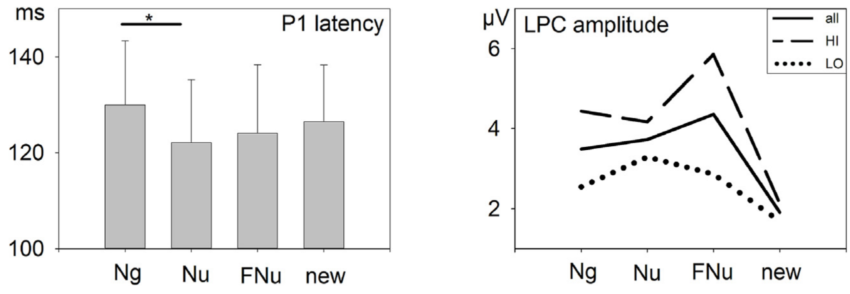

Fig. 1. ERP results: P1 mean latencies are shown on the left with data for the three types of conditioned pseudowords (Ng – negative, Nu – neutral, FNu – frequent neutral) as well as for new pseudowords. Error bars indicate standard deviations, the asterix indicates the significant comparison at $p < .05$. On the right mean LPC amplitudes are illustrated. The solid line indexes mean amplitudes for all participants for the 4 types of words, the dashed line indicates mean amplitudes of good learners (HI) and the dotted line of not-so-good learners (LO).

3.2.1.2. P1 amplitude. The 4 × 2 × 2 repeated measures ANOVA on P1 amplitudes revealed no main effect of category nor a significant interaction comprising the factor category ($ps > .335$).

3.2.2. N1

The 4 × 2 × 2 repeated measures ANOVA revealed no significant main effect or interaction including the factor category on N1 latencies ($ps > .136$) nor N1 amplitudes ($ps > .431$).

3.2.3. Frontal negativity (FN400)

A repeated measures ANOVA with the within subjects factor category (Ng, Nu, FNu, new) was carried out on mean amplitudes over a fronto-central electrode cluster. There was a significant main effect of category on FN400 amplitudes F (3, 75) = 12.89; $p < .001$; $\eta^2 = 0.340$. Pairwise comparisons revealed significantly more negative amplitudes for new pseudowords ($M = -1.72$) compared to negative ($M = -0.16$) and frequent neutral ($M = 0.64$; ps < .001), but not compared to neutral pseudowords ($M = -0.73$; $p = .108$). Additionally, amplitudes to neutral and frequent neutral pseudowords differed from each other ($p = .016$), while all other pairwise comparisons were not significant ($ps > .168$).

3.2.4. LPC amplitude

A repeated measures ANOVA with the within-subjects factor category (Ng, Nu, FNu, new) was carried out on mean amplitudes over a centro-parietal electrode cluster. There was a significant main effect of category on LPC amplitudes F (3, 75) = 9.68; $p < .001$; $\eta^2 = 0.279$. Pairwise comparisons revealed significantly lower LPC amplitudes for new pseudowords ($M = 1.91$) compared to neutral ($M = 3.73$; $p = .011$), negative ($M = 3.49$; $p = .007$) as well as frequent neutral pseudowords ($M = 4.36$; $p = .001$). Mean plots can be gathered from Fig. 1 and grand averages from Fig. 2. All other pairwise comparisons were not significant ($ps > .265$).

3.3. Correlation analyses

Exploratory correlation analyses were computed to examine the functional relationships between the effects at the P1 component and the LPC effects – separately for the main conditions, i.e. emotional effects (negative – neutral) and familiarity effects (frequent neutral – neutral). Even without a main effect of emotion or familiarity visible in the above ANOVAs, a significant correlation between P1 and LPC effects would indicate a functional relationship above and beyond individual differences: Participants with more positive going amplitudes for one condition at the P1 would reveal also more positive going amplitudes for this condition at the LPC (and vice a versa). The results reveal that P1 emotional effects significantly predict later LPC emotional effects while similar effects are not visible for familiarity (see Table 2).

3.3.1. Individual differences

Based on previous findings of large inter-individual differences in EC performance that correlate with the LPC emotion effects (e.g. Fritsch & Kuchinke, 2013) and inspection of the present results we decided to split half the sample of participants on their performance measure in a group of good (HI) and below average learners (LO, performance ≤ .90) to be exploratively modelled as an additional between-subjects factor in the ERP data. An overall performance score was computed by summing up scores of all three experimental conditions and transforming them into a percentage score of correct responses. Repeating the above mentioned ANOVAs for the ERP data led to no qualitatively different results for P1, N1 and frontal negativity data (no significant interaction effects comprising the factors category or group, all $ps > .119$).

This is different for the LPC data, here a significant group*category interaction was evident (F (3, 72) = 3.13; $p = .031$; $\eta^2 = 0.115$). Splitting up this effect for the different groups revealed no category effect in the LO sample (F (3, 36) = 2.14; $p = .112$; $\eta^2 = 0.151$), but in the HI sample (F (3, 36) = 11.01; $p < .001$; $\eta^2 = 0.498$). Of note is, that the HI category effect differed from that in the whole sample analysis (Fig. 1). The Bonferroni-corrected pairwise comparisons revealed significant differences between

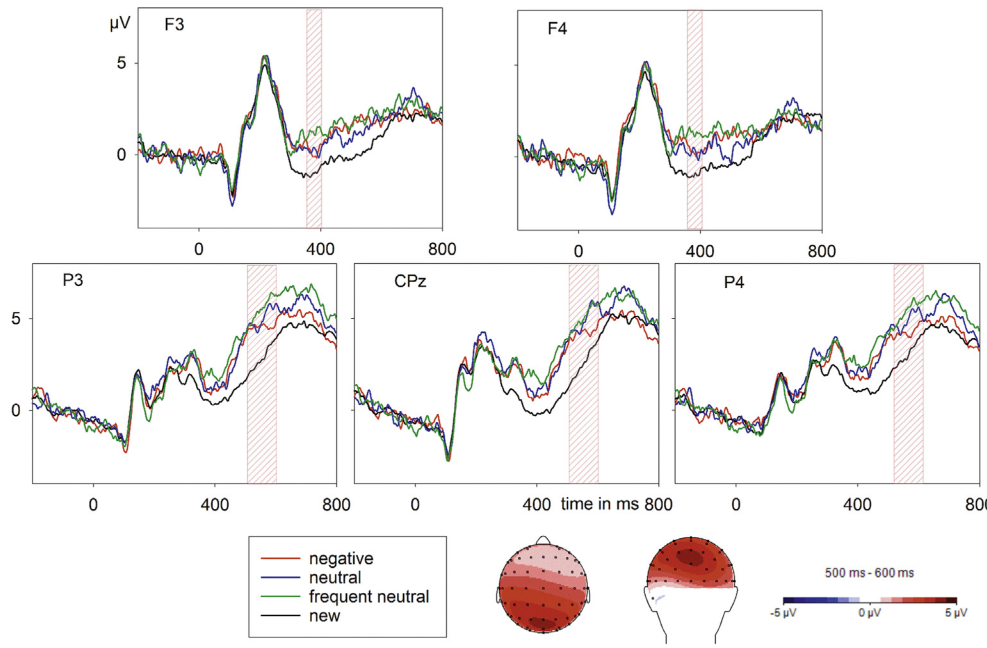

Fig. 2. Grand Average ERP waveforms for selected electrodes. Shaded areas in the top row display the analyzed time window of the frontal negativity. Shaded areas and topography in the bottom row display the analyzed LPC time window.

Table 2
Correlation analyses.

	P1 emotion effect					P1 familiarity effect			
	latency		amplitude			latency		amplitude	
	LH	RH	LH	RH		LH	RH	LH	RH
LPC emo	.293* (.129)	-.324* (.129)	.528* (.146) <	.368* (.142)	LPC fam	.218 (.133)	.322 (.176)	.311 (.204)	.312 (.173)

Pearson correlations and standard errors in brackets separately for the 2 conditions between P1 and LPC. Standard errors and p-values (*p < .05) are based on bootstrapped samples.

negative (M = 4.44) and new pseudowords (M = 2.14; p = .035), and between frequent neutral (M = 5.86) and neutral (M = 4.17; p = .004) respectively new pseudowords (p = .002).

4. Discussion

Behavioral data are clear-cut, evaluative conditioning of negative valence to previously unknown pseudoword stimuli is effective (Hofmann et al., 2010). Participants are able to recognize and evaluate these negatively conditioned stimuli as being more negative (although they were not able to categorize them above chance level in the awareness check in rating 2). In addition, EC is also affected by the frequency of paired associations. Stimuli that are conditioned three times as often compared to other stimuli are recognized to a higher degree as being studied before. This effect is likely based on the higher familiarity of these stimuli. Familiarity refers directly to recognition memory processes that enhance the likelihood of retrieval (Rugg & Yonelinas, 2003). The results also provide some evidence of a 'mere exposure' effect (e.g., Zajonc, 2001) in that frequent neutral pseudowords are rated significantly above zero (the neutral mid-point of the valence scale) indicating slightly positive going evaluations that are typical for familiar stimuli. Still the direct comparison between the two neutral conditions does not reach significance. Of interest is, that an overall enhancement effect by both variables, negative valence and familiarity, as initially predicted is not visible in the behavioral data. Only frequent neutral pseudowords reveal some facilitated access to successful retrieval, while negative pseudowords cannot be discriminated from neutral ones at this level. Unfortunately, the awareness check could not reveal above chance level performance for negative items, i.e. our participants could not explicitly identify the pseudowords that belonged to the negative category. Still, in EC literature, it is a well-known result that implicit evaluation and explicit awareness diverge (De Houwer et al., 2001). While this could be a result of the present design (if participants are aware of the asymmetrical distribution of negative and neutral pseudowords they might have adapted their response strategies in rating 2), it has been discussed that explicit awareness is not a prerequisite of EC success (De Houwer et al., 2001; Hofmann et al., 2010).

At the neurophysiological level, data are rather mixed: There is some evidence of evaluative conditioning differences at the earliest ERP deflection around 100 ms, namely the P1 latency in this study. Visible over left-hemisphere posterior electrodes where early verbal processing reveals largest modulations (e.g. Briesemeister, Kuchinke, Jacobs, & Braun, 2015; Chen, Davis, Pulvermüller, & Hauk, 2015) P1 peaks occur at longer latencies for negative compared to neutral pseudowords. Frequent neutral words have medium latencies that are not significantly different from the other conditioned stimuli. In previous EC studies differences between negative and neutral conditioned stimuli were detected in P1 amplitudes (Fritsch & Kuchinke, 2013; Kuchinke et al., 2015; Schacht, Adler, Chen, Guo, & Sommer, 2012). Although P1 amplitude differences are more often reported, the present results complement these observations and are most likely an indicator of enhanced attentional processing elicited by the negative valence. The fact that the familiarity manipulation does not affect this very early stage of processing goes well in line with studies reporting earliest word frequency modulations occurring slightly later (at N1, Sereno et al., 1998; Chen et al., 2015) and most robustly around 200 ms together with lexical access (e.g., Hauk & Pulvermüller, 2004; Scott et al., 2009). This is different to what is known from repetition priming where P1 modulations are known for the more familiar repeated words. A limitation of the present study is that we did not implement a full 2*2 (valence*familiarity) factorial design. Because the P1 repetition priming effect was only visible for negative items (familiar vs. unfamiliar negative words) in the Mendez-Bertolo et al. (2011b) study, there is the possibility that a frequent-negative condition would have revealed different results at the P1.

Based on present results the familiarity manipulation did not affect these early processing stages but was found to modulate a centro-frontal negativity around 350–400 ms after stimulus onset (more negative-going amplitudes the more unfamiliar a condition is). Examinations of the time course of visual word recognition and how it is affected by word frequency often report effects in this mid-time range that likely reflect enhanced post-lexical processing. More negative going amplitudes for low-frequency words over frontal electrodes were also reported by Dufau et al. (2015), and often positivities over central parietal brain regions are observed (Hauk & Pulvermüller, 2004; Laszlo & Federmeier, 2014). A common effect of item familiarity (in recognition memory studies) is a frontal negativity between 300 and 500 ms (the FN400; for a review see Rugg & Curran, 2007) with more negative going amplitudes for unfamiliar items. Such frontal negativities indicate familiarity-based recognition of previously learned items. Since we employed a yes/no recognition memory task, we cannot rule out that this design enhanced familiarity based processing. Still, these enhancement effects revealed a difference between neutral and frequent neutral pseudowords, with the latter ones showing less negative going amplitudes or most familiar processing.

Together these results seem to indicate the fundamental difference between objective frequency representations learned across thousands of occurrences during reading compared with the relatively few learning trials in the present paradigm (Ng and Nu were studied 20 times total, FNu 60 times). None of the pseudowords in the present study are expected to have a 'lexical' representation, thus all the effects that are observed reflect rather short-term modulations. Still, conditioned negative valence is much more effective to modulate earliest processing compared to neutral conditioned valence but also compared to higher familiarity. Thus, negative valence seems to trigger early attentional processing (reflected in these first deflections in the ERP) more effectively compared to the expected higher association strengths between physical features and mental representations of a pseudoword as a result of the familiarity manipulation.

At later processing stages indicated by the LPC component these differences between conditioned stimuli disappear when examining the whole sample. Here, only differences to new pseudowords are visible, with the latter having the smallest LPC effect. Similar results have been reported before in EC (Fritsch & Kuchinke, 2013; Kuchinke et al., 2015; Montoya, Larbig, Pulvermüller, Flor, & Birbaumer, 1996). LPC effects have been linked to evaluative processing and stimulus familiarity (new stimuli eliciting smaller LPCs, see Rugg & Curran, 2007) and repetition (larger LPC amplitudes for repetition versus first presentation, see Mueller, White, & Kuchinke, 2017). Again it will be interesting to reveal why the familiarity manipulation did not effect LPC amplitudes. In a first attempt to examine this effect, the sample was split in two halves in order to compare good and not-so-good learners. This exploratory analysis shifted the overall effect pattern: While participants with lower EC performance scores showed ERP deflections at the LPC that were not affected by the stimulus categories, results of good learners revealed two main patterns. In this group an effect of conditioned valence was visible (with higher LPC amplitudes for negative stimuli) additionally to an effect of familiarity manipulation compared to unconditioned new and conditioned neutral stimuli. Amplitudes were largest for this frequent neutral condition.

Thus, successful learning seems to go along with evaluation processes that are better in mirroring differences between categories. While new stimuli elicited lowest LPC amplitudes, good learners' neurophysiological responses indicate that both, negative and frequent neutral stimuli, are processed deeper and with additional effort. This likely indicates some similarities in the processing of negative valence and familiarity information at this evaluative stage of processing (in good learners). Summarizing the above results still points to fundamental differences between these conditions. Negative valence affects verbal processing at earlier stages, while familiarity differences are visible only at post-identification, evaluative processing. It should be noted that the statistical power to achieve these results in two samples of 13 participants is relatively low, and therefore (besides the large effect sizes obtained in the group of good learners) these analyses are clearly treated as exploratory and future studies incorporating larger sample sizes are necessary to examine and replicate these results. Still, this view is supported by the correlation analyses that clearly indicate that individual differences in emotion effects at the earliest ERP deflections are indicative of later processing differences at the LPC. An effect that is not visible for the familiarity manipulation.

At the theoretical level these results might be informative for models of visual word recognition. Theoretical models of visual word recognition are surprisingly silent when it comes to emotional effects. This might be based on the fact that a semantic level is often considered but not fully implemented in such models (e.g. Coltheart, Rastle, Perry, Langdon, & Ziegler, 2001; Perry, Ziegler, & Zorzi, 2007; Seidenberg & McClelland, 1989; but see; Hofmann, Kuchinke, Biemann, Tamm, & Jacobs, 2011; Hofmann & Jacobs, 2014). An open question is then how emotional modulations can be implemented in such models. Such computational models of visual word recognition implement word frequency as a-priori differences in resting level activations on the hypothetical word level (e.g., Grainger & Jacobs, 1996). Words with a higher frequency are modelled as having higher resting levels sometimes also seen as a kind of pre-activation based on the higher familiarity of these words, and during the process of word identification such a heightened basis leads to overall higher activation of high-frequency words that are therefore identified faster and with less effort. It has been discussed previously whether differences in predefined resting levels are also suitable for the modelling of emotional word features (Kuchinke, 2007). The present data support the view that at least for early lexical processing until a word is identified, familiarity and emotional valence need to be modelled differently (see also Kuchinke, 2007, p. 62). Thus, an affective mechanism needs to be implemented independent of heightened resting levels for more familiar stimuli that operates before lexical access occurs – and that is still linked to activation differences at post-identification stages.

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