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Blunted cardiovascular reactivity during social reward anticipation in subclinical depression

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ABSTRACT

The present study extends past research about reduced reward responsiveness in depression by assessing effort-related cardiovascular responses during anticipation of a social reward. Dysphoric (i.e., subclinically depressed) and nondysphoric participants worked on a cognitive task. Half the participants in each group expected the possibility to subscribe to a social exchange internet site. Effort mobilization during task performance was assessed by participants' cardiovascular reactivity. Confirming the predictions, nondysphoric participants in the social-reward condition had higher reactivity of pre-ejection period, systolic blood pressure, and heart rate, compared to the other three cells. In contrast, dysphoric participants' cardiovascular reactivity was generally low. These findings indicate that social-reward function is indeed impaired in subclinical depression. Implications for social punishment are discussed.

1. Introduction

1.1. Reward responsiveness in depression

Depression is a high-prevalence disorder (Kessler and Wang, 2009), which is characterized, amongst others, by reduced responsiveness to rewards (for reviews see Eshel and Roiser, 2010; Pizzagalli et al., 2011). The wealth of empirical studies strongly suggest that individuals with clinical and subclinical depression are impaired in their response to rewards both during the anticipatory (i.e., motivational) phase and during the consummatory (i.e., emotional) phase (for a detailed discussion about the distinction between these two phases see Berridge and Robinson, 2003; Gard et al., 2006). Specifically, depressed individuals report less anticipated pleasure (e.g., Chentsova-Dutton and Hanley, 2010), show impaired reward-learning behavior (e.g., Huys et al., 2013; Liu et al., 2011; Vrieze et al., 2013), demonstrate impaired reward-related decision making (e.g., Kunisato et al., 2012; Treadway et al., 2012), have reduced activity in approach-related cortical regions (e.g., Shankman et al., 2013; for a review see Thibodeau et al., 2006), and show altered activity in reward-related brain regions (for a review see Zhang et al., 2013). Recently, we have shown reduced effort-related cardiovascular reactivity during goal pursuit in subclinical depression (Brinkmann and Franzen, 2013; Brinkmann et al., 2009; Franzen and Brinkmann, 2015, 2016a).

1.2. Social rewards in depression

The great majority of this converging literature has relied on monetary rewards, which have universal significance and which are easy to quantify and apply. Recently, arguments have been advanced that social rewards might be more meaningful but also especially affected in depression (Forbes, 2009; Forbes and Dahl, 2012). However, their role has not been fully understood. To date, a couple of studies have demonstrated associations between depression and reduced neural responses during the viewing of pleasant facial expressions and words (Epstein et al., 2006; Monk et al., 2008; Surguladze et al., 2005) and during the sight and taste of pleasant chocolate stimuli (McCabe et al., 2009; McCabe et al., 2012). These findings point to the general nature of reduced reward responsiveness in depression, beyond monetary rewards.

With respect to social rewards in particular, three neuro-imaging studies have shown altered responsiveness in reward-related brain areas of depressed and high-risk individuals during the consummatory phase (Davey et al., 2011; Healey et al., 2014; Olino et al., 2015). In these studies, social reward consumption has been operationalized by receiving positive social feedback, by viewing pictures of peers who returned participants' liking, and by being accepted by a previously liked peer. However, these studies are limited in their focus on participants' neural response during the consummatory phase. From a motivational point of view, it would be informative to know whether or not depressed individuals mobilize more effort or achieve better results when anticipating a positive social consequence.

Only two recent studies have investigated behavior and effort mobilization during social reward anticipation. One study revealed that

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remitted depressed individuals show impaired reward-learning when expecting social praise as reward feedback for correct responses (Pechtel et al., 2013). Another study demonstrated that dysphoric (i.e., subclinically depressed) participants mobilize less effort when expecting social approval in form of the possibility to enter one's name in a public "best list" (Brinkmann et al., 2014). Specifically, reduced effort mobilization was evidenced by a weaker response of systolic blood pressure (SBP) during task performance.

1.3. Effort mobilization and cardiovascular response

Effort mobilization refers to the resources a person is mobilizing at a point in time in order to carry out a certain behavior (Gendolla and Wright, 2009). Effort-related cardiovascular response is an important peripheral measure that directly relates to the anticipatory, motivational phase of reward processing. It provides information about the vigor with which individuals pursue their goals. The integrative approach by Wright (1996) brings together the predictions of motivational intensity theory (Brehm and Self, 1989) with considerations about psychophysiological responses in active coping situations (Obrist, 1981). Specifically, Wright argued that effort mobilization during goal pursuit can be operationalized by cardiovascular parameters that are influenced by beta-adrenergic sympathetic nervous system (SNS) impact on the heart.

Among the most common noninvasive cardiovascular parameters is the pre-ejection period (PEP). PEP refers to 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, which is determined by beta-adrenergic SNS impact on the heart (Kelsey, 2012; Sherwood et al., 1990). Other common cardiovascular parameters include systolic blood pressure (SBP) and diastolic blood pressure (DBP). SBP strongly depends on the force of myocardial contraction and to a lesser extent on vascular resistance. Whereas the impact of myocardial contraction via its impact on cardiac output is mainly mediated by beta-adrenergic SNS activation, the impact of vascular resistance is mainly mediated by alpha-adrenergic SNS activation. In contrast, DBP is predominantly determined by vascular resistance and therefore mainly by alpha-adrenergic SNS activation. Finally, heart rate (HR) is determined by both sympathetic and parasympathetic activation and is therefore not an unambiguous indicator of beta-adrenergic SNS activation (Berntson et al., 1993; Brownley et al., 2000; Levick, 2003; Papillo and Shapiro, 1990). Taken together, PEP can be considered a reliable means for operationalizing effort mobilization (Kelsey, 2012; Wright, 1996). SBP qualifies as a secondary measures of effort mobilization that has been successfully used in the framework of motivational intensity theory, whereas the evidence for DBP and HR is mixed (for reviews see Gendolla et al., 2012a; Gendolla et al., 2012b).

According to motivational intensity theory (Brehm and Self, 1989), rewards should have a direct impact on effort mobilization, that is, on cardiovascular reactivity, when task difficulty is fixed but unknown to the performing individuals (termed "unclear difficulty"). Under these circumstances, they cannot adjust their effort mobilization with respect to task difficulty but must rely on the importance of success. In other words, the higher the reward at stake, the more important is success and, therefore, the higher is the effort people mobilize (Richter, 2012; for a more detailed discussion of motivational intensity theory and its predictions see Richter, 2013; Richter et al., 2016). Using tasks with unclear difficulty, several studies have demonstrated that clinically and subclinically depressed individuals show weaker cardiovascular responses during the execution of cognitive tasks, which are instrumental to obtain a monetary reward (Brinkmann and Franzen, 2013; Brinkmann et al., 2009; Franzen and Brinkmann, 2015, 2016b; Franzen et al., 2016). At least two processes are possibly involved in causing reduced effort-related cardiovascular reactivity by depressed individuals in this situation. First, due to mood-congruency biases, rewards are undervalued and do not increase success importance. Second, external control perceptions lead to reduced instrumentality of effort mobilization for obtaining rewards (Franzen and Brinkmann, 2016b).

1.4. The present study

To date, one study has demonstrated blunted SBP reactivity in subclinically depressed individuals during the anticipation of a social reward (Brinkmann et al., 2014). The aim of the present study was to conduct a conceptual replication of the Brinkmann et al. study to answer the remaining open questions. First, effort-related cardiovascular reactivity informs about the vigor with which individuals pursue their goals and helps drawing a complete picture of depressed individuals' behavior in a reward situation. The present study is the first one focusing on PEP as the most direct, noninvasive cardiovascular indicator of effort mobilization in a social reward situation. Second, social reward function in depression has not received much attention, and social reward is not a unitary concept. In the present study we use a more active kind of social reward in order to vary and diversify the types of social rewards and to be able to draw general conclusions about social reward function in depression.

In the present study, we asked dysphoric (i.e., subclinically depressed) and nondysphoric students to perform a mental arithmetic task under unclear-difficulty instructions. Half of the participants worked on the task expecting no specific consequence of their performance (no-reward condition). The other half of the participants were led to believe that, in case they met the performance standard, they could subscribe to a new internet site, as described in more detail below (social-reward condition). We expected a dysphoria x reward interaction effect describing a 3:1 pattern. Specifically, we hypothesized that nondysphoric participants in the social-reward condition would show higher PEP reactivity, reflecting higher effort mobilization, than nondysphoric participants in the no-reward condition and than dysphoric participants in either condition. We expected the same 3:1 pattern for SBP reactivity as a secondary dependent variable. We also assessed DBP and HR, mainly for the interpretability of the PEP pattern, as will be presented in the Discussion section (Obrist et al., 1987). Finally, we predicted that nondysphoric participants in the social-reward condition would report higher success importance and higher motivation to obtain the reward than the three other groups.

2. Methods

2.1. Participants and design

The present study was a 2 (dysphoric vs. nondysphoric) × 2 (no reward vs. social reward) between-persons design. After having obtained approval of the protocol by the local ethical committee, we recruited students of the University of Geneva with various majors by blackboards advertisements. Participants filled in an online version of the Center for Epidemiologic Studies – Depression Scale (CES-D; Radloff, 1977). Among participants, we invited those who scored in the lower quartile (≤9) or in the upper quartile (≥17) of the distribution via an anonymous code. One month later, these students participated in the experimental session in exchange for 15 Swiss Francs (about 15 USD) and were randomly assigned to one of the two reward conditions. From the 88 participants, we excluded data of 19 participants whose CES-D scores did not stay within the limits (≤9 or ≥17) when assessed a second time during the experimental session. Moreover, we removed data of 3 participants whose impedance cardiograms could not be analyzed due to bad signal quality.

The final sample consisted of 66 students with a mean age of 24.02 years, $SD = 4.93$. Thirty-three participants were located in the upper quartile of the CES-D score distribution ($M = 27.18$, $SD = 8.10$, range = 17–45) and were referred to as dysphoric. The remaining 33

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