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Helping from the heart: Voluntary upregulation of heart rate variability predicts altruistic behavior

Boris Bornemann[a,*], Bethany E. Kok[a], Anne Böckler[a,b], Tania Singer[a]

[a] Department of Social Neuroscience, Max Planck Institute for Human Cognitive and Brain Sciences, Germany
[b] Department of Psychology, Würzburg University, Germany

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ABSTRACT

Our various daily activities continually require regulation of our internal state. These regulatory processes covary with changes in High Frequency Heart Rate Variability (HF-HRV), a marker of parasympathetic activity. Specifically, incidental increases in HF-HRV accompany positive social engagement behavior and prosocial action. Little is known about deliberate regulation of HF-HRV and the role of voluntary parasympathetic regulation in prosocial behavior. Here, we present a novel biofeedback task that measures the ability to deliberately increase HF-HRV. In two large samples, we find that a) participants are able to voluntarily upregulate HF-HRV, and b) variation in this ability predicts individual differences in altruistic prosocial behavior, but not non-altruistic forms of prosociality, assessed through 14 different measures. Our findings suggest that self-induction of parasympathetic states is involved in altruistic action. The biofeedback task may provide a measure of deliberate parasympathetic regulation, with implications for the study of attention, emotion, and social behavior.

1. Introduction

As we go through the various activities of our day, our internal milieu continually changes. The adaptations of our internal states are mirrored in changes of autonomic system activity (Kreibig, 2010; Porges, 2007; Thayer & Lane, 2009). In this paper, we focus on changes in parasympathetic activity, particularly activity of the vagus nerve, which can be estimated by measuring the high frequency band of heart rate variability (HF-HRV; e.g., Task-Force, 1996). Some behaviors, such as solving a cognitively demanding task or coping with a stressful situation, are accompanied by reductions in HF-HRV, indicative of vagal withdrawal (Duschek, Muckenthaler, Werner, & del Paso, 2009; Graziano & Derefinko, 2013; Luque-Casado, Perales, Cárdenas, & Sanabria, 2015). Other behaviors, such as positive social engagement, have been linked to increases in HF-HRV, indicative of vagal upregulation (Bazhenova, Plonskaia, & Porges, 2001; Hastings et al., 2008; Miller et al., 2013; Porges, 2003). The degree to which people show these situation-dependent adaptations in HF-HRV, termed vagal flexibility (Muhtadie, Koslov, Akinola, & Mendes, 2014), has been hypothesized to relate to psychological health (Beauchaine, 2001). Indeed, it has been found that people who exhibit lower HF-HRV in stressful situations and higher HF-HRV during positive social engagement show better stress coping (Bazhenova et al., 2001), fewer depressive symptoms (Oppenheimer, Measelle, Laurent, & Ablow, 2013), and are less likely to be diagnosed with psychopathology (Musser et al., 2011; Shahrestani, Stewart, Quintana, Hickie, & Guastella, 2014).

The role of vagal upregulation in positive social engagement led researchers to pursue the hypothesis that it is also involved in altruistic feelings and behaviors (e.g., Barraza, Alexander, Beavin, Terris, & Zak, 2015; Miller, Kahle, & Hastings, 2015). Following Batson, (2014, p.6), we define behaviors as altruistically motivated if they follow from a “motivational state with the ultimate goal of increasing another’s welfare”. A link between altruism and vagal upregulation is in line with the implication of the vagus in the mammalian “care-system” (Panksepp, 2006, 2011; also called “affiliative system”, Depue & Morrone-Strupinsky, 2005), a biological system that evolved in mammals for the care of the offspring but may lie at the basis of caring or altruistic acts in general (Eisenberger & Cole, 2012; Gordon, Martin, Feldman, & Leckman, 2011; Panksepp, 2011; Preston, 2013). In rodents, the vagus nerve closely interacts with the neuropeptide oxytocin, which is a hallmark of the care/affiliative system (Charpak, Armstrong, Mühlethaler, & Dreifuss, 1984; Depue & Morrone-Strupinsky, 2005;

* Corresponding author at: Max Planck Institute for Human Cognitive and Brain Sciences, Stephanstraße 1a, 04103 Leipzig, Germany.
E-mail address: bornemann@cbs.mpg.de (B. Bornemann).

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Dreifuss, Raggenbass, Charpak, Dubois-Dauphin, & Tribollet, 1988; Panksepp, 2011; Tribollet, Charpak, Schmidt, Dubois-Dauphin, & Dreifuss, 1989) to bring about the state of quiescence that is involved in care-giving behaviors (McCall & Singer, 2012; Porges, 2003; Uvnäs-Moberg, 1998). In humans, intranasal administration of oxytocin increases HF-HRV (Kemp et al., 2012; Norman et al., 2011) and facilitates parasympathetic responses to social stimuli (Gamer & Büchel, 2012), underlining the implication of vagal activation in the care/affiliative system. Several studies support the hypothesis that altruistic feelings and behaviors are accompanied by increases in vagal activity. Intraindividual increases in HF-HRV accompany the experience of compassion, induced by videos on human suffering (Oveis, 2002; Stellar, Cohen, Oveis, & Keltner, 2015), and HF-HRV is elevated when people witness the altruistic actions of others (Hutchinson, 2012). Children who show less HF-HRV reduction when exposed to a toddler in distress display more empathetic concern (Gill & Calkins, 2003), and those who maintain higher HF-HRV when hearing about sick and incapacitated children are more willing to share their own resources with them (Miller et al., 2015). Similarly, in adults, the degree of HF-HRV upsurge when viewing a video depicting human suffering positively predicts their readiness to donate money to a related charity (Barraza et al., 2015).

