Anhedonic symptoms of depression are linked to reduced motivation to obtain a reward

Franzen, Jessica; Brinkmann, Kerstin

How to cite

FRANZEN, Jessica, BRINKMANN, Kerstin. Anhedonic symptoms of depression are linked to reduced motivation to obtain a reward. In: Motivation and emotion, 2016, vol. 40, n° 2, p. 300–308. doi: 10.1007/s11031-015-9529-3

This publication URL: https://archive-ouverte.unige.ch/unige:91461

Publication DOI: 10.1007/s11031-015-9529-3

Anhedonic Symptoms of Depression are Linked to Reduced Motivation to Obtain a Reward

Jessica Franzen & Kerstin Brinkmann
Geneva Motivation Lab, University of Geneva, Switzerland

Motivation and Emotion, 40, 300-308
doi:10.1007/s11031-015-9529-3

Abstract

People with depression report reduced motivation to obtain a reward and reduced affective responses to reward. However, studies focusing on the relation between anhedonia and deficits in reward processing are scarce. Furthermore, studies investigating wanting through cardiovascular reactivity and liking through facial electromyography in human beings are also scarce. In this study, we used the Temporal Experience of Pleasure Scale (TEPS) score as a continuous predictor variable of anhedonia and we manipulated two within-person conditions (wanting vs. liking). Participants earned money if their performance on a memory task exceeded a particular standard. As expected, effort-related cardiovascular reactivity and self-reports during the anticipatory phase were lower for participants scoring high on anhedonia. Moreover, task performance outcomes were worse for highly anhedonic participants. However, the zygomaticus major muscle’s activity during the consummatory phase was unrelated to the anhedonia score. The present study underlines the importance of anhedonic symptoms particularly in reduced anticipatory motivation to obtain a reward.

Keywords

Anhedonia**,** depression, reward wanting and liking, cardiovascular reactivity, muscular reactivity

1. Introduction

The concept of anhedonia was introduced by Ribot (1897) to describe insensitivity toward pleasure and represents a main symptom of major depressive disorder (MDD). This symptom is defined by the Diagnostic and Statistical Manual of Mental Disorders (DSM-5; American Psychiatric Association, 2013) as the “markedly diminished interest or pleasure in all, or almost all, activities most of the day, nearly every day (as indicated by either subjective account or observation)”. According to the DSM-5, this symptom is as important as negative mood because at least one of the two symptoms must be present to diagnose an MDD episode. According to Lewinsohn and colleagues, anhedonia is a frequent characteristic of MDD. Among adolescents who had experienced a MDD episode in their lifetime, 67% reported both negative mood and anhedonia, only 28% reported negative mood without anhedonia, and 5% reported anhedonia without negative mood (Lewinsohn, Pettit, Joiner, & Seeley, 2003). Moreover, anhedonia does not reflect an absence or a presence of pleasure, but appears on a continuum of hedonic tone (Ho & Sommers, 2013). Finally, this symptom can be considered a risk factor leading to the development of depression (Loas, 1996).

The concept of pleasure is a central element of anhedonia, and impairments in reward processing can be specifically related to this symptom. Several authors emphasize the importance of the chronology of the experience of pleasure and the differentiation between anticipatory and consummatory pleasure (Gard, Gard, Kring, & John, 2006; Klein, 1984). Anticipatory pleasure is related to a specific aspect of motivation that is linked to desire, whereas consummatory pleasure is related to satiation and resolution of desire. Moreover, these two components are linked to two of the three components described by Berridge and colleagues (e.g., Sherdell, Waugh, & Gotlib, 2012). Berridge and colleagues suggest three psychological components to be involved in the complex construct of reward processing: reward wanting, reward liking, and reward learning (Berridge, 2003; Berridge & Kringelbach, 2008; Berridge & Robinson, 1998). In the present study, we first focus on reward wanting, which is defined as the motivation to obtain a reward and which is linked to the experience of desire. According to the literature investigating this component, it corresponds to the anticipatory pleasure proposed by Gard and colleagues. Then, we focus on reward liking, which is defined as the affective responses to reward and which is linked to the experience of pleasure. According to the literature investigating this component, it corresponds to the consummatory pleasure proposed by Gard and colleagues.

Concerning reward wanting in particular, most of the behavioral, neuroimaging, and self-report studies conclude that dysphoric (Chentsova-Dutton & Hanley, 2010) and depressed

(Smoski, Rittenberg, & Dichter, 2011) individuals show reduced reward responsiveness. However, studies investigating the association between anhedonia and reduced wanting are rare. A study by Pizzagalli and colleagues (Pizzagalli, Iosifescu, Hallett, Ratner, & Fava, 2009) took anhedonic symptoms into account. Applying signal detection theory, this study used response bias toward the more frequently reinforced stimulus as a measure of reward sensitivity. The results showed that depressed patients did not develop a response bias toward the more frequently reinforced stimuli and that this impairment was most prominent in patients reporting anhedonic symptoms. However, this study did not dissociate between the anticipatory and consummatory phases of reward processing.

Although motivation is the central concept of the anticipatory component of reward processing, only a few studies have investigated reward anticipation from a motivational point of view (Brinkmann & Franzen, 2013; Brinkmann, Franzen, Rossier, & Gendolla, 2014; Brinkmann, Schüpbach, Ancel Joye, & Gendolla, 2009; Franzen & Brinkmann, 2015). These studies used effort mobilization to operationalize wanting. Effort mobilization is defined as the mobilization of resources in order to attain goals (Gendolla & Wright, 2009) and represents the intensity of motivation. In motivational intensity theory (Brehm & Self, 1989), rewards are considered to be variables influencing success importance, which has a direct impact on effort mobilization when task difficulty is unclear or unfixed (i.e., when the performance standard is unknown or when the performance standard can be chosen by the individual; Brehm & Self, 1989; Richter, 2012). In other words, the bigger the reward, the more important success is and therefore, the greater the effort mobilization is. In the specific case of depression, which is characterized by reduced reward responsiveness, rewards do not increase success importance, and consequently do not lead to higher effort mobilization.

In his integrative model, Wright (1996) predicted that effort mobilization can reliably be quantified as the impact of the sympathetic nervous system on the heart in the context of task performance. In particular, reactivity of 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, follows the effort pattern predicted by motivational intensity theory. Reactivity of systolic blood pressure (SBP), diastolic blood pressure (DBP), and heart rate (HR) also respond to effort mobilization, even though these measures are less direct than the PEP (Papillo & Shapiro, 1990). Several studies have demonstrated an increase in cardiovascular reactivity during reward anticipation in comparison to a neutral condition in healthy participants (Richter & Gendolla, 2006, 2007, 2009). A few other studies focusing on subclinical depression demonstrate that dysphoric individuals show reduced cardiovascular reactivity when incentives are anticipated (Brinkmann & Franzen, 2013; Brinkmann et al., 2009, 2014; Franzen & Brinkmann, 2015). However, none of these studies have investigated the relationship between anhedonia and cardiovascular reactivity during reward anticipation.

In contrast to wanting, liking in depression has been less investigated. Studies using self-report, behavioral, and neuroimaging measures show reduced affective responses to reward in depressed individuals (Dichter, Kozink, McClernon, & Smoski, 2012; Forbes et al., 2009). However, studies investigating the consummatory phase through facial expressions in human beings are scarce. Facial electromyographic (EMG) activity has been considered an objective and subtle measure of positive and negative affective states. Numerous studies have consistently demonstrated that facial EMG activity over the zygomaticus major muscle region is greater during positive emotional episodes than in negative ones (Cacioppo, Petty, Losch, & Kim, 1986). In contrast, a study focusing on subclinical depression showed that in comparison to the control group, dysphoric individuals do not show increased activity of the zygomaticus major muscle in response to happy expressions (Sloan, Bradley, Dimoulas, & Lang, 2002).

In summary, a considerable number of studies have focused on the hyposensitivity to reward in a population of depressed or dysphoric individuals. However, only a few studies have investigated the specific symptom of anhedonia, which is supposed to be associated with this altered reward processing. Moreover, even though it has been suggested that anhedonia should be considered in a dimensional perspective (Ho & Sommers, 2013), even less studies have measured this symptom on a continuum. We believe that symptom-focused transdiagnostic studies are necessary and that an in-depth investigation of the specific role of anhedonia in reduced reward responsiveness is important and overdue. Besides, the majority of the previous studies assessed this deficit in reward sensitivity by means of behavioral and neuroscientific measures. Studies measuring wanting via cardiovascular reactivity and studies measuring liking via muscular reactivity are scarce or completely lacking. The use of specific objective and subjective measures of wanting and liking, as advanced in the theoretical proposals (Berridge & Robinson, 1998), has the potential to bring forward basic knowledge about reward processing as well as specific knowledge about the role of anhedonia.

In order to close these gaps in literature, the present study aimed to examine if anhedonic symptoms relate to deficits in the motivation to obtain a reward (i.e., wanting) and in the affective responses to reward (i.e., liking). A self-report scale was used to evaluate anticipatory and consummatory pleasure, while cardiovascular, muscular, behavioral, and self-report measures were used to assess the two major components of reward processing.

Concerning wanting, we hypothesized that cardiovascular reactivity, performance accuracy, and self-reported wanting would be positively related to anticipatory pleasure. Concerning liking, we expected muscular reactivity and self-reported liking to be positively related to consummatory pleasure.

2. Method

2.1. Participants and experimental design

The final sample consisted of 42 university students, including 29 women and 13 men aged between 18 and 41 years (*M* = 24.64, *SD* = 5.72). These participants were recruited through flyers placed on the university blackboards. Participants received 10 Swiss Francs (about 10 USD) for their anonymous and voluntary participation. In line with previous research that has tested samples composed of dysphoric (i.e., subclinically depressed) and nondysphoric participants, we oversampled dysphoric participants by asking potential participants to first answer an online depression questionnaire, the Center for Epidemiologic Studies – Depression Scale (CES-D; Radloff, 1977). If their individual score was in the lower or higher quartile of the distribution, they were invited to take part in the experiment, resulting in an initial sample of 49 participants. Six of them had to be excluded due to the bad signal quality of the physiological recordings. One participant had to be excluded because his/her PEP reactivity, the primary measure of wanting, was extremely high (more than 3 standard deviations above the overall mean). For our secondary measures, SBP and DBP, two participants had to be excluded due to the bad quality of these measures during the habituation phase or the task. The final sample for these two measures was therefore composed of 40 participants. The present study used a cross-sectional design with the TEPS score (Temporal Experience of Pleasure Scale; Gard et al., 2006)—a questionnaire focused on anticipatory and consummatory pleasure—as the continuous predictor variable, and we manipulated two within-persons conditions (wanting vs. liking).

2.2 Experimental task and incentive manipulation

The experimental task was adapted from the classic Sternberg task (Sternberg, 1966) and was composed of 28 trials. For each trial, a varying number of black letters were each presented in the middle of the screen for 1 second. Then, a target letter was presented in blue font. Participants had to decide whether this target letter had been part of the list of black letters presented previously by pressing one of two specified keys. Following this response, the message “answer recorded” was presented in the middle of the screen. If participants did not answer after 2 seconds, the message “please answer more quickly” appeared in the middle of the screen for 1 second. Then, a new trial began.

In order to create a task that would be in accordance with the predictions of motivational intensity theory, it was necessary to create one with an unclear level of difficulty. Therefore, each trial was composed of a varying number of letters (from 3 to 9 letters) and the performance standard was given only at the end of the task. Moreover, participants only received information about the general procedure of the task but were not given any further details, such as the number of trials or the length of the trials (i.e., the difficulty).

After receiving the task instructions, participants were informed that, in addition to the promised payment, they could win an additional 10 Swiss Francs (about 10 USD) at the end of the experiment if their performance was equal or greater than a performance standard. Unbeknownst to participants, the performance standard was manipulated in order to give a reward to all participants and thus to have a measure of liking for all participants. The individual performance standard was calculated by subtracting 2 from each participant's correct responses so that all participants received the reward.

2.3. Cardiovascular and muscular measures

In order to measure responsiveness to reward during anticipation (i.e., reward wanting), cardiovascular measures were assessed noninvasively during two measurement periods—habituation and task performance. All obtained measures were directly transferred to and stored on a computer drive so that both experimenter and participants were ignorant of the values. For the measurements of the PEP (in ms) and HR (in beats per minute [bpm]), electrocardiogram (ECG) and thoracic impedance (impedance cardiogram, ICG) signals were continuously sampled at 1000 Hz using a Cardioscreen® 1000 haemodynamic monitoring-system (medis, Ilmenau, Germany) (for a validation study see Scherhag et al., 2005). Four dual gel-pad sensors (medis-ZTECT™) were placed on the right and left sides of the base of the participant’s neck and on the right and left middle axillary lines at the level of the xiphoid. A Vasotrac® APM205A monitor (MEDWAVE®, St. Paul, MN) (for a validation study, see Belani et al., 1999) assessed SBP and DBP (both in millimeter of mercury [mmHg]). The system’s sensor was placed on the wrist on top of the radial artery of the participants’ non-dominant arm and recorded a measure every 12 to 15 heartbeats.

In order to measure the affective responses to reward (i.e., reward liking), muscular measures were assessed during two measurement periods, both lasting 25 seconds: firstly, when participants received information about their own performance in comparison to the performance standard; and secondly, when participants were told that they won the 10 Swiss Francs. The electromyographical (EMG) signal was continuously sampled at 1000 Hz using MindWare Technologies LTD, Gahanna, OH. Five solid gel electrodes (3 SG3-N, Multi Bio Sensors Inc., MedCaT B.V, Netherlands) were used, of which two assessed the activity of the zygomaticus major muscle. The first one was placed 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). The second electrode was positioned approximately 1 cm further along this imaginary line. Two other electrodes assessed the activity of the corrugator supercilii muscle in order to have an experimental setting that is comparable with other studies in our laboratory (however, its activity was not analyzed in the present study). Finally, one isolated ground electrode served as a reference and was attached to the forehead on the edge of the hairline, an electrically inactive site (Fridlund & Cacioppo, 1986). The EMG signal was amplified with a constant gain of 1000 and electrical activity was measured using a bipolar recording, as recommended by Fridlund and Cacioppo (1986). In order to maximize the signal-to-noise ratio, the EMG signal was filtered with a 10-500 Hz passband, as recommended by Tassinary and colleagues (Tassinary, Cacioppo, & Vanman, 2007).

2.4. Behavioral and self-report measures

In order to assess anticipatory reward responsiveness on a behavioral level, performance outcomes of the modified Sternberg task were considered: the number of correct responses (out of 28 trials) and the global reaction time for all trials during the 5 minute task performance.

In order to measure subjective wanting, 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 ranging from 0 (*not motivated*) to 100 (*very motivated*). We also measured subjective liking (“To what extent the reward you received causes pleasure in you?”) on a visual analogue scale ranging from 0 (*no pleasure*) to 100 (*a lot of pleasure*).

Several authors advise to bear in mind that the symptom of anhedonia occurs on a continuum of hedonic tone and advise to measure it in a dimensional manner (Ho & Sommers, 2013). Therefore, we used the French version (Loas et al., 2009) of the TEPS to measure individual trait dispositions in both the anticipatory and consummatory components of the experience of pleasure. Composed of 18 items ranging from 1 (*absolutely wrong*) to 6 (*absolutely right*), this questionnaire measures general pleasure by summing all items including two reverse-scored items (Cronbach's α = .70). This questionnaire also includes two subscales, the anticipatory pleasure subscale (TEPS-ANT, *M* = 44.02, *SD* = 5.68), and the consummatory pleasure subscale (TEPS-CON, *M* = 37.19, *SD* = 5.98). For both subscales, higher scores indicate a greater level of pleasure. The anticipatory pleasure subscale is composed of 10 items (Cronbach's α = .54) reflecting the pleasure experienced in the anticipation of a positive stimulus (e.g., "When something exciting is coming up in my life, I really look forward to it"). The consummatory pleasure subscale is composed of 8 items (Cronbach's α = .61) reflecting current pleasure in response to a stimulus (e.g., "I love the sound of rain on the windows when I'm lying in my warm bed"). Finally, it is necessary to note that a high score on the TEPS sub-scales refers to greater anticipatory or consummatory pleasure. Conversely, a low score on the TEPS sub-scales refers to greater anticipatory or consummatory anhedonia.

2.5. Procedure

This study was conducted individually using a personal computer and experimental software (Inquisit 3.0, Millisecond Software, Seattle, WA) presenting all instructions and stimuli. At the beginning, the experimenter, who was unaware of both the hypotheses and the conditions of the study, welcomed participants, asked them to take a seat and to fill in a consent form. Then, the experimenter placed cardiovascular and muscular sensors on participants and left the room to monitor the experiment from another room. The participants then began the first phase of the study, in which they answered two questionnaires, the CES-D and the TEPS. When they had finished, the experimenter reentered the room and started the second phase of the study. Participants first read general information regarding the study and provided some socio-demographic information. Then, they watched an 8-minute excerpt from a neutral documentary movie, during which cardiovascular baseline measures were assessed. Afterwards, task and reward instructions were given to the participants, who then evaluated their motivation to obtain the reward (i.e., subjective measure of wanting). Next, participants completed the modified Sternberg task for 5 minutes, during which cardiovascular and performance measures were assessed. When participants had finished the task, they were informed about the performance standard and their own performance score. They were also informed that they had obtained the reward. During the transmission of this performance and reward information, muscular measures were assessed. Participants then evaluated the hedonic value of the reward (i.e., subjective measure of liking). Finally, the experimenter reentered the room, removed the physiological sensors, gave the promised payment and extra monetary reward, thanked, and debriefed the participants.

2.6. Data analysis

For the PEP analyses, the ICG's first derivative (ICG dZ/dt signal) was ensemble averaged over periods of 1 minute and synchronized with the ECG signal. The ECG R-onset and the ICG B-point were automatically detected by LabVIEW-based software (National Instruments, Austin, TX) developed in our laboratory (Richter, 2009). The R-onset and B-point were then visually inspected by two independent raters and modified when necessary, as recommended by Sherwood et al. (1990). The PEP (in milliseconds) was computed as the time interval between the ECG R-onset and the ICG B-point (Berntson, Lozano, Chen, & Cacioppo, 2004). The arithmetic mean of both raters' PEP values were used for analyses (ICC(2,1) = .98, Shrout & Fleiss, 1979). HR (in beats per minute) was determined by means of the same software that detects and counts R-peaks in the ECG signal.

Means of PEP, HR, SBP, and DBP measures assessed during the last 4 minutes of the habituation period constituted the baseline scores (Cronbach's αs > .97), while means of measures assessed during the 5-minute task performance were used as task scores (Cronbach's αs > .97). Cardiovascular reactivity scores were then calculated by subtracting baseline scores from task scores (see Kelsey et al., 2007; Llabre et al., 1991).

For electromyographic recordings, two reactivity scores were calculated for the zygomaticus major muscle: a mean score and a maximum score. For the mean score, a baseline mean total was created by averaging all data points assessed just after the task, during the 2 seconds before participants received the information about the performance standard and their own performance. Two reward mean scores were created; firstly, by averaging all data points assessed during the first 2 seconds of the period when participants received the information about their own performance; and secondly, during the first 2 seconds of the period when participants were told they obtained the reward. Muscular reactivity mean scores were then calculated as the difference of reward scores minus the baseline score. For the maximum scores, the procedure was exactly the same. The only difference being that instead of averaging all data points, the maximum value for each period was used. Therefore, we had a baseline maximum score, two reward maximum scores, and two muscular reactivity maximum scores (Fridlund & Cacioppo, 1986; Tassinary et al., 2007).

For both the wanting and liking periods, we decided to assess and analyze only those dependent measures, for which we had specific predictions. Accordingly, concerning wanting, all dependent cardiovascular, behavioral, and self-report variables were subjected to simple regression analyses, with the anticipatory pleasure score as the predictor. Similarly, simple regression analyses were performed for all dependent liking measures (muscular and self-report), with the consummatory pleasure score as the predictor.

3. Results

3.1. Preliminary baseline analyses

SBP, DBP, HR, and PEP baseline scores were regressed onto anticipatory pleasure in separate simple regression analyses. These analyses revealed no influence of anticipatory pleasure on SBP, DBP, HR, and PEP baseline scores, Fs < 3.38, ps > .07, R^2s < .08. Likewise, regression analyses showed no significant impact of consummatory pleasure on zygomaticus mean and maximum baseline scores, Fs < 1, ps > .36, R^2s < .02.

3.2. Wanting analyses

Each cardiovascular reactivity score was regressed onto the TEPS-ANT score as the predictor. Results revealed a significant impact of the predictor on PEP reactivity, our main cardiovascular dependent variable, $F(1, 40) = 4.35$, $p = .04$, $R^2 = .10$, ß = -.31. Confirming our hypothesis, this negative relationship demonstrated that higher anticipatory pleasure was related to greater PEP reactivity, as indicated by a stronger shortening of the PEP (see Figure 1A). For HR, results also revealed a significant impact, $F(1, 40) = 4.98$, $p = .03$, $R^2 = .11$, ß = .33. These analyses confirmed that higher anticipatory pleasure was related to greater HR reactivity (see Figure 1B). Regression analyses for SBP and DBP reactivity were not significant, Fs < 1, R^2s < .01.

On the behavioral level, regressing the number of correct responses onto the TEPS-ANT score revealed a significant influence, $F(1, 40) = 9.94$, $p < .01$, $R^2 = .20$, ß = .45. Confirming our hypothesis, these results showed a positive relationship between high anticipatory pleasure and correct responses (see Figure 1C). The regression analysis for global reaction time was not significant, $F(1, 40) = 0.49$, $p = .49$, $R^2 = .01$.

Finally, a regression analysis was performed for the self-report measure of wanting. This analysis showed a significant result, $F(1, 40) = 4.52$, $p = .04$, $R^2 = .10$, ß = .32, and thus demonstrated that higher anticipatory pleasure was related to higher motivation to obtain the reward (see Figure 1D).

3.3. Liking analyses

In simple regression analyses, muscular reactivity was regressed on the TEPS-CON score as a predictor. Results showed no significant effects for the 2 mean and the 2 maximum reactivity scores, *F*s < 1, *ps* > .80, R^2s < 1. Contrary to our hypothesis, the activity of the zygomaticus major muscle did not significantly relate to consummatory pleasure; this did not occur when participants received the information about their own performance or when they were told they won the 10 Swiss Francs.

Concerning the self-report measure of liking, the regression analysis showed no significant result, $F(1, 40) = 1.02$, $p = .32$, $R^2 = .02$. Contrary to our hypothesis, this analysis showed no impact of the TEPS-CON score on the subjective measure of liking.

4. Discussion

Using cardiovascular, muscular, behavioral, and self-report measures, the present study aimed at investigating the impact of anhedonic symptoms of depression on reward responsiveness during anticipation and consumption. Moreover, we took into account a dimensional rather than a categorical perspective of anhedonia.

Concerning wanting, the results of the present study entirely confirmed our predictions. They showed a positive relationship between anticipatory pleasure and all our measures of reward responsiveness. In other words, anticipatory anhedonia was negatively related to reward responsiveness. This negative relationship was first shown with our main cardiovascular measure of effort mobilization, the PEP. The same results were found for HR reactivity, but not for SBP and DBP reactivity. These results are in accordance with previous motivational intensity theory studies conducted with healthy participants (Richter & Gendolla, 2006, 2007, 2009; Wright, Killebrew, & Pimpalapure, 2002) and with subclinically depressed participants (Brinkmann et al., 2009, 2014; Brinkmann & Franzen, 2013; Franzen & Brinkmann, 2015).

Furthermore, on the behavioral level, results also showed a deficit in wanting, demonstrating that anticipatory anhedonia was negatively related to correct responses. These results are in line with previous behavioral studies according to which depressed patients are less willing to expend effort for rewards (e.g., Treadway, Bossaller, Shelton, & Zald, 2012) and do not improve task performance corresponding to reward contingencies (e.g., Pizzagalli et al., 2009) compared to nondepressed participants. In their model of decisional anhedonia, Treadway and colleagues discuss several explications of this motivational deficit and affirm that this deficit is due to impairments in cost-benefit decision-making. In particular, they suggest that depressed individuals tend to overestimate the costs of obtaining rewards, to underestimate the anticipated benefits, and to fail integrating cost/benefit information.

Finally, the results of the self-report measure confirm our predictions: There is a negative relationship between anticipatory anhedonia and the reported motivation to obtain a reward. These results are in line with previous self-report studies (Chentsova-Dutton & Hanley, 2010). Taken together, the results of the present study contribute to the depression literature: firstly, they provide additional evidence of a deficit in wanting through cardiovascular, behavioral, and self-report measures; secondly, they show that this deficit is specifically related to anhedonic symptoms of depression.

Concerning liking, the results of the present study did not confirm our hypothesis suggesting that anhedonic symptoms are associated with reduced affective responses to reward and self-reported liking. Using facial EMG, results showed that consummatory anhedonia was not negatively correlated to the reactivity of the zygomaticus major muscle. We think that the absence of significant results might be due to the methodology of the study. In this study, liking was assessed during two different periods: firstly, when participants received the information that their own performance exceeded the standard, and secondly, when participants were told they won the 10 Swiss Francs. It is difficult to predict at what exact point in time participants understood they won the reward; some participants might have understood it during the first period and other participants only during the second period. As EMG activity is very quick and subtle, it is possible that our procedure, composed of two separate periods, might have added too much variance to the data. Although one study demonstrated that dysphoric individuals show reduced activity of the zygomaticus major muscle in response to happy expressions (Sloan et al., 2002), another study did not find the expected effect on facial expressions in anhedonic individuals (Fiorito & Simons, 1994). Finally, even though facial expressions are a common and valid operationalization of liking, this measure is also prone to pretense (Tibboel et al., 2011).

Taking together, the results of the present study are in line with previous studies run in our laboratory with dysphoric participants. These previous studies focusing on the wanting component of reward processing demonstrate reduced cardiovascular reactivity in dysphoria when anticipating positive consequences (Brinkmann & Franzen, 2013; Brinkmann et al., 2009; Franzen & Brinkmann, 2015). The present study extends those findings in two ways: firstly, by focusing on the role of the specific symptom of anhedonia; and secondly by additionally investigating the liking component of the reward processing.

From a conceptual point of view, the present study advances important knowledge about the symptom of anhedonia. Some recent reviews (see Thomsen et al., 2015; Treadway & Zald, 2011) suggest to reconceptualize the concept of anhedonia. They propose not to regard anhedonia as a unique construct but to consider that anhedonia can be expressed as "impairments in the ability to experience, pursue, and/or learn from rewards" (Thomsen et al., 2015, p. 9), thus emphasizing different facets or components of anhedonia. The present study follows this conception by discriminating between the anticipatory and the consummatory components of anhedonia. Moreover, the use of specific objective and subjective measures allowed us to specifically test both components. The results of the present study underline that motivational processes are a core feature of the symptom of anhedonia.

With regard to the symptom of anhedonia, it is important to acknowledge a potential limitation concerning the generalizability of the present results to the spectrum of depressive disorders. The TEPS we have used in the present study mainly assesses trait aspects of anhedonia. Therefore, it is conceivable that this measures does not perfectly map on the episodic nature of depression (Thomsen et al., 2015).

In summary, this study could not corroborate the hypothesis that consummatory facial expressions and self-reported liking differ as a function of self-reported consummatory anhedonia. Importantly, using a multi-method approach, this study confirms that there is a negative association between wanting and anticipatory anhedonia. The higher individuals score on anticipatory anhedonia, the lower their anticipatory responsiveness to monetary reward is. These results underline the important impact of anhedonic symptoms of depression on reduced anticipatory motivation to obtain a reward.

References

American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders (5th ed.) (DSM-5)*. Washington DC: Author.

Belani, K., Ozaki, M., Hynson, J., Hartmann, T., Reyford, H., Martino, J. M., … Miller, R. (1999). A new noninvasive method to measure blood pressure: Results of a multicenter trial. *Anesthesiology, 91*, 686–692. doi:10.1097/00000542-199909000-00021

Berntson, G. G., Lozano, D. L., Chen, Y.-J., & Cacioppo, J. T. (2004). Where to Q in PEP. *Psychophysiology*, *41*, 333–337. doi:10.1111/j.1469-8986.2004.00156.x

Berridge, K. C. (2003). Pleasures of the brain. *Brain and Cognition*, *52*, 106–128. doi:10.1016/S0278-2626(03)00014-9

Berridge, K. C., & Kringelbach, M. L. (2008). Affective neuroscience of pleasure: Reward in humans and animals. *Psychopharmacology*, *199*, 457–480. doi:10.1007/s00213-008-1099-6

Berridge, K. C., & Robinson, T. E. (1998). What is the role of dopamine in reward: hedonic impact, reward learning, or incentive salience? *Brain Research. Brain Research Reviews*, *28*(3), 309–69. Retrieved from http://www.ncbi.nlm.nih.gov/pubmed/9858756

Brehm, J. W., & Self, E. A. (1989). The intensity of motivation. *Annual Review of Psychology*, *40*, 109–131. doi:10.1146/annurev.ps.40.020189.000545

Brinkmann, K., & Franzen, J. (2013). Not everyone’s heart contracts to reward: Insensitivity to varying levels of reward in dysphoria. *Biological Psychology*, *94*, 263–271. doi:10.1016/j.biopsycho.2013.07.003

Brinkmann, K., Franzen, J., Rossier, C., & Gendolla, G. H. E. (2014). I don’t care about others' approval: Dysphoric individuals show reduced effort mobilization for obtaining a social reward. *Motivation and Emotion*, *38*, 790–801. doi:10.1007/s11031-014-9437-y

Brinkmann, K., Schüpbach, L., Ancel Joye, I., & Gendolla, G. H. E. (2009). Anhedonia and effort mobilization in dysphoria: Reduced cardiovascular response to reward and punishment. *International Journal of Psychophysiology*, *74*, 250–258. doi:10.1016/j.ijpsycho.2009.09.009

Cacioppo, J. T., Petty, R. E., Losch, M. E., & Kim, H. S. (1986). Electromyographic activity over facial muscle regions can differentiate the valence and intensity of affective reactions. *Journal of Personality and Social Psychology*, *50*, 260–268. doi:10.1037//0022-3514.50.2.260

Chentsova-Dutton, Y., & Hanley, K. (2010). The effects of anhedonia and depression on hedonic responses. *Psychiatry Research*, *179*, 176–180. doi:10.1016/j.psychres.2009.06.013

Dichter, G. S., Kozink, R. V., McClernon, F. J., & Smoski, M. J. (2012). Remitted major depression is characterized by reward network hyperactivation during reward anticipation and hypoactivation during reward outcomes. *Journal of Affective Disorders, 136*, 1126–1134. doi:10.1016/j.jad.2011.09.048

Fiorito, E. R., & Simons, R. F. (1994). Emotional imagery and physical anhedonia. *Psychophysiology, 31*, 513–521. doi:10.1111/j.1469-8986.1994.tb01055.x

Forbes, E. E., Hariri, A. R., Martin, S. L., Silk, J. S., Moyles, D. L., Fisher, P. M., … Dahl, R. E. (2009). Altered striatal activation predicting real-world positive affect in adolescent major depressive disorder. *The American Journal of Psychiatry*, *166*, 64–73. doi:10.1176/appi.ajp.2008.07081336

Franzen, J., & Brinkmann, K. (2015). Blunted cardiovascular reactivity in dysphoria during reward and punishment anticipation. *International Journal of Psychophysiology*, *95*, 270–277. doi:10.1016/j.ijpsycho.2014.11.007

Fridlund, A. J., & Cacioppo, J. T. (1986). Guidelines for human electromyographic research. *Psychophysiology*, *23*, 567–589. doi:10.1111/j.1469-8986.1986.tb00676.x

Gard, D. E., Gard, M. G., Kring, A. M., & John, O. P. (2006). Anticipatory and consummatory components of the experience of pleasure: A scale development study. *Journal of Research in Personality*, *40*, 1086–1102. doi:10.1016/j.jrp.2005.11.001

Gendolla, G. H. E., & Wright, R. A. (2009). Effort. In D. Sander & K. R. Scherer (Eds.), *Oxford companion to emotion and the affective sciences* (pp. 134–135). New York: Oxford University Press.

Ho, N., & Sommers, M. (2013). Anhedonia: A concept analysis. *Archives of Psychiatric Nursing*, *27*, 121–129. doi:10.1016/j.apnu.2013.02.001

Kelsey, R. M., Ornduff, S. R., & Alpert, B. S. (2007). Reliability of cardiovascular reactivity to stress: Internal consistency. *Psychophysiology*, *44*, 216–225. doi:10.1111/j.1469-8986.2007.00499.x

Klein, D. F. (1984). Depression and anhedonia. In D. Clark & J. Fawcett (Eds.), *Anhedonia and deficit states* (pp. 1–14). New York: PMA Publishing.

Lewinsohn, P. M., Pettit, J. W., Joiner, T. E., & Seeley, J. R. (2003). The symptomatic expression of major depressive disorder in adolescents and young adults. *Journal of Abnormal Psychology*, *112*, 244–252. doi:10.1037/0021-843X.112.2.244

Llabre, M. M., Spitzer, S. B., Saab, P. G., Ironson, G. H., & Schneiderman, N. (1991). The reliability and specificity of delta versus residualized change as measure of cardiovascular reactivity to behavioral challenges. *Psychophysiology*, *28*, 701–711. doi:10.1111/j.1469-8986.1991.tb01017.x

Loas, G. (1996). Vulnerability to depression: A model centered on anhedonia. *Journal of Affective Disorders, 41*, 39–53. doi:10.1016/0165-0327(96)00065-1

Loas, G., Monestes, J.-L., Ameller, A., Bubrovszky, M., Yon, V., Wallier, J., … Gard, D. E. (2009). Traduction et étude de validation de la version française de l'échelle temporelle du plaisir (EETP, Temporal Experience of Pleasure Scale [TEPS], Gard et ala., 2006): Etude chez 125 étudiants et chez 162 sujets présentant un trouble psychiatrique. *Annales Médico-Psychologiques*, *167*, 641–648. doi:10.1016/j.amp.2009.09.002

Papillo, J. F., & Shapiro, D. (1990). The cardiovascular system. In L. G. Tassinary & J. T. Cacioppo (Eds.), *Principles of psychophysiology: Physical, social, and inferential elements* (pp. 456–512). New York: Cambridge University Press.

Pizzagalli, D. A., Iosifescu, D., Hallett, L. A., Ratner, K. G., & Fava, M. (2009). Reduced hedonic capacity in major depressive disorder: Evidence from a probabilistic reward task. *Journal of Psychiatric Research*, *43*, 76–87. doi:10.1016/j.jpsychires.2008.03.001

Radloff, L. S. (1977). The CES-D scale : A self report depression scale for research in the general population. *Applied Psychological Measurement*, *1*, 385–401. doi:10.1177/014662167700100306

Ribot, T. (1897). *The psychology of the emotions*. London: W. Scott Pub. Co.

Richter, M. (2009). *Bluebox (version 1.24) [computer software]*.

Richter, M. (2012). Cardiovascular response to reward. In R. A. Wright & G. H. E. Gendolla (Eds.), *How motivation affects cardiovascular response: Mechanisms and applications* (pp. 79–91). Washington DC: APA Press.

