**Wanting and Liking in Dysphoria: Cardiovascular and Facial EMG Responses during
Incentive Processing**

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Abstract

Theories and research on depression point to reduced responsiveness during reward anticipation and in part also during punishment anticipation. They also suggest weaker affective responses to reward consumption and unchanged affective responses to punishment consumption. However, studies investigating incentive anticipation using effort mobilization and incentive consumption using facial expressions are scarce. The present studies tested reward and punishment responsiveness in a subclinically depressed sample, manipulating a monetary reward (Study 1) and a monetary punishment (Study 2). Effort mobilization was operationalized as cardiovascular reactivity, while facial expressions were measured by facial electromyographic reactivity. Compared to nondysphorics, dysphorics showed reduced pre-ejection period (PEP) reactivity and blunted self-reported wanting during reward anticipation but reduced PEP reactivity and normal self-reported wanting during punishment anticipation. Compared to nondysphorics, dysphorics showed reduced zygomaticus major muscle reactivity and blunted self-reported liking during reward consumption but normal corrugator supercilii muscle reactivity and normal self-reported disliking during punishment consumption.

Keywords: depression, dysphoria, reward responsiveness, punishment responsiveness, cardiovascular reactivity, EMG reactivity

Introduction

Major depressive disorder (MDD) is a common and recurrent psychiatric disorder with two core diagnostic criteria: depressed mood and anhedonia. Anhedonia is defined as the loss of interest or pleasure (5th edition of the Diagnostic and Statistical Manual of Mental Disorders; American Psychiatric Association, 2013) and has often been conceptualized in terms of impairments in reward and punishment processing (see Eshel & Roiser, 2010; Pizzagalli, 2014, for reviews).

Reward processing is considered a complex construct involving two major components. Firstly, the anticipatory component—or reward *wanting*—corresponds to the motivation to obtain a reward. Secondly, the consummatory component—or reward *liking*—is defined as the affective responses to reward (Berridge & Kringelbach, 2008; Berridge & Robinson, 2003; Gard, Gard, Kring, & John, 2006). In contrast, punishment processing has not been investigated in the same detail as reward. We suggest that this concept can also be divided into two main components: firstly, punishment *wanting*, which is the motivation to avoid a punishment; and secondly, punishment *disliking*, which corresponds to the affective responses to punishment.

Reward and punishment anticipation in depression

Regarding the anticipatory component of reward processing, theories and empirical results converge on the conclusion that individuals with depression show impaired, that is, reduced approach behavior (e.g., Depue & Iacono, 1989; Dickson & MacLeod, 2006; Fowles, 1994), which is also linked to reduced positive reinforcement from the environment (Beck, Rush, Shaw, & Emery, 1979; Jacobson, Martell, & Dimidjian, 2001). Using behavioral, neuroimaging, and self-report measures, the majority of studies focusing on reward anticipation have demonstrated that clinical and subclinical depression is associated with

reduced motivation to obtain rewards and with reduced reward responsiveness (e.g., Forbes et al., 2009).

Concerning the anticipatory component of punishment processing, theories and empirical results are inconsistent (for a review, see Eshel & Roiser, 2010), with some studies showing reduced punishment responsiveness in clinical and subclinical depression (Gotlib et al., 2010; Schiller, Minkel, Smoski, & Dichter, 2013) and other studies finding no differences (Knutson, Bhanji, Cooney, Atlas, & Gotlib, 2008; Olino et al., 2011). We believe that these inconsistencies are due to the different levels of analysis and to a differential response pattern to be discussed later. For now, two elements have to be considered: On the one hand, depression is characterized by avoidance behavior (see Ottenbreit & Dobson, 2004; Trew, 2011, for reviews), which goes along with a preserved motivation to avoid punishments. On the other hand, avoidance behavior in depression is of a passive, maladaptive nature: Indeed, depression is characterized by disengagement (Rottenberg, Gross, & Gotlib, 2005), by hopelessness (Abramson, Seligman, & Teasdale, 1978), and by a strong behavioral inhibition system, which leads to passive avoidance (Fowles, 1994). Taking these elements together, we expect individuals with depression to be motivated to avoid a punishment but to show a passive avoidance behavior in anticipation of that punishment, which prevents them from successfully avoiding it. In contrast, nondepressed individuals are expected to be motivated to avoid a punishment and to show an active avoidance behavior.

Reward and punishment anticipation from an effort mobilization perspective

In contrast to the many behavioral and particularly neuroimaging studies, only a few studies have investigated reward and punishment anticipation from a motivational perspective. These studies used effort-related cardiovascular reactivity as the operationalization of anticipatory reward and punishment responsiveness (Brinkmann &

Franzen, 2013; Brinkmann, Franzen, Rossier, & Gendolla, 2014; Brinkmann, Schüpbach, Ancel Joye, & Gendolla, 2009; Franzen & Brinkmann, 2015). Results demonstrate that subclinical depression (i.e., dysphoria) is linked to reduced effort mobilization during incentive anticipation compared to the effort nondysphoric individuals mobilize. These studies are based on motivational intensity theory (Brehm & Self, 1989) and define effort mobilization as the mobilization of resources to attain goals (Gendolla & Wright, 2009). When task difficulty is unclear (i.e., when the performance standard is unknown) or unfixed (i.e., when the performance standard can be chosen by the individual), motivational intensity theory postulates that success importance has a direct impact on effort mobilization. Rewards and punishments, in turn, are variables that influence success importance (Brehm & Self, 1989; Richter, 2012): *The greater the reward or the punishment, the greater the importance of success and, therefore, the greater the effort mobilization. Choosing a task with unclear task difficulty thus allows for investigating the direct impact of a reward or punishment on the effort that people mobilize. Concerning the specific case of individuals with depression, rewards are not expected to increase success importance, and thus should not lead to higher effort mobilization. In contrast, punishments are expected to increase success importance (i.e., the subjective motivation to avoid a punishment). However, due to the passive nature of avoidance behavior in depression discussed above, effort mobilization should be weak, despite high subjective success importance.*