All of these studies demonstrate that adjustments in HF-HRV co-occur with certain emotions and behaviors. In particular, incidental increases in HF-HRV accompany altruistic feelings and behaviors. A possible explanation is that the upsurges in vagal activity reflect *deliberate* self-regulatory efforts, specifically the activation of emotional-motivational systems related to positive social engagement and care-giving (Panksepp, 2011; Porges, 2003; Thayer & Lane, 2009). This claim, however, has never been directly tested. We therefore designed a task to measure deliberate upregulation of vagal activity. We hypothesized that people who more readily activate the vagus in such a deliberate self-regulation paradigm would also be more inclined to activate it in social interaction situations. Thus, higher ability to self-induce vagal activity should relate to more altruistic behavior. This would indicate that the biological processes which accompany altruistic actions are at least partially under conscious regulatory control.

To study voluntary upregulation of vagal activity, we developed a procedure that continually (roughly every 2.5 s) feeds back a short term estimate of HF-HRV to participants as the altitude of a ball on a computer screen. We informed participants that the ball mirrors some aspect of their mental-bodily state and asked them to make it go up (which happened when HF-HRV increased). Participants were not told which parameter is indicated by the ball nor suggested any strategies to influence it (see Supplementary material for full instructions). This procedure is different from previous HF-HRV feedback procedures (see Wheat & Larkin, 2010 for a review), in all of which participants were told to attain regulation by slower breathing (e.g., Druschky & Druschky, 2015; Dziembowska et al., 2015; Karavidas et al., 2007; Lehrer et al., 2003; Nolan et al., 2005), or participants' attention was drawn to breathing as a possible way to take influence in the biofeedback (Cowan, Kogan, Burr, Hendershot, & Buchanan, 1990; Lehrer et al., 1997). First, an open instruction to regulate one's mental-bodily state is more conducive to measuring individual differences in participant's inclination and ability to increase vagal activity than a purely physiological approach. Second, and more importantly, restricting regulation of HF-HRV to breathing related strategies may be problematic because of the complex relationship of breathing, HF-HRV, and vagal activity: Although slower breathing may indeed have stimulating effects on the vagus (Bernardi, Porta, Gabutti, Spicuzza, & Sleight, 2001; Grossman, 1983; Pal & Velkumary, 2004; Vaschillo, Vaschillo, & Lehrer, 2006), it may also be an artifact to the measurement of vagal activity through HF-HRV because there is a negative relationship between respiration rate and HF-HRV even in the absence of changes in vagal activity (Grossman & Taylor, 2007; Quintana & Heathers, 2014). Of course, in our task, participants may also use breathing changes to influence HF-HRV. We therefore measured respiration rate throughout the experiment and control for it when using individual differences in the biofeedback as an approximate measure for vagal upregulation. As this type of HF-HRV biofeedback without any strategy instruction is novel, a first aim of this study was to investigate whether people are able to self-induce increases in HF-HRV in this task.

To assess aspects of prosociality and particularly altruistic behavior, we used a large battery of classical behavioral measures and self-reports that have been assessed in the context of the ReSource project, a longitudinal study on mental training, from which we used baseline data for the purposes of the present paper (for details Singer et al., in press). This task battery included game theoretical paradigms (Berg, Dickhaut, & McCabe, 1995; Camerer, 2003; Fehr & Fischbacher, 2004), ecologically valid computer tasks (Hare, Camerer, Knoepfle, O'Doherty, & Rangel, 2010; Leiberg, Klimecki, & Singer, 2011), hypothetical distribution tasks (Jones & Rachlin, 2006; Van Lange, 1999), and self-reports on socio-emotional dispositions (Caprara, Steca, Zelli, & Capanna, 2005; Davis, 1983; Henning & Six, 1977). In a previous study (Böckler, Tusche, & Singer, 2016), a factor analysis on these measures yielded four factors representing largely independent subcomponents of prosociality, namely Altruistically Motivated Behavior (AMB), Norm Motivated Behavior (NMB), Strategically Motivated Behavior (SMB), and Self-Reports (SR) of socio-emotional dispositions. The first three factors are all comprised of different types of behavioral measures that assess aspects of human prosociality, whereas the last factor contained only trait-level questionnaires. The first three factors distinguish between the motivations that underlie prosocial behavior. In the case of NMB and SMB, prosocial behaviors are motivated by adherence to social norms and strategic considerations to maximize one's own profits, respectively. In contrast, