Money or smiles: Independent ERP effects of associated monetary reward and happy faces

Wiebke Hammerschmidt[1,2], Louisa Kulke[1,2] Christina Bröring[2] & Annekathrin Schacht[1,2] *

*[1]Leibniz ScienceCampus "Primate Cognition", Göttingen, Germany, [2]Affective Neuroscience and Psychophysiology Laboratory, Institute of Psychology, University of Göttingen, Germany, * aschach@uni-goettingen.de*

In comparison to neutral faces, facial expressions of emotion are known to elicit attentional prioritization, mainly demonstrated by means of event-related potentials (ERPs). Recent evidence indicated that such a preferential processing can also be gained by neutral faces when associated with increased motivational salience via reward. It remains, however, an open question, whether impacts of inherent emotional salience and associated motivational salience might be integrated. In the present study, participants (*N*=42) learned to categorize happy and neutral faces as reward- and zero-outcome-related via an associative learning paradigm. After successful learning, a consolidation phase followed to strengthen the learned associations. ERPs were recorded throughout the experiment. In the learning phase, happy faces boosted the face-sensitive N170 and the emotion-related EPN component, compared to neutral faces, whereas effects of associated motivational salience were absent. In the subsequent consolidation phase, happy faces again elicited enhanced N170 and EPN amplitudes, while reward-associated faces – irrespective of their expressions – amplified the LPC, a component linked to higher-order evaluations. Interactions between expressions and associated outcome conditions were absent in all ERP components of interest. The present study offers new evidence that acquired salience impacts stimulus processing but independent of the effects driven by happy facial expressions.

Keywords: Motivational Salience, Emotional Expression, Associative Learning, Event-related Brain Potentials (ERPs).

Introduction

Because of limited cognitive resources, the human brain has evolved efficient selection mechanisms that bias perception in favour of salient, i.e. behaviourally relevant or physically distinct, information. Stimuli of increased salience have been demonstrated to directly capture attention and impact visual processing capacities (e.g., Vuilleumier & Pourtois, 2007; Zeelenberg, Wagenmakers, & Rotteveel, 2006), resulting in facilitated sensory encoding even at initial processing stages (e.g., Della Libera & Chelazzi, 2006). Faces, and in particular facial expressions of emotion, were demonstrated to be especially salient, as they not only provide important information about others in social interactions, but also have an intrinsic relevance to assure survival and well-being. Therefore, it has been assumed that humans have evolved a biological preparedness to rapidly detect emotional expressions (e.g., Öhman & Mineka, 2001). For facial expressions of emotion, a preferential processing has been unveiled both at the behavioral and neural level, mainly for angry facial expressions (e.g., Recio, Shmuilovich, & Sommer, 2014; Recio, Sommer, & Schacht, 2011; Rellecke, Palazova, Sommer, & Schacht, 2011; Rellecke, Sommer, & Schacht, 2012; Schupp et al., 2004). However, for happy facial expressions a recognition advantage has been demonstrated (Kirita & Endo, 1995), manifested in an increased and faster recognition accuracy compared to other facial expressions potentially based one the exclusive role of happiness as a positive expression (Calvo & Lundqvist, 2008; Leppänen & Hietanen, 2004). In addition, as humans are highly social beings, facial expressions of emotion are not only emotionally relevant, but also motivationally relevant, as, for instance, a happy face might carry a rewarding value similar to other reinforcers (Rolls, 2013). Traditional theories of attention focused on bottom-up (i.e., stimulus-driven) and top-down (i.e., goal-directed) attention mechanisms (e.g., Corbetta & Shulman, 2002) to explain how relevant stimuli are preferentially processed. However, such accounts have recently been challenged by studies demonstrating a preferential processing of previously reward-associated stimuli, which occurs even when the stimuli themselves do not carry increased salience, when they are task-irrelevant, or when the reward is suspended over time (Anderson, 2013). To fill this gap, Anderson proposed a general value-driven attention mechanism to explain the attentional prioritization of not only stimuli of inherent emotional salience but also of stimuli that acquired their salience through learning processes. Supporting evidence for this assumption comes from studies indicating overlapping neural activity in the ventromedial prefrontal cortex (vmPFC) and ventral striatum, elicited by both emotional facial expressions and monetary reward (Lin, Adolphs, & Rangel, 2012). Furthermore, motivational relevance has been widely equated with emotional stimulus valence or seen as a precursor of emotional significance in some scientific approaches (e.g., Lang & Bradley, 2010; Pessoa, 2015). This led to the obvious investigation of potential modifications of inherently emotional stimuli through learned associations of motivational salience.

An excellent tool to gain insights into the neuro-cognitive mechanisms underlying

the prioritized processing of emotional stimuli are event-related brain potentials (ERPs) since they allow dissociating between different processing stages. In the domain of facial expressions of emotion, a large number of studies revealed rather robust modulations of dissociable ERP components over time: The Early Posterior Negativity (EPN), a typical emotion-related ERP component reflecting an enhanced sensory encoding of stimuli carrying inherent salience, starts around 150-200 ms after stimulus onset (Recio et al., 2011; Rellecke et al., 2012; Schupp et al., 2004) and has been demonstrated to be elicited by happy expressions (Bublatzky, Gerdes, White, Riemer, & Alpers, 2014; Calvo & Beltrán, 2013; Hammerschmidt, Sennhenn-Reulen, & Schacht, 2017; Sato, Kochiyama, Yoshikawa, & Matsumura, 2001). Another ERP component of interest in emotion processing is the Late Positivity Complex (LPC, or LPP; e.g., Schupp et al., 2004). The LPC is linked to higher-order stages of stimulus evaluation, developing around 300 ms and lasting for several hundred milliseconds (e.g., Rellecke et al., 2011). The ERP component is typically modulated by angry expressions, presumably due to their increased evolutionary relevance (Schupp et al., 2004), however, also happy expressions might modulate the LPC component (Bublatzky et al., 2014; Recio et al., 2011; Rellecke et al., 2012). Moreover, the P1 component, peaking around 100 ms at occipital electrodes, presumably reflects rapid activation of the extrastriate visual cortex (Di Russo, Martinez, & Hillyard, 2003) and is mainly impacted by negative expressions (e.g., Hammerschmidt et al., 2017; Pourtois, Grandjean, Sander, & Vuilleumier, 2004; Rellecke et al., 2012). The N170 component, typically following the P1 in face processing, is an occipito-temporal negativity linked to holistic face perception (Bentin, Allison, Puce, Perez, & McCarthy, 1996). Several studies reported N170 modulations by emotional expressions, including happy expressions (e.g., Bublatzky et al., 2014; Marinkovic & Halgren, 1998), but the conjuncture of N170 modulations by emotional expressions is still on debate (for reviews, see Hinojosa, Mercado, & Carretié, 2015; Rellecke, Sommer, & Schacht, 2013). In addition to these robust ERP effects elicited by facial expressions, also neutral faces associated with motivational salience were reported to impact dissociable ERP components over time. A recent study by Hammerschmidt and co-workers (Hammerschmidt, Sennhenn-Reulen, et al., 2017) directly compared the neural correlates of processing facial expressions of emotion and neutral faces associated with motivational salience by means of ERPs. Interestingly, reward-associated neutral faces elicited enhanced amplitudes of the P1 component, similar to P1 amplification by angry facial expressions. Whereas the prioritization of associated motivational salience was restricted to initial processing stages (P1), beneficial processing of facial expressions of emotions spread over to subsequent stages of more elaborative stimulus processing (EPN, LPC). In other studies, however, neutral faces implicitly associated with monetary reward have been shown to elicit enhanced LPC amplitudes (Hammerschmidt, Kagan, Kulke, & Schacht, 2017), replicating previous findings that the LPC component seems to be sensitive to reward associations (Rossi et al., 2017; Schacht, Adler, Chen, Guo, & Sommer, 2012). According

to the value-driven attention mechanism (Anderson, 2013), the processing of inherent emotional and associated motivational salience should share certain similarities. However, previous evidence could not finally answer this question, as effects of associated motivational salience were not demonstrated to lead to a sustained attentional prioritization over processing stages, as suggested for facial expressions of emotion. Therefore, both types of salience need to be directly integrated to investigate to what extent they share similar or even common processing characteristics, a question to which previous evidence is inconclusive.

Interactions of associated reward and emotional expression were reported on reaction times (Wei & Kang, 2014), but only when the facial expression was task-relevant. Further, Yao and colleagues (Yao, Ding, Qi, & Yang, 2014) demonstrated that the preferential processing of angry expressions can be extenuated through reward associations. However, the authors only investigated effects on the N2pc component, linked to spatial attention (Kiss, Van Velzen, & Eimer, 2008), and disregarded the investigation of emotion-related ERP components.

The present study aims at clarifying whether the preferential processing of inherently happy facial expressions might be impacted by motivational salience (reward) acquired via explicit associative learning, using a paradigm similar to Hammerschmidt et al. (Hammerschmidt, Sennhenn-Reulen, et al., 2017). Since in that study, effects of associated salience were restricted to the reward condition, here only happy and neutral faces were orthogonally associated with gain or zero-outcome respectively. Directly after reaching a predefined learning criterion, a consolidation phase was added to strengthen the learned associations. ERPs were recorded to compare the effects of the factors expressions, outcome and their potential interaction over different stages of face processing.

Replicating previous findings, we hypothesized reward associations to be learned faster than zero-outcome-associations (Hammerschmidt, Sennhenn-Reulen, et al., 2017; Kulke, Bayer, Grimm, & Schacht, 2017; Rossi et al., 2017), as well as faster reaction times for reward compared to zero-outcome-associations (Hammerschmidt, Sennhenn-Reulen, et al., 2017). In line with the literature, happy faces were expected to trigger the typical emotion-related EPN component (e.g., Hammerschmidt et al., 2017; Rellecke et al., 2012; Sato et al., 2001) both in the learning and consolidation phase. A reward-modulation on the P1 component was expected for neutral faces associated with monetary gain (Hammerschmidt, Sennhenn-Reulen, et al., 2017). In addition, if associated motivational and inherent emotional salience are interacting on sensory processing stages, happy faces associated with reward were expected to elicit even stronger P1 modulations. The potential interaction of emotional expression and associated outcome was investigated on all measurements, behavioral data and ERPs. Finally, the changes in participants' mood by overall increasing monetary gain during the experiment were assessed.

Materials and Methods

Participants

Data was collected from 48 participants. Four participants were excluded, as they did not reach the required learning criterion within 10 to 30 blocks, two due to artifacts. The remaining forty-two participants (20 female) had an age range between 19 and 30 years (mean age = 23.9 years, *SD* = 2.7), normal or corrected-to-normal vision and no neurological or psychiatric disorders according to self-report. All participants were right-handed (according to Oldfield, 1971) and were reimbursed with their individual bonus, ranging between 38.10 and 59.70 euro (*M* = 49.82 euro, *SD* = 5.47 euro).

Stimuli

Sixteen colored facial stimuli (8 female, 8 male) were selected from the Karolinska Directed Emotional Faces (KDEF) database (Lundqvist, Flykt, & Öhman, 1998) showing happy and neutral expressions respectively. A grey ellipsoid mask, ensuring a uniform figure/ground contrast, surrounded the stimuli within an area of 130 x 200 pixels (4.59 x 7.06 cm) and let only the internal face area visible. Facial stimuli were matched for luminance across conditions (according to Adobe Photoshop CS6™), $F(1,30) = 2.907$, $p = 0.099$, and were presented at a central position on the screen on a light gray background, corresponding to a visual angle of 4.6° x 7.1°. Feedback symbols were presented in grey circles in the center of the screen (248 x 248 pixels, 5 x 5 cm) and were constructed perceptually identical (800 pixels respectively): a green plus (correct reward condition), a dark grey equality sign (correct zero-outcome condition) or a red cross (error). Feedback colors were equi-luminant.

Procedure

The study was conducted in accordance with the Declaration of Helsinki and approved by the local Ethics committee of the Institute of Psychology at the University of Goettingen. Participants were informed about the procedure and gave written informed consent prior to the experiment. Participants were seated in a dimly lit, sound-attenuated room at a viewing distance of 57 cm to the computer screen. During the experiment, 8 inherently happy and neutral expressions were associated with monetary gain, or no outcome via an associative learning paradigm (similar to Hammerschmidt et al., 2017). The participants' task was to learn the correct outcome-expression assignment for each of the faces presented. As no test trials were provided, the first block had to be answered by chance. The feedback scheme was explained prior to the experiment: Faces that had to be categorized as reward-related were associated with +20 cents (in case of correct classification) or -10 cents (incorrect classification). For faces that had to be categorized as zero-outcome-related, feedback was either 0 cents (correct) or -10 cents (incorrect). If the participants missed to answer a trial within 5000 ms, 50 cents were removed from their bonus. Responses were given by button press; response-to-button assignment was balanced across participants, as well as face-to-expression/outcome assignment, but remained stable for each participant. Stimuli were presented block-wise, each block consisted of all sixteen facial stimuli in fully randomized order. The experiment consisted of 40 blocks (640 trials in total), separated by a self-determined break and information about the current amount of the individual bonus. A

learning criterion was defined (48 of the last 50 trials correct) to assure successful learning. If the learning criterion was not reached within 10 to 30 blocks, data was excluded from analysis (N = 4). The remaining trials, until reaching 40 blocks, were presented to allow for consolidation. A black fixation point (5 x 5 pixels) was presented for 2000 ms in each trial, followed by the face for maximum 5000 ms, disappearing with button press. Afterwards, a blank screen for 1500 ms and the feedback symbol for 1000 ms were presented; the inter-trial interval was 1000 ms. While ERPs were recorded, a chin rest was used. The German Multidimensional Mood Questionnaire (MDBF; Steyer, Notz, Schwenkmezger, & Eid, 1997) was completed before and after the task.

EEG Recording, Pre-processing and Analyses

The electroencephalogram (EEG) was recorded from 64 electrodes, placed in an electrode cap (Easy-Cap, Biosemi, Amsterdam, Netherlands) according to the extended 10-20 system (Pivik et al., 1993). The common mode sense (CMS) electrode and the driven right leg (DRL) passive electrode were used as reference and ground electrodes (cf., http://www.biosemi.com/faq/cms&drl.htm). Six external electrodes were used, inferior and laterally to the eyes to record blinks, and on the left and right mastoids. Signals were recorded at a sampling rate of 2048 Hz (downsampled to 500 Hz for ERP analysis) and a bandwidth of 104 Hz (http://www.biosemi.com/faq/adjust filter.htm), offline filtered with a Low Cutoff (0.03183099 Hz, Time constant 5 s, 12 dB/oct), a High Cutoff (40 Hz, 48 dB/oct), and a Notch Filter (50 Hz). Data was processed with BrainVision Analyzer (Brain Products GmbH, Munich, Germany), average-referenced and corrected for blinks using Surrogate Multiple Source Eye Correction with default parameters (MSEC, Ille, Berg, & Scherg, 2002; application is detailed in Scherg, 2003) as implemented in BESA (Brain Electric Source Analysis, MEGIS Software GmbH, Gräfelfing, Germany). The continuous EEG signal was segmented into epochs of 1200 ms (both for analysis of face and feedback stimuli), starting 200 ms before stimulus onset referring to a 200 ms pre-stimulus baseline. Electrodes with a noisy or no signal were interpolated by spherical splines in BrainVision Analyzer (Order of splines: 4; maximal degree of Legendre Polynomials: 10; Lambda: 1E-05). Epochs containing artifacts (criteria: voltage steps > 50 µV, 200µV/200 ms intervals difference of values, amplitudes exceeding -150µV/150 µV, activity < 0.5 µV) were eliminated. Segments were averaged per Subject, Phase (2 – learning, consolidation), Expression (2 – happy, neutral) and Outcome (2 – reward, zero outcome). Based on a previous study (Hammerschmidt, Sennhenn-Reulen, et al., 2017), time windows and regions of interest (ROIs) electrodes for target face-related ERP components were chosen as follows: i) P1: 75-125 ms, O1 and O2; ii) N170: 130-180 ms, P9 and P10; iii) EPN: 200-350 ms, P9, P10, Iz, Oz, O1, O2, PO7 and PO8; iv) LPC: 350-700 ms, Pz, P1, P2, CPz and POz. P1 components were quantified as the most positive peak (with O2 as reference electrode), N170 component as the most negative peak (with P10 as reference electrode); EPN and LPC were quantified as mean amplitudes. For

statistical analysis, repeated-measures (rm)ANOVAs were computed, including the factors Expression (2 – happy, neutral) and Outcome (2 – reward, zero outcome) for the learning and consolidation phase, respectively.

Analyses of behavioral data

To investigate the differences in learning curves between conditions, posterior distributions for the probability (the coefficient p of a Bernoulli distribution) to attribute the outcome category correctly were modeled. The number of trials until the learning criterion was met differed between participants. To account for these differences in trial number, the proportion of time (until the learning criterion was met) was considered (see Figure 1). Significant differences between these learning curves were defined based on a criterion of non-overlapping 99 % simultaneous credible bands (for more details, see Hammerschmidt et al., 2017). For reaction times and accuracy data, repeated-measures (rm)ANOVAs were computed, including the factors, Expression (2, happy, neutral) and Outcome (2, reward, zero outcome).

Results

Learning Phase

Behavioral Data

Participants (N = 42) learned the outcome associations adequately within 10 to 26 blocks (M = 17.2 blocks, SD = 4.8 blocks). In the happy face condition, reward-associated faces were learned faster, differing from zero-outcome- related faces from the beginning until 53.9% of the learning criterion was met. At this time, participants were correct 74.9% of the time for zero-outcome-associated and 83.9% for reward-associated faces. In the neutral face condition, positively associated faces were learned faster, differing from neutral faces from 38.5% until 54.3% of the learning criterion was met. Note however, that in the very beginning, there was an advantage for zero-outcome-associated compared to reward-associated faces until 13.3% of the learning criterion was met (see Figure 1).

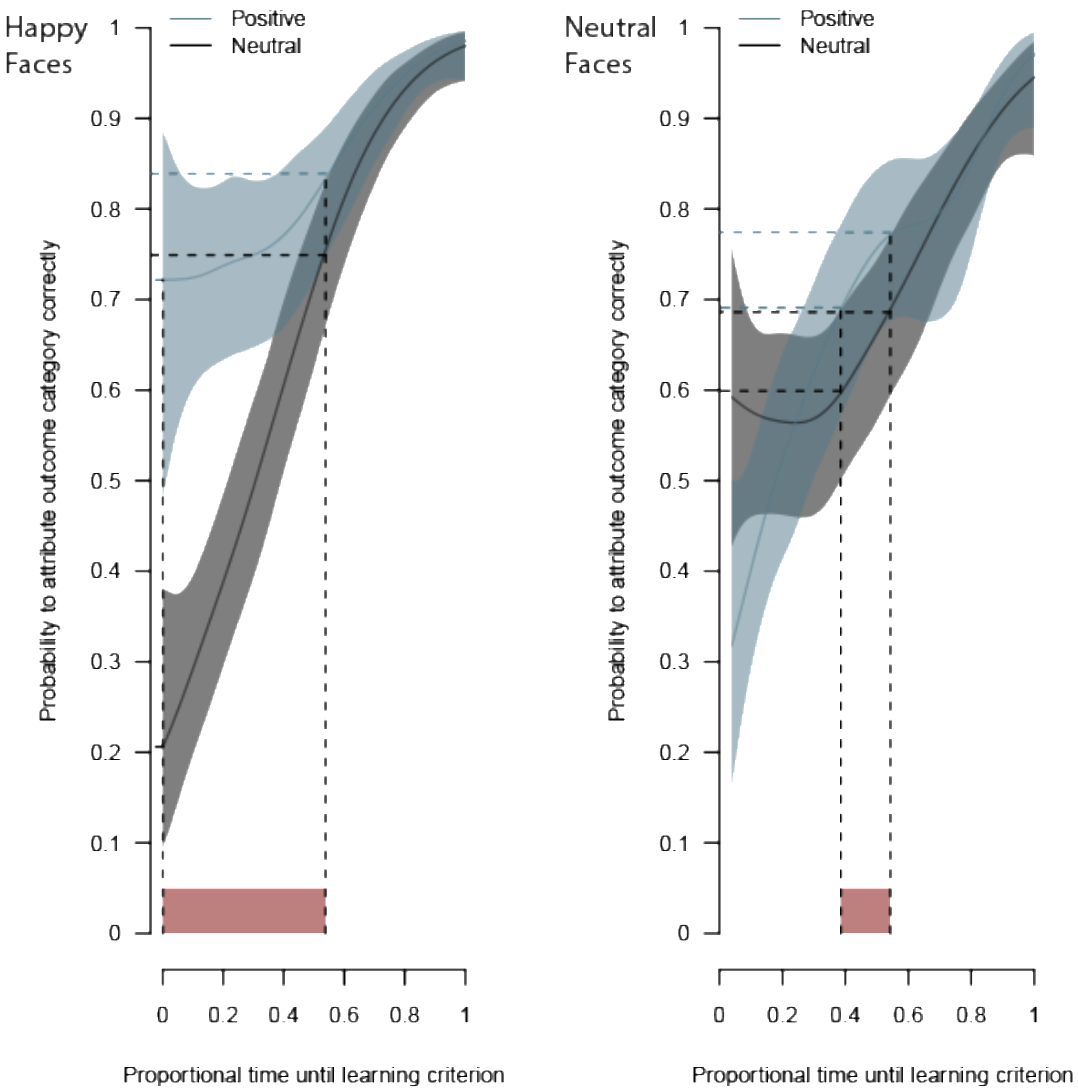

Figure 1. *Posteriori mean probabilities to attribute the outcome category correctly during the learning phase (illustrated by horizontal dashed lines) at the lower and upper bounds of the time intervals until the learning criterion was met (illustrated by red areas).*

Reaction times (RTs) revealed a main effect of the factor Emotion, $F(1,41) = 5.647$, $p = 0.022$, $\eta^2_p = 0.121$, with faster reaction times for happy compared to neutral facial expressions, and the factor Outcome, $F(1,41) = 11.347$, $p = 0.002$, $\eta^2_p = 0.217$, with faster reaction times for reward- in comparison to zero-outcome-associated faces; an interaction effect was absent. Mean reaction times per experimental condition are summarized in Table 1.

Table 1. *Mean reaction times in ms and accuracy in % for learning and consolidation phase (SEMs in parentheses), contrasted for all factor levels of Expression and Outcome.*

	Emotion	Outcome	RTs	Accuracy*
Learning Phase	Happy	Reward	1485 (57)	-
		Zero Outcome	1608 (61)	-
	Neutral	Reward	1598 (64)	-
		Zero Outcome	1646 (63)	-
Consolidation Phase	Happy	Reward	942 (27)	99.3 (0.2)
		Zero Outcome	1006 (29)	99.1 (0.2)
	Neutral	Reward	986 (25)	98.8 (0.3)
		Zero Outcome	1016 (28)	99.1 (0.3)

*Adequate accuracy of each participant during the learning phase was assured by a required learning criterion (48 of the last 50 trials correct).

ERPs to Target Faces

A main effect of the factor Expression was revealed on the N170 component, $F(1,41) = 14.855$, $p < 0.001$, $\eta^2_p = 0.266$, with enhanced negative amplitudes for happy compared to neutral expressions. This main effect of Expression was also found on the EPN component, $F(1,41) = 42.405$, $p < 0.001$, $\eta^2_p = 0.508$, reflecting larger posterior negativities for happy in comparison to neutral expressions (see Figure 2). Modulations of P1 and LPC components by the factors Expression or Outcome were absent. No evidence was revealed for interaction effects on all ERP components of interest.

Consolidation Phase

Behavioral Data

Accuracy was at ceiling for all conditions (Ms = 98.8-99.2%) during the consolidation phase and did not differ in terms of the factors Emotion and Outcome, $F(1,41) < 1$. RTs of the consolidation phase showed a main effect of the Factor Outcome, $F(1,41) = 17.235$, $p < 0.001$, $\eta^2_p = 0.296$, with faster reaction times for reward- compared to zero-outcome associated faces. A main effect of the factor Emotion and an interaction were absent. Mean reaction time and accuracy values per experimental condition are summarized in Table 1.

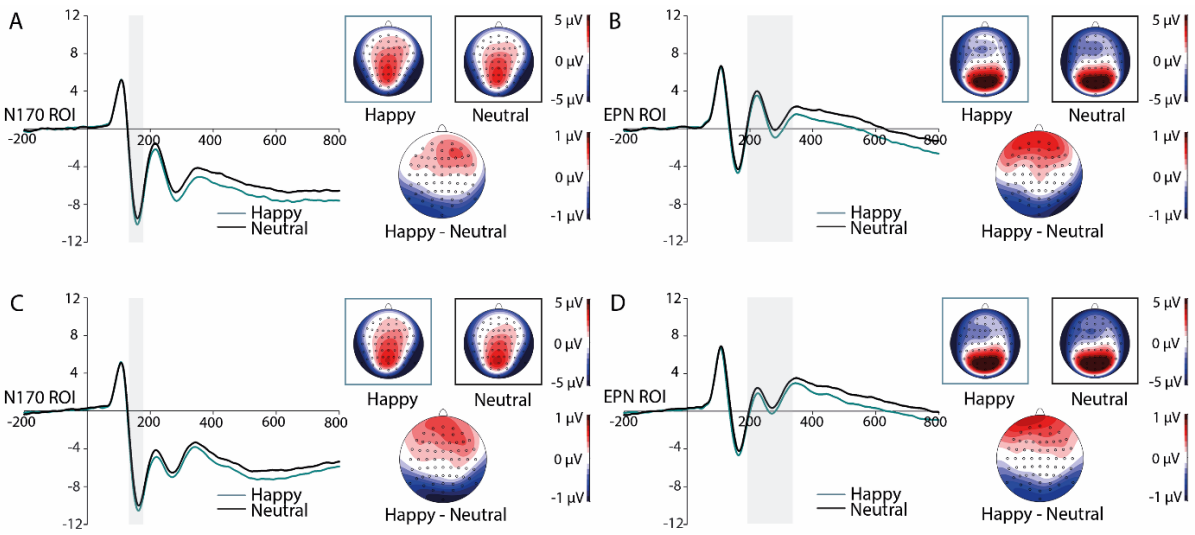

***Figure 2**. Grand-averaged ERPs at N170-ROI electrodes for happy and neutral faces during the learning (A) and consolidation phase (C) with corresponding scalp distributions and topographies of ERP differences between indicated emotion categories. Grand-averaged ERPs at EPN-ROI electrodes for happy and neutral faces during the learning (B) and consolidation phase (D) with corresponding scalp distributions and topographies of ERP differences between indicated emotion categories. Highlighted areas display the time windows of ERP analyses.*

ERPs to Target Faces

A main effect of the factor Expression was revealed for happy in comparison with neutral facial expressions on the N170 component, $F(1,41) = 21.015$, $p < 0.001$, $\eta^2_p = 0.339$. A main effect for the factor Expression was shown on the EPN component with enhanced negativities for happy compared to neutral facial expressions, $F(1,41) = 15.923$, $p < 0.001$, $\eta^2_p = 0.280$ (see Figure 2). Furthermore, a main effect of the factor Outcome was found on the LPC component with boosted amplitudes for reward- compared to zero-outcome-associated faces, $F(1,41) = 5.260$, $p = 0.027$, $\eta^2_p = 0.114$ (see Figure 3). The P1 component was not modulated by factors Expression and Outcome. Interactions between the factors Expression and Outcome were absent on all components of interest.

Mood

Participants' mood (according to MDBF) was significantly better after the associative learning task, $F(1,41) = 9.718$, $p = 0.003$, $\eta^2_p = 0.192$, whereas alertness was reduced compared to the beginning of the experiment, $F(1,41) = 16.034$, $p < 0.001$, $\eta^2_p = 0.281$. The task did not impact participants' calmness.

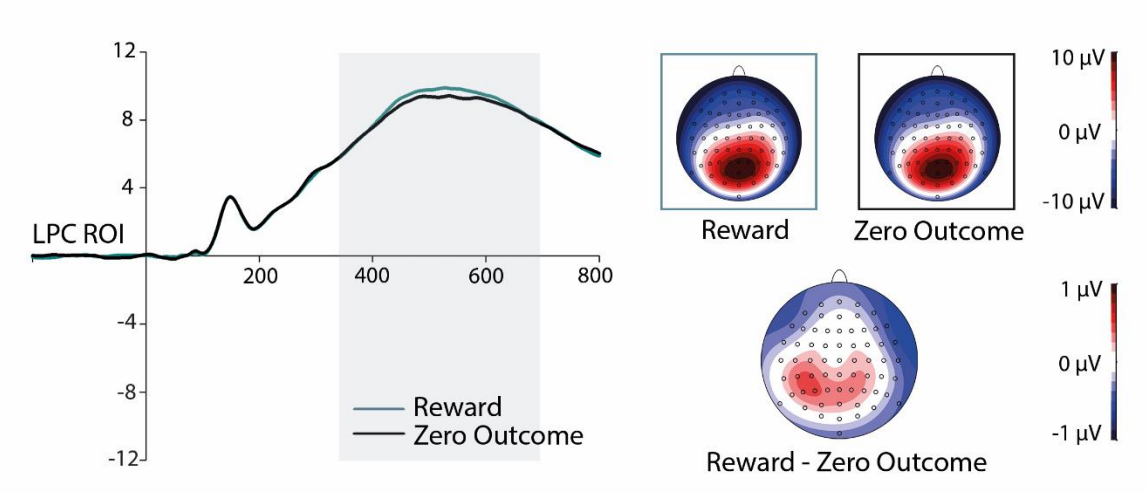

***Figure 3**. Grand-averaged ERPs at LPC-ROI electrodes in response to reward- and neutral-associated faces during the consolation phase with corresponding scalp distributions (left panel) and topographies of ERP differences (right panel) between indicated motivation categories. Highlighted area displays the time windows of ERP analysis.*

Discussion

The aim of the present study was the investigation of a potential integration of inherent emotional and associated motivational salience, as, due to the value-driven attention mechanism proposed by Anderson (Anderson, 2013), their processing should share similar or even common processing characteristics. To this aim, happy and neutral faces were associated with monetary gain or zero outcome via explicit associative learning. The experiment was divided into a learning and consolidation phase to investigate ERPs during and after successful learning. On average, outcome associations had no impact on visual processing during the learning phase, whereas in the consolidation phase, LPC amplitudes, referred to an elaborative processing of relevant stimuli, were enhanced by reward associations. The amplified LPC to reward-associated neutral faces replicates findings of recent similarly designed studies, which could show such effects after implicit reward learning (Hammerschmidt, Kagan, et al., 2017) and associations of reward to (neutral) letters from unfamiliar alphabets (Rossi et al., 2017; Schacht et al., 2012). Importantly, the learning data corroborate our finding of a reward-driven LPC irrespective of the facial expression. Associations of happy faces with reward were learned the fastest, potentially due to an advantage of congruency of expression and outcome valence. However, neutral faces associated with neutral outcome were learned better in the beginning but were outperformed by reward associations during learning. Across both phases, an advantageous effect of reward was further evident in the reaction times, as responses to reward-associated faces were faster than those to faces associated with no outcome. Interestingly, the effect of facial expressions with shorter reaction times for happy than neutral faces was limited to the learning phase but vanished during