Wright (1996) suggests that effort mobilization can be operationalized by cardiovascular parameters that are influenced by sympathetic activation. This suggestion is based on two theories: firstly, Brehm and Self's (1989) motivational intensity theory; and secondly, Obrist's (1981) active coping approach, which considers engagement in active coping tasks to be associated with beta-adrenergic sympathetic nervous system impact on the heart. Among the most common noninvasive cardiovascular parameters is the pre-ejection

period (PEP), which is the time interval between the onset of left ventricular excitation and the opening of the heart's aortic valve. This cardiovascular parameter is a reliable and direct measure of the force of myocardial contraction and therefore of beta-adrenergic influences on the myocardium (Gendolla, 2012). Other cardiovascular parameters include systolic blood pressure (SBP), which strongly depends on the force of myocardial contraction. In contrast, diastolic blood pressure (DBP) is predominantly determined by total peripheral resistance, which is not systematically influenced by sympathetic activation. Finally, heart rate (HR) is determined by both sympathetic and parasympathetic activation (Papillo & Shapiro, 1990). Following Wright's integrative model, PEP can be considered a reliable means for operationalizing effort mobilization. Historically, SBP has also been successfully used in the framework of motivational intensity theory, whereas the evidence for DBP and HR is mixed (for a review, see Gendolla, Wright, & Richter, 2012).

Several studies in the framework of motivational intensity theory have demonstrated that healthy participants show increased PEP and SBP reactivity during reward anticipation, compared to a neutral condition (Richter & Gendolla, 2006, 2007, 2009). In contrast, during performance of mental tasks that are instrumental for obtaining a reward or avoiding a punishment, increases in PEP, SBP, and HR reactivity of dysphoric participants are either nonexistent or significantly reduced compared to nondysphorics' reactivity (Brinkmann & Franzen, 2013; Brinkmann et al., 2009, 2014; Franzen & Brinkmann, 2015). There is thus first evidence for reduced effort-related cardiovascular reactivity in dysphoria during the anticipation of positive or negative consequences. However, none of these studies have simultaneously investigated the two components of reward and punishment processing, which are the anticipatory and the consummatory phase. A complete picture of the whole process of reward and punishment responsiveness on a peripheral physiological level is still lacking.

Reward and punishment consumption in depression

In comparison to the anticipatory component of reward and punishment processing, theory regarding the consummatory component is less extensive. With respect to consummatory affective responses, it is of note that a lack of positive affect and pleasurable life experiences along with a pronounced negative affect are important features of depression (Clark & Watson, 1991). Moreover, individuals with depression perceive less positive affect and more negative affect in their environment (Beck et al., 1979; Jacobson et al., 2001) and have difficulties enjoying pleasant events (Costello, 1972; Klein, 1974; Meehl, 1975). Based on these considerations, we expect individuals with clinical and subclinical depression to show reduced affective responses to reward but similar affective responses to punishment when compared to nondepressed individuals.

On an empirical level, the consummatory component has been studied less extensively than the anticipatory component. Using self-report, behavioral, and neuroimaging measures, the majority of the studies show weaker affective responses to reward in clinical and subclinical depression (Dichter, Kozink, McClernon, & Smoski, 2012; Forbes et al., 2009). A few studies have investigated punishment consumption and found no differences between depressed and nondepressed individuals in their affective responses to punishment (Bress, Foti, Kotov, Klein, & Hajcak, 2013).

Reward and punishment consumption from a facial expressions perspective

The majority of studies focusing on the consummatory phase have used central physiological measures. A more direct and very specific measure of the affective reactions to rewards and punishments with high temporal resolution is facial electromyography (EMG; Berridge & Kringelbach, 2008; Berridge & Robinson, 2003). Facial EMG allows for the objective and unobtrusive measurement of subtle positive and negative affective states.

Empirical research consistently shows that facial EMG activity over the corrugator supercilii muscle region (i.e., “frowning”) is higher during exposure to negative than positive stimuli and correlates with self-reported negative affect (e.g., Cacioppo, Petty, Loesch, & Kim, 1986; Larsen, Norris, & Cacioppo, 2003; Tan et al., 2012). In contrast, facial EMG activity over the zygomaticus major muscle region (i.e., “smiling”) is higher during exposure to positive than negative stimuli and correlates with self-reported positive affect (e.g., Cacioppo et al., 1986; Larsen et al., 2003; Tan et al., 2012). Therefore, facial EMG is a very promising way of gaining insights on how the receipt of a reward or a punishment is expressed and experienced. However, studies investigating reward and punishment consumption through human facial expressions are scarce.

The few studies that focus on facial EMG activity in depression demonstrate that individuals with clinical and subclinical depression respond with increased activity of the corrugator supercilii muscle to unhappy expressions (Sloan, Bradley, Dimoulas, & Lang, 2002), unpleasant images (Sloan, Strauss, & Wisner, 2001), and sad imagery (Schwartz, Fair, Salt, Mandel, & Klerman, 1976), just as do nondepressed control participants. However, in comparison to nondepressed participants, individuals with clinical and subclinical depression do not show an increased activity of the zygomaticus major muscle in response to happy expressions (Sloan et al., 2002), pleasant images (Sloan et al., 2001), and happy imagery (Schwartz et al., 1976). Based on these findings, we expect that there are normal affective responses to negative events but reduced affective responses to positive events in depression.

The present studies

Reward and punishment responsiveness in clinical and subclinical depression has been a focus of past and recent research. Findings mainly stem from studies involving self-report, behavioral, or central physiological measures (see Eshel & Roiser, 2010, for a review).

However, studies using specific peripheral physiological indicators of the anticipatory and consummatory components are scarce. A couple of studies have investigated effort-related cardiovascular reactivity as a specific and objective measure of reward and punishment anticipation (Brinkmann & Franzen, 2013; Brinkmann et al., 2009, 2014; Franzen & Brinkmann, 2015). To the best of our knowledge, facial EMG as a specific and objective measure of reward and punishment consumption (Berridge & Kringelbach, 2008; Berridge & Robinson, 2003) has not been investigated to date.

Based on the findings reported above, the aim of the present studies was twofold: Firstly, we aimed at investigating reward and punishment responsiveness in subclinical depression (i.e., dysphoria) not only during anticipation but also separately during consumption. Secondly, we aimed at using a multi-method approach and at assessing specific objective peripheral measures together with subjective self-report measures. The present studies allow us to compare anticipatory and consummatory responses to the same incentive and to integrate information from self-report and peripheral physiology. This approach is crucial for punishment responsiveness in particular, as we expect a differential response pattern with respect to the two phases but also with respect to self-report and physiology during anticipation.

In both studies, cardiovascular reactivity was used to assess anticipatory reward and punishment responsiveness during the performance of an instrumental task allowing to obtain a reward or to avoid a punishment. Self-reported wanting was used to evaluate the motivation to obtain the reward or to avoid the punishment. Facial EMG reactivity and self-reported (dis)liking were used to assess the affective responses to reward and punishment consumption. Beyond the advantages of the peripheral physiological measures discussed above, effort-related cardiovascular reactivity and facial expressions might give hints for specific therapeutic approaches that target specific impairments in effort mobilization or in

(dis)pleasure expression in response to positive or negative consequences. Both study protocols were approved by the appropriate local ethics committee.

Concerning reward processing and in line with the absence of approach behavior in depression, we predicted that dysphoric individuals would report reduced motivation to obtain the reward and show reduced anticipatory reward responsiveness. Furthermore, we expected that dysphoric individuals would show reduced affective responses during reward consumption.

Regarding punishment processing and considering the presence of avoidance behavior in depression, we hypothesized that dysphoric individuals would report normal motivation to avoid the punishment. However, because avoidance behavior *is of a passive nature* in depression, we predicted reduced anticipatory punishment responsiveness. Furthermore, we expected that dysphoric individuals would show unchanged affective responses during punishment consumption.

Study 1: Reward processing

The first study was a quasi-experiment with two between-person conditions (dysphorics vs. nondysphorics) and two within-person conditions (reward anticipation vs. consumption). Concerning the anticipatory component, we expected reduced PEP reactivity and reduced self-reported wanting of dysphoric participants in comparison to nondysphoric participants. *As SBP is a less reliable indicator of sympathetic impact on the myocardium than PEP, SBP can but does not necessarily have to mirror the PEP pattern. We assessed HR and DBP for the sake of interpretability of PEP reactivity (to be discussed later).* Regarding the consummatory component, we predicted that dysphoric participants would show reduced zygomaticus major muscle reactivity and reduced self-reported liking.

Method

Participants. Participants were recruited from an introductory psychology course in exchange for course credit. Three to six weeks before the experimental session, potential participants filled in the Center for Epidemiologic Studies – Depression Scale (CES-D, Radloff, 1977). If their score on this depression questionnaire was situated in the lower quartile or the upper quartile of the distribution, they were invited via an anonymous code to participate in the experimental session, where we administered the CES-D a second time. From the initial sample of 44 participants in the experimental session, only those whose CES-D scores stayed within the lower (≤ 12) or upper (≥ 18) quartile of the CES-D were retained for analyses ($N = 37$). Furthermore, two participants were excluded because of the bad signal quality of primary physiological recordings (PEP, EMG).

The final sample was composed of 35 university students, 27 women and 8 men aged between 18 and 44 ($M = 22.11$, $SD = 5.10$). Eighteen participants were situated in the lower quartile of the CES-D ($M = 6.11$, $SD = 3.71$) and were referred to as nondysphorics. Seventeen participants were located in the upper quartile of the CES-D ($M = 28.00$, $SD = 6.06$) and were referred to as dysphorics.

Experimental task and reward manipulation. The experimental task was an adapted version of the D2 mental concentration test (Brickenkamp & Zillmer, 1998). For each trial, a fixation cross was presented in the middle of the screen for 500 milliseconds. Then, a picture that could depict the letter “d” or the letter “p” was presented, accompanied by 1 to 4 apostrophes below or above the letter. Then, the picture was masked and participants had to identify if the picture depicted or not the letter “d” accompanied by exactly 2 apostrophes by pressing a “yes” or a “no” key on the keyboard. After the participants’ response, the message

“answer recorded” appeared. If no answer had been recorded after 3 seconds, the message “please answer more quickly” appeared for 1 second. Then, a new trial started.

It was important to create a task with an unclear level of difficulty in order to apply the predictions of motivational intensity theory regarding the direct impact of rewards and punishments on effort mobilization. The D2 task was chosen as a common concentration task that can easily be modified into a task with unclear difficulty. Accordingly, participants only received information about the general procedure of the task but none of its details, such as the total number of trials or the duration of the stimulus presentation (i.e., the difficulty). In fact, there were 51 trials with varying stimulus durations (66, 200, or 333 milliseconds). Moreover, the required performance standard was revealed only at the end of the task.

Concerning the reward manipulation, participants were informed that they could win 10 Swiss Francs (about 10 USD) at the end of the experiment if their performance was equal to or greater than a performance standard that would be revealed later. In order to have a measure of the consummatory component for all participants, an individual performance standard was secretly created for each individual, and the reward was given to all participants. The computer program calculated the individual performance standard by subtracting 2 from each participant's number of correct responses.

Physiological measures. Cardiovascular measures were collected noninvasively during the habituation period and during task performance. PEP (in milliseconds [ms]) and HR (in beats per minute [bpm]) were measured using a Cardioscreen® 1000 haemodynamic monitoring-system (medis, Ilmenau, Germany) (for a validation study see Scherhag et al., 2005). This system continuously samples electrocardiogram (ECG) and impedance cardiogram (ICG) signals at 1000 Hz and uses four dual gel-pad sensors (medis-ZTECT™). These were placed on each side of the base of the participant's neck and on each side of the thorax at the level of

the xiphoid. We used a Vasotrac® APM205A monitor (MEDWAVE®, St. Paul, MN) (for a validation study, see Belani et al., 1999) to assess SBP and DBP (both in millimeter of mercury [mmHg]). However, as the device ceased to function in the middle of the assessment period, no blood pressure data are available for 14 of the 35 participants. Thus, we decided to exclude SBP and DBP data from the analyses.

Facial EMG was assessed just before and during the transmission of the reward information. A MindWare monitor (MindWare Technologies LTD, Gahanna, OH) was used to record the facial EMG signal, which was continuously sampled at 1000 Hz. This system uses three 4-mm Ag/AgCl surface electrodes filled with specific conductive gel. Two of them were used for the activity of the zygomaticus major muscle and the last one was an isolated ground electrode which served as a reference. The first electrode was positioned in the middle of an imaginary line extending from the corner of the lip at rest (i.e., cheilion) to the corner of the ear (i.e., ipsilateral condylion). Continuing along this imaginary line, the second electrode was placed approximately 1 cm further back. The third electrode was attached to the forehead on the edge of the hair line, an electrically inactive site (Fridlund & Cacioppo, 1986). The EMG signal was filtered with a 10-500 Hz passband in order to maximize the signal-to-noise ratio (Tassinari, Cacioppo, & Vanman, 2007). Electrical activity was measured using a bipolar recording, and the EMG signal was amplified with a constant gain of 1000 (Fridlund & Cacioppo, 1986).

Subjective measures. In order to measure the severity of depressive symptomatology, we used the French version of the CES-D (Fuhrer & Rouillon, 1989). This self-report depression scale was initially developed for community samples. It consists of 20 items investigating the frequency of depressive symptoms during the past week using 4-point scales ranging from 0 (*never, very seldom*) to 3 (*frequently, always*). The total score is calculated by summing all

items (four reverse-scored items) and can vary from 0 to 60 (Cronbach's α of the CES-D assessed during the experimental session = .94).

Furthermore, participants indicated their motivation to obtain the reward ("To what extent are you motivated to obtain the 10-Swiss-Francs reward?") on a visual analogue scale from 0 (*not motivated*) to 100 (*very motivated*). Similarly, we measured subjective affective responses to reward ("To what extent the reward you received causes pleasure in you?") on a visual analogue scale from 0 (*no pleasure*) to 100 (*a lot of pleasure*).

Procedure. This study was divided into two parts, a questionnaire session and an experimental session. Participants first answered the CES-D and, depending on the quartile they found themselves in, were invited for the experimental session.

The experimental session was individual, took about 40 minutes, and was conducted on a personal computer with experimental software (Inquisit 3.0, Millisecond Software, Seattle, WA) that presented all instructions and stimuli. At the beginning, the experimenter, who was blind to both the hypotheses and the experimental conditions of the study, welcomed the participants, and asked them to take a seat and to sign a consent form. Afterwards, the experimenter applied the sensors for the measure of cardiovascular and facial EMG activity, left the room, and monitored the experiment from an outside control room. Participants then started the first part of the experimental session, which consisted of two questionnaires—the CES-D and an unrelated questionnaire—both ostensibly for an unrelated questionnaire validation study. When they had finished, the experimenter reentered the room, started the second part of the experimental session, and left the room. During this second part, participants first read introductory study information and answered some biographical questions. Next, participants watched an 8-minute excerpt of a neutral documentary movie, during which cardiovascular baseline measures were assessed. After this habituation period,

task and reward instructions were provided and participants evaluated their motivation to obtain the reward. Following this, they worked on the D2-concentration task for 5 minutes, during which cardiovascular and performance measures were assessed. After the last trial, a blank screen appeared for 2 seconds, followed by the information that the task was finished (5 seconds). Then, participants were informed about the performance standard, about their own performance score, and about having won the reward (10 seconds). Facial EMG measures were assessed during the brief rest period and the transmission of the reward information. Participants then evaluated the affective value of the reward. The experimenter then reentered the room, removed the physiological recordings material, and gave the monetary reward. Finally, participants were thanked and debriefed.

Data reduction. For PEP measures, the first derivative of the change in thoracic impedance was computed. The resulting dZ/dt signal was synchronized with the ECG signal and ensemble averaged over periods of 60 seconds. The ECG R-onset was automatically detected by LabVIEW-based software (National Instruments, Austin, TX) developed in our laboratory (Richter, 2009), and the ICG B-point (the indicator of the opening of the aortic valve) was visually determined by two independent raters, as recommended by Sherwood et al. (1990). The PEP was determined as the time interval between ECG R-onset and ICG B-point (Berntson, Lozano, Chen, & Cacioppo, 2004). Because the inter-rater agreement was high ($ICC(2,1) = .99$, Shrout & Fleiss, 1979), the arithmetic mean of both raters' PEP values was used for statistical analyses. HR (in beats per minute), was determined by means of the same software that detects and counts R-peaks in the ECG signal, which were visually confirmed afterwards.

PEP and HR baseline scores (Cronbach's $\alpha > .98$) were computed as the arithmetic means of PEP and HR measures assessed during the last 4 minutes of the habituation period.

Arithmetic means of PEP and HR measures assessed during the 5-minute task performance constituted task scores (Cronbach's α s > .98). Cardiovascular reactivity scores were then computed for each participant and both cardiovascular parameters by subtracting baseline scores from their respective task scores (see Kelsey et al., 2007; Llabre et al., 1991).

For the zygomaticus major muscle activity, EMG recordings were assessed. Two reactivity scores—a mean score and a maximum score—were computed. For the mean score, a baseline mean score was computed as the arithmetic mean of all data points assessed during the last 2 seconds of the rest period, just before participants were informed they had obtained the reward. A reward mean score was computed as the arithmetic mean of all data points assessed during the first 2 seconds of the period when participants were told they had obtained the reward. The muscular reactivity mean score was then computed as the difference between the reward score and the baseline score. The maximum score was computed with exactly the same procedure. However, instead of averaging all data points, we took the maximum value of each period to calculate the baseline maximum score, the reward maximum score, and the muscular reactivity maximum score (Fridlund & Cacioppo, 1986; Tassinary et al., 2007). Concerning our hypotheses, mean and maximum reactivity scores are comparable. Therefore, both are considered primary EMG measures.

Independent samples *t*-tests were computed to compare dysphoric and nondysphoric participants on all physiological and self-report measures. Given the small number of men in the present study, we repeated all analyses by including women only. As the results did not change, we report the results for the whole sample without considering the participants' gender.

Results

Preliminary analyses. Preliminary analyses revealed no significant group effect for the PEP baseline measure, $t(33) = 0.52, p = .48$, and for the two EMG baseline scores, $ts < 1.62, ps > .09$. However, results revealed a significant effect for the HR baseline measure, $t(33) = 2.26, p = .03, \eta_p^2 = .07$, suggesting that the nondysphoric group had a lower HR baseline value than the dysphoric group. Means and standard errors of the baseline measures for PEP, HR, EMG mean score, and EMG maximum score are presented in Table 1.

Reward anticipation analyses. Concerning anticipatory reward responsiveness, analyses revealed a significant result for PEP, our main cardiovascular dependent variable, $t(33) = 2.15, p = .04, \eta_p^2 = .13$. These results demonstrate that nondysphorics' PEP reactivity was higher than dysphorics' PEP reactivity, which confirms our hypothesis (see Figure 1A). The t -test for HR reactivity was not significant, $t(33) = -0.05, p = .96$ (see Table 2 for means and standards errors of all physiological reactivity scores).

Regarding the subjective motivation to obtain a reward, the t -test revealed a significant group difference, $t(33) = -2.14, p = .04, \eta_p^2 = .13$. Confirming our hypothesis, this result indicates a higher level of subjective motivation in the nondysphoric group ($M = 69.28, SE = 4.04$) than in the dysphoric group ($M = 55.24, SE = 5.21$) (see Figure 1B).

Reward consumption analyses. Regarding objective measures of the consummatory component, t -tests revealed a significant result for the EMG maximum reactivity score, $t(33) = -2.19, p = .04, \eta_p^2 = .13$. As illustrated in Figure 1C, nondysphorics' EMG maximum reactivity was significantly higher than dysphorics' EMG maximum reactivity. The t -test for EMG mean reactivity was not significant, $t(33) = -1.01, p = .32$, contrary to our hypothesis suggesting enhanced EMG mean reactivity in nondysphoric participants (see Table 2 for means and standards errors).

The analyses of the subjective measure of the consummatory component revealed a significant group difference, $t(33) = -2.30$, $p = .03$, $\eta_p^2 = .14$. This result confirms that subjective liking was higher for nondysphoric participants ($M = 73.17$, $SE = 3.56$) than for dysphoric participants ($M = 57.94$, $SE = 5.68$) (see Figure 1D).

Brief Discussion

The aim of the first study was to investigate the two components of reward processing (i.e., anticipation and consumption) in dysphoric and nondysphoric participants, using both objective and subjective measures. The results of this study generally confirm our predictions: During reward anticipation, dysphoric participants show reduced PEP reactivity and report less motivation to obtain the reward. During reward consumption, dysphoric participants show weaker zygomaticus major muscle reactivity (EMG maximum score) and report reduced pleasure experience. However, this effect was not found for the EMG mean score.

Taken together, these findings demonstrate that in comparison to nondysphoric participants, dysphoric participants are less motivated to obtain a reward and show reduced reward responsiveness during anticipation. Furthermore, results suggest that compared to nondysphoric participants, dysphoric participants show weaker objective and subjective affective responses to reward during consumption.

Study 2: Punishment processing

The second study focused on the two components of punishment processing. This study was quasi-experimental and composed of two between-person conditions (dysphorics vs. nondysphorics) and two within-person conditions (anticipation vs. consumption). During punishment anticipation, we expected dysphoric participants to show unchanged self-reported wanting (i.e., normal motivation to avoid the punishment) but reduced PEP reactivity. During

punishment consumption, we predicted that dysphoric and nondysphoric participants would show comparable reactivity of the corrugator supercilii muscle and comparable self-reported disliking.

Method

Participants. Participants were university students recruited from an introductory psychology course who were given course credit for their participation. The final sample consisted of 30 participants, including 27 women and 3 men aged between 18 and 42 ($M = 21.37$, $SD = 4.96$). Sixteen participants scored in the lower quartile of the CES-D ($M = 5.25$, $SD = 3.07$) and were referred to as nondysphorics. Fourteen participants scored in the upper quartile of the CES-D ($M = 25.57$, $SD = 9.71$) and were referred to as dysphorics.

We used the same procedure as the in the first study for the selection of participants. Participants who scored in the lower (≤ 10) or in the upper quartile (≥ 15) of the current CES-D distribution were invited to the experimental session. From the sample of 43 participants in the experimental session, only those whose CES-D scores stayed within the limits set by the initial distribution were kept for analyses ($N = 34$). Additionally, 4 participants were excluded because of the bad signal quality of cardiovascular recordings (PEP, HR).

Procedure, experimental task, and punishment manipulation. The procedure of this study was identical to the first study. The study was composed of two parts—a questionnaire session and an experimental session. The experimental task was exactly the same as the one used in the first study (adapted version of the D2 mental concentration test; Brickenkamp & Zillmer, 1998). Concerning the punishment manipulation, participants were informed of their initial credit of 10 Swiss Francs (about 10 USD) and that they stood to lose it at the end if their performance was weaker than a performance standard, which would be revealed later. In

order to have a measure of the consummatory component for all participants, an individual performance standard was secretly created for all participants by adding 2 to each participant's number of correct responses, so that all participants lost their initial credit.

Physiological and subjective measures. PEP and HR reactivity were collected with the same system (Cardioscreen® 1000 haemodynamic monitoring-system) as in the first study. Systolic blood pressure (SBP, in millimeters of mercury [mmHg]) and diastolic blood pressure (DBP, in millimeters of mercury [mmHg]) were measured noninvasively using a Dinamap Procare 300 monitor (GE Medical Systems, Information Technologies Inc., Milwaukee, WI). A blood pressure cuff was placed over the brachial artery above the elbow of the participants' nondominant arm and automatically inflated every minute.

Facial EMG was recorded with the same system (MindWare Technologies LTD, Gahanna, OH) as in the first study. Three 4-mm Ag/AgCl surface electrodes filled with specific conductive gel were used, two to measure the activity of the corrugator supercilii muscle and one to use as a ground electrode. The first electrode was positioned just superior to the eyebrow along an imaginary vertical line that traverses the inner commissure of the eye fissure (i.e., endocanthion). The second one was placed laterally to the first, approximately 1 cm from the edge of the eyebrow. The third electrode was attached to the forehead on the edge of the hairline.

Concerning the subjective measures, we used the CES-D to assess depressive symptomatology (Cronbach's α of the CES-D during the experimental session = .96). Subjective motivation to avoid the punishment ("To what extent are you motivated to avoid the loss of the 10 Swiss Francs?") was assessed on a visual analogue scale. Similarly, we measured subjective affective responses to punishment ("To what extent the loss of money causes displeasure in you?") on a visual analogue scale.

Data reduction. PEP and HR activity was extracted in the same manner as in the first study.

Raw SBP and DBP readings (one per minute) were used without further reduction.

Cardiovascular baseline scores (Cronbach's α s > .98), task scores (Cronbach's α s > .97), and reactivity scores were computed as in the first study. The corrugator supercilii muscle activity was assessed using the same procedure as in the first study. Two reactivity scores were obtained: a mean score and a maximum score (Fridlund & Cacioppo, 1986; Tassinari et al., 2007). Given the small number of men in this sample, we repeated all analyses by including women only. As the results did not change, we report the results for the whole sample without considering the participants' gender.

Results

Preliminary analyses. Independent samples *t*-tests revealed no significant group differences of any of the cardiovascular baseline measures, t s < 0.99, p s > .33, and of the two EMG baseline scores, t s < -0.97, p s > .34. Means and standard errors of these physiological baseline measures are presented in Table 3.

Punishment anticipation analyses. The result of the PEP measure, our main dependent cardiovascular variable, was significant, $t(28) = -2.15$, $p = .04$, $\eta_p^2 = .15$. As illustrated in Figure 2A, this finding demonstrates that nondysphorics' PEP reactivity was higher than dysphorics' PEP reactivity. The *t*-tests for HR reactivity, SBP reactivity, and DBP reactivity were not significant, t s < -1.12, p s > .27 (see Table 4 for means and standard errors of all physiological reactivity scores).

The analysis of the self-reported motivation to avoid the punishment showed no significant group difference, $t(28) = 1.37$, $p = .18$. This suggests that the subjective motivation

to avoid punishment was not significantly different between the nondysphoric group ($M = 73.56$, $SE = 3.95$) and the dysphoric group ($M = 63.79$, $SE = 6.18$) (see Figure 2B).

Punishment consumption analyses. Concerning our measures of the consummatory component, t -tests revealed no significant group differences for the two EMG reactivity scores, $ts < -0.26$, $ps > .79$. Means and standard errors of these measures are presented in Table 4. Moreover, t -tests were not significant for self-reported disliking, $t(28) = 0.33$, $p = .74$, suggesting that dysphoric participants ($M = 52.29$, $SE = 7.56$) reported a similar displeasure than nondysphoric participants ($M = 55.25$, $SE = 5.20$) during punishment consumption. These two results indicate that objective and subjective disliking did not significantly differ between dysphorics and nondysphorics (see Figures 2C and 2D).

Brief Discussion

Using both objective and subjective measures, the aim of the second study was to investigate the two components of punishment processing in dysphoric and nondysphoric participants. Concerning the anticipatory component, the results of our main cardiovascular dependent variable confirm our predictions. As expected, dysphoric participants show reduced PEP reactivity in comparison to nondysphoric participants. Still in line with predictions, dysphoric and nondysphoric participants report similar motivation to avoid the punishment. Concerning the consummatory component, results corroborate that there is no evidence for a difference between dysphoric and nondysphoric participants. More precisely, both groups show similar reactivity of the corrugator supercilii muscle and report a similar experience of displeasure.

Taken together, these findings show a differential response pattern of dysphoric participants: While dysphoric participants are subjectively motivated to avoid a punishment,

they show reduced punishment responsiveness during punishment anticipation. Results concerning the consummatory component suggest that both dysphoric and nondysphoric participants show similar objective and subjective affective responses during punishment consumption.

General discussion

The aim of the present studies was firstly the investigation of two distinct phases—anticipation and consumption—of reward and punishment processing in subclinical depression within the same experiment. Past studies often times focused on one component or did not clearly dissociate the phases. Secondly, we aimed at assessing subjective evaluations along with specific peripheral physiological measures (i.e., effort-related PEP reactivity and facial EMG responses) that promise new insights beyond the central physiological measures of past studies.

Anticipatory component

Results concerning the anticipatory component of reward and punishment processing confirm our hypotheses. Both studies demonstrate that dysphoric participants show reduced PEP reactivity, our primary cardiovascular measure, during reward and punishment anticipation. These results add to the evidence from previous studies with dysphoric participants within the framework of motivational intensity theory (Brinkmann & Franzen, 2013; Brinkmann et al., 2009, 2014; Franzen & Brinkmann, 2015).

For the interpretation of PEP reactivity, it should be noted that PEP reactivity is not only determined by sympathetic influence on the myocardium, but also by cardiac preload and cardiac afterload. Left ventricular filling is one of the most important determinants of preload, while aortic diastolic pressure is one determinant of afterload (Sherwood et al.,

1990). Therefore, PEP reactivity should be evaluated only in light of changes in HR and DBP, with changes in HR indicating changes in preload and changes in DBP indicating changes in afterload. In particular, if PEP changes were due to a change in afterload, one would expect that a shortening of the PEP would be accompanied by a decrease of DBP. In a similar vein, if PEP changes were due to a change in ventricular filling, one would expect that a shortening of the PEP would be accompanied by a decrease of HR (Obrist, Light, James, & Strogatz, 1987; Sherwood et al., 1990). Descriptive data of both studies show that the shortening of PEP in the nondysphoric groups was accompanied by an increase of HR and DBP. Therefore, it seems unlikely that changes in PEP were caused by changes in aortic diastolic pressure or ventricular filling.

In contrast to PEP reactivity, SBP, DBP, and HR reactivity did not significantly differ between dysphoric and nondysphoric participants. The lack of an effect on HR reactivity can be explained by the fact that HR is determined by both sympathetic and parasympathetic branches of the autonomous nervous system. Thus, sympathetic influences could have been masked by parasympathetic influences. In a similar vein, the absence of an effect on SBP and DBP reactivity can be explained by the fact that blood pressure is a function of heart rate, myocardial contractility, and peripheral resistance. Sympathetic effects on blood pressure could have been masked by changes in total peripheral resistance. In line with these physiological explications, past research based on motivational intensity theory has revealed mixed evidence for HR and DBP (for a review, see Gendolla, Brinkmann, & Silvestrini, 2012). Concerning SBP, past research has relied on and found effects on SBP reactivity (e.g., Gendolla & Wright, 2005). However, several recent studies focusing on incentives did not find an effect on SBP (Brinkmann & Franzen, 2013; Franzen & Brinkmann, 2015; Freydefont & Gendolla, 2012).

Apart from PEP reactivity, results of the self-report data in both studies support our hypothesis that dysphoric individuals have reduced motivation to obtain the reward (Study 1) but similar motivation to avoid the punishment (Study 2), compared to nondysphoric individuals. Results for reward are in line with previous self-report studies (Chentsova-Dutton & Hanley, 2010). Dysphoric individuals' unchanged motivation to avoid a punishment has been reported, for instance, by Layne (1980).

The differential response pattern of dysphoric participants during punishment anticipation in Study 2 deserves further discussion, particularly in light of previous inconsistent findings about punishment responsiveness in depression (see Eshel & Roiser, 2010, for a review). We think that this inconsistency could be due to the lack of differentiation between the motivation to avoid a punishment and the behavioral response given by the individuals during a period where active behavior is required to avoid a negative consequence. As demonstrated by the similar self-reported wanting measure in Study 2, we suppose that both nondepressed individuals and individuals with depression are motivated to avoid a punishment by showing avoidance behavior (see Ottenbreit & Dobson, 2004, for a review). However, whereas nondepressed individuals show active avoidance behavior leading to successful avoidance of the punishment, individuals with depression show passive avoidance behavior, which translates into reduced responsiveness and is a maladaptive way of avoiding the punishment. In this context, it is important to note that we conceive of reduced effort mobilization as a maladaptive passive avoidance behavior and not necessarily as a lack of behavior, which might be an adaptive avoidance response in certain circumstances.

The dissociation between subjective responses on the one hand and physiological and behavioral responses on the other hand—as evidenced in Study 2—underlines the importance of an in-depth analysis of the mechanisms underlying punishment responsiveness in depression. For example, we have shown elsewhere (Franzen & Brinkmann, 2016, Study 1)

that a rather external locus of control might be responsible for dysphoric individuals' reduced effort mobilization during monetary punishment anticipation, despite a preserved self-reported motivation to avoid the monetary loss. Moreover, this dissociation implies that therapeutic interventions should specifically target the behavioral component, i.e., the passive avoidance behavior, not necessarily the subjective component.

Consummatory component

Concerning the consummatory component of reward and punishment processing, results of both studies support our predictions. Specifically, the first study demonstrated that dysphoric participants showed decreased zygomaticus major muscle reactivity and reported less pleasure than nondysphoric participants during reward consumption. The second study demonstrated that both groups showed similar reactivity of the corrugator supercilii muscle and both groups reported a similarly unpleasant experience during punishment consumption. These results are in line with previous studies investigating facial expressions in response to emotional material in a dysphoric sample (Sloan et al., 2001, 2002). Moreover, this congruence between facial EMG measures and subjective evaluations has also been demonstrated in past research (Lang, Reenwald, Bradley, & Hamm, 1993). In particular, corrugator supercilii activity is positively correlated with rated displeasure, whereas zygomaticus major activity is positively correlated with rated pleasure.

One could argue that the results of the present studies reflect a general pattern of sad facial expression in dysphoria (e.g., Schwartz et al., 1976). However, it is important to note that we measured facial EMG reactivity as a change from baseline. Dysphoric and nondysphoric participants did not significantly differ in terms of facial activity during baseline. Moreover, they did not significantly differ during punishment consumption but they did show reduced facial EMG reactivity during reward consumption. These results lead to the

conclusion that dysphoric individuals do not show a general pattern of sad facial expression but that the presence of rewards or punishments modulates their facial expressions.

Limitations and Future Directions

There are a couple of specific features and limitations of the present studies, which give rise to directions for future research. Firstly, we investigated reward and punishment responsiveness in two separate experiments with two different (albeit similar) samples. This choice was based on the difficulty to formulate specific hypotheses for comparing reward and punishment responsiveness. Monetary gains and losses typically are of different value for people. Following the endowment effect (Kahneman et al., 1991), we can expect that monetary punishment leads to stronger responses, but it is difficult to predict how this translates into a specific difference for reward and punishment responsiveness (e.g., by which factor PEP reactivity of nondysphoric participants should be stronger during punishment anticipation compared to reward anticipation?). Even though we ran two separate experiments, the samples and effect sizes were quite similar. Both samples were composed of university students from an introductory psychology class, and the CES-D scores of the two studies did not significantly differ, neither for the nondysphoric group, nor for the dysphoric group. In both studies, effect sizes for significant effects were rather large, with η_p^2 of about .14, which indicate that dysphoric and nondysphoric participants strongly differ in their reward and punishment responsiveness.

Secondly, a limitation of the present studies might be the short time interval of 7 seconds between the end of the last task trial and the transmission of the reward or punishment information, which might have been relatively short for EMG activity to reach baseline level. Even though inter-trial intervals of 5 or 6 seconds are common in EMG research (e.g., Larson et al., 2003; Tan et al., 2012), future studies might improve the

dissociation of the anticipatory and the consummatory phase by using a longer—but still credible—time interval between the two phases.

Thirdly, in the present studies we had one-time measurements (i.e., one reactivity measure) for the anticipatory and for the consummatory components. This choice was due to the relatively slow responding of cardiovascular measures, which prevented multiple repetitions of the anticipation phase, and the fact that we intended to keep the design similar for both phases. Future studies that are interested only in the consummatory component might take advantage of repeatedly measuring EMG response and self-report on a trial-by-trial basis to enhance reliability.

Conclusion

In summary, using both physiological and self-report measures, the present two studies confirm our predictions. With a focus on reward processing, the first study confirmed that compared to nondysphoric individuals, dysphoric individuals show reduced self-reported motivation to obtain a reward, accompanied by reduced cardiac responsiveness to reward during anticipation. Moreover, affective responses (self-report and facial expressions) during reward consumption were reduced as well in dysphoria. The second study focused on punishment processing and corroborated that in comparison to nondysphoric individuals, dysphoric individuals have a similar self-reported motivation to avoid the punishment, but show reduced cardiac responsiveness during punishment anticipation. Furthermore, dysphoric individuals' affective responses (self-report and facial expressions) during consumption were similar to those of nondysphoric individuals.

The results of the present studies underline the importance to differentiate not only between reward and punishment responsiveness, but also between the anticipatory component and the consummatory component of incentive processing. In addition, both the subjective experience of incentive processing and the objective physiological response are important

dimensions to consider. In doing so, it is possible to conceive specific treatments that are able to alleviate these particular impairments in depression.

Several therapies for impaired reward responsiveness in depression have been proposed. For instance, behavioral activation is an appropriate therapy to increase the motivation to obtain a reward. The aim of this structured approach is to help [individuals with depression](#) to reengage in pleasant activities, which increase reinforcement from the environment, and in turn elicit the experience of pleasure (Cuijpers, van Straten, & Warmerdam, 2007; Hopko, Lejuez, Lepage, Hopko, & Mcneil, 2003). Furthermore, positive psychotherapy can be used to increase affective responses to reward. The aim of this therapy is to highlight positive emotions, engagement, and meaning and to help [individuals with depression](#) rediscovering pleasure (Seligman, Rashid, & Parks, 2006).

While several therapies for coping with impairments in reward responsiveness in depression exist, much less has been developed for improving punishment responsiveness. A specific impairment in punishment responsiveness is the passive response given by [individuals with depression](#), which is not appropriate and does not lead to successfully avoiding a negative consequence. An alleviation of this maladaptive response can be reached, for instance, by behavioral therapy. Individual are asked to identify a problematic behavior and to find an alternative behavior, which would be more adaptive in the given situation (Carvalho & Hopko, 2011).

[As the specific impairments are different from one individual to another, we suggest choosing the therapeutic approach that specifically targets the central complain of the patient. For instance, whereas one patient might have specific difficulties to successfully approach rewards and therefore benefits from behavioral activation therapy, another might not experience any positive feelings during episodes of positive, rewarding consequences and](#)

therefore rather benefit from working on facial expressions in order to improve pleasure expression and experience.

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Figure Captions

Figure 1. Means and standard errors of (A) Pre-Ejection Period reactivity and (B) self-reported wanting during reward anticipation, as well as means and standard errors of (C) EMG reactivity and (D) self-reported liking during reward consumption in Study 1.

Figure 2. Means and standard errors of (A) Pre-Ejection Period reactivity and (B) self-reported wanting during punishment anticipation, as well as means and standard errors of (C) EMG reactivity and (D) self-reported liking during punishment consumption in Study 2.

Figures

Figure 1

Figure 2

Tables

Table 1

Means and Standard Errors of Physiological Baseline Values in Study 1

	<i>M</i>			
	PEP	HR	EMG mean	EMG max
Nondysphorics	103.06	72.40	0.0042	0.0218
Dysphorics	99.47	79.00	0.0068	0.0473
	<i>SE</i>			
	PEP	HR	EMG mean	EMG max
Nondysphorics	4.14	1.80	0.0009	0.0054
Dysphorics	2.67	2.32	0.0012	0.0151

Note. PEP is indicated in milliseconds, HR is indicated in beats per minute, and EMG is indicated in microvolts.

Table 2

Means and Standard Errors of Physiological Reactivity in Study 1

	<i>M</i>			
	PEP	HR	EMG mean	EMG max
Nondysphorics	-8.82	3.38	0.00013	0.02
Dysphorics	-2.74	3.28	-0.00077	-0.02
	<i>SE</i>			
	PEP	HR	EMG mean	EMG max
Nondysphorics	2.49	1.62	0.00066	0.01
Dysphorics	1.23	1.15	0.00060	0.01

Note. PEP is indicated in milliseconds, HR is indicated in beats per minute, and EMG is indicated in microvolts.

Table 3

Means and Standard Errors of Physiological Baseline Values in Study 2

	<i>M</i>					
	PEP	HR	SBP	DBP	EMG mean	EMG max
Nondysphorics	101.34	77.84	101.02	56.89	0.0066	0.0280
Dysphorics	95.04	75.14	99.84	58.27	0.0088	0.0346
	<i>SE</i>					
	PEP	HR	SBP	DBP	EMG mean	EMG max
Nondysphorics	4.65	2.35	3.50	1.71	0.0012	0.0040
Dysphorics	4.15	3.18	2.19	1.28	0.0016	0.0056

Note. PEP is indicated in milliseconds, HR is indicated in beats per minute, SBP and DBP are indicated in millimeters of mercury, and EMG is indicated in microvolts.

Table 4

Means and Standard Errors of Physiological Reactivity in Study 2

	<i>M</i>					
	PEP	HR	SBP	DBP	EMG mean	EMG max
Nondysphorics	-9.97	1.34	5.13	4.30	-0.00007	-0.00064
Dysphorics	-3.14	3.03	6.12	3.29	-0.00005	-0.00005
	<i>SE</i>					
	PEP	HR	SBP	DBP	EMG mean	EMG max
Nondysphorics	2.83	0.83	1.75	0.71	0.00168	0.00011
Dysphorics	1.04	1.30	1.71	0.90	0.00131	0.00018

Note. PEP is indicated in milliseconds, HR is indicated in beats per minute, SBP and DBP are indicated in millimeters of mercury, and EMG is indicated in microvolts.