Richter, M., & Gendolla, G. H. E. (2006). Incentive effects on cardiovascular reactivity in active coping with unclear task difficulty. *International Journal of Psychophysiology*, *61*, 216–225. doi:10.1016/j.ijpsycho.2005.10.003

Richter, M., & Gendolla, G. H. E. (2007). Incentive value, unclear task difficulty, and cardiovascular reactivity in active coping. *International Journal of Psychophysiology*, *63*, 294–301. doi:10.1016/j.ijpsycho.2006.12.002

Richter, M., & Gendolla, G. H. E. (2009). The heart contracts to reward: Monetary incentives and preejection period. *Psychophysiology*, *46*, 451–457. doi:10.1111/j.1469-8986.2009.00795.x

Scherhag, A., Kaden, J. J., & Kentschke, E. (2005). Comparison of impedance cardiography and thermodilution-derived measurements of stroke volume and cardiac output at rest and during exercise testing. *Cardiovascular Drugs and Therapy*, *19*, 141–147. doi:10.1007/s10557-005-1048-0

Sherdell, L., Waugh, C. E., & Gotlib, I. H. (2012). Anticipatory pleasure predicts motivation for reward in major depression. *Journal of Abnormal Psychology*, *121*(1), 51–60. doi:10.1037/a0024945

Sherwood, A., Allen, M. T., Fahrenberg, J., Kesley, R. M., Lovallo, W. R., & Van Doornen, L. J. P. (1990). Methodological guidelines for impedance cardiography. *Psychophysiology*, *27*, 1–23. doi:10.1111/j.1469-8986.1990.tb02171.x

Shrout, P. E., & Fleiss, J. L. (1979). Intraclass correlations: Uses in assessing rater reliability. *Psychological Bulletin*, *86*, 420–428. doi:10.1037/0033-2909.86.2.420

Sloan, D. M., Bradley, M. M., Dimoulas, E., & Lang, P. J. (2002). Looking at facial expressions: Dysphoria and facial EMG. *Biological Psychology*, *60*, 79–90. doi:10.1016/S0301-0511(02)00044-3

Smoski, M. J., Rittenberg, A., & Dichter, G. S. (2011). Major depressive disorder is characterized by greater reward network activation to monetary than pleasant image rewards. *Psychiatry Research*, *194*, 263–270. doi:10.1016/j.pscychresns.2011.06.012

Sternberg, S. (1966). High-speed scanning in human memory. *Science*, *153*, 652–654. doi:10.1126/science.153.3736.652.tle

Tassinary, L. G., Cacioppo, J. T., & Vanman, E. J. (2007). The skeletomotor systeme: Surface electromyography. In J. T. Cacioppo, L. G. Tassinary, & G. G. Berntson (Eds.), *Handbook of psychophysiology (3rd edition)* (pp. 267–299). New York: Cambridge University Press.

Thomsen, K. R., Whybrow, P. C., & Kringelbach, M. L. (2015). Reconceptualizing anhedonia: novel perspectives on balancing the pleasure networks in the human brain. *Frontiers in Behavioral Neuroscience*, *9*, 1–23. doi:10.3389/fnbeh.2015.00049

Tibboel, H., De Houwer, J., Spruyt, A., Field, M., Kemps, E., & Crombez, G. (2011). Testing the validity of implicit measures of wanting and liking. *Journal of Behavior Therapy and Experimental Psychiatry*, *42*, 284–292. doi:10.1016/j.jbtep.2011.01.002

Treadway, M. T., Bossaller, N. A., Shelton, R. C., & Zald, D. H. (2012). Effort-based decision-making in major depressive disorder: A translational model of motivational anhedonia. *Journal of Abnormal Psychology*, *121*, 553–558. doi:10.1037/a0028813

Treadway, M. T., & Zald, D. H. (2011). Reconsidering anhedonia in depression: lessons from translational neuroscience. *Neuroscience and Biobehavioral Reviews*, *35*(3), 537–55. doi:10.1016/j.neubiorev.2010.06.006

Wright, R. A. (1996). Brehm’s theory of motivation as a model of effort and cardiovascular response. In P. M. Gollwitzer & J. A. Bargh (Eds.), *The psychology of action: Linking cognition and motivation to behavior* (pp. 424–453). New York: Guilford Press.

Wright, R. A., Killebrew, K., & Pimpalapure, D. (2002). Cardiovascular incentive effects where a challenge is unfixed: Demonstrations involving social evaluation, evaluator status, and monetary reward. *Psychophysiology*, *39*, 188–197. doi:10.1017/S0048577202011137

Wright, R. A., & Kirby, L. D. (2001). Effort determination of cardiovascular response: An integrative analysis with applications in social psychology. In M. P. Zanna (Ed.), *Advances in experimental social psychology* (pp. 255–307). New York: Academic Press.

Acknowledgements

Jessica Franzen, Kerstin Brinkmann, Geneva Motivation Lab, University of Geneva, Switzerland. This research was supported by a research grant from the Swiss National Science Foundation (SNF 100014-134557) awarded to the second author. Parts of the present research were presented at the 26th Annual Convention of the Association for Psychological Science, San Francisco, CA, May 23-25, 2014. Please address correspondence to Jessica Franzen, Geneva Motivation Lab, University of Geneva, FPSE, Department of Psychology, 40 Bd. du Pont d'Arve, CH-1211 Geneva 4, Switzerland. Electronic mail can be sent to jessica.franzen@unige.ch.

Figure Captions

Figure 1. Relation between anticipatory pleasure (TEPS-ANT) and pre-ejection period reactivity, heart rate reactivity, number of correct responses, and self-report wanting. The solid lines represent the regression lines, the dashed lines represent the 95% confidence intervals.

Figures

Figure 1