consolidation. Although the task was demanding, as indicated by a decrease of participants' alertness, mood increased, presumably due to the overall gain of monetary reward. Together, these findings highlight the increased behavioral relevance of reward associations. Early P1 modulations were expected to be elicited by reward associations (Hammerschmidt, Sennhenn-Reulen, et al., 2017). For their absence three explanations might be considered: First, a special feature of the present experiment was the restriction to happy and neutral faces as target stimuli on the one hand and gain and zero outcomes on the other hand, leading to the complete absence of any aversive stimulus. One might assume that effects of reward are stronger or even limited to conditions when a negative counterpart (e.g. angry face or monetary loss) is present, while participants in our study have primarily been rewarded. Second, in contrast to our previous study (Hammerschmidt, Sennhenn-Reulen, et al., 2017), no delay between learning and subsequent testing was implemented. The consolidation of emotional or rather arousing stimuli has been suggested to require time (Sharot, Delgado, & Phelps, 2004), however, also P3 effects modulated by monetary reward were found without overnight consolidation suggesting that this is not mandatory for the occurrence of reward associations (Rossi et al., 2017). Third, similar studies (Bayer et al., 2017; Kulke et al., 2017; Schacht et al., 2012) used a different task during delayed testing, while in the present study, the categorization task remained the same and the task relevance of the stimuli did not change throughout the experiment. Therefore, the experimental design, e.g. the task, might play a crucial role in understanding impacts of associated motivational salience and need to be spotlighted in further research.

Happy expressions impacted the face-sensitive N170 and the typical emotion-related EPN component both during learning and consolidation. The N170 reflects the configural encoding of a facial stimulus. There is still an ongoing debate whether this process might be impacted by facial expressions of emotion (for reviews, see Hinojosa et al., 2015; Rellecke et al., 2013). However, several studies could demonstrate that the N170 component might be modulated by happy facial expressions (e.g., Bublatzky et al., 2014; Marinkovic & Halgren, 1998). The emotion-related EPN component was modulated by happy facial expressions. This finding is in line with the conventional link of the EPN to an enhanced encoding of sensory information (Rellecke et al., 2011, 2012; Schacht & Sommer, 2009) that occurs independent of context and task demands. Interestingly, as can be seen in Figure 2, the difference distributions of the N170 resembled those of the EPN, indicating a potential overlap of these two ERP components (Rellecke et al., 2011; Schacht & Sommer, 2009). Future research is needed to fully dissociate these two prominent ERP components and their potential modulations by emotional aspects.

Importantly, no interaction of the factors Emotion and Outcome was detected, neither on the behavioral level nor in any of the ERP components of interest, indicating that no integration of the two sources of salience takes place. This absence of interaction effects corroborates studies on emotional words (Kaltwasser, Ries, Sommer, Knight, & Willems, 2013) and

behavioral findings for faces in a study, where the emotional expression was not task-relevant (Wei & Kang, 2014). A decrease of the preferential processing of angry (but not happy) faces was previously demonstrated in modulations of the N2pc (Yao et al., 2014), a component linked to spatial attention (Kiss et al., 2008).

Together, the results of the present study only partially support the value-driven attention mechanism proposed by Anderson (Anderson, 2013). According to this assumption, the prioritized processing of effects of associated motivational and inherent emotional salience should be highly similar. In order to investigate whether both types of salience share common processing characteristics, they were orthogonally combined in an associative learning paradigm. The present findings however indicate that these two types of salience were not integrated, as reflected by the absence of interaction effects, diverging brain topographies, and the occurrence of effects in different time windows, under the given experimental conditions.

Conclusion

Enhanced LPC amplitudes for reward associations independent of the facial expressions (happy, neutral) were demonstrated during the consolidation phase. Happy expressions modulated configural and typical emotion-related ERP components (N170, EPN) during both learning and consolidation. In none of the ERP components and neither in the behavioral data, an interaction between associated and inherent salience occurred. Together, the findings of the present study thus provide novel evidence that within the positive valence dimension both types of emotional/motivational salience are processed in an independent way.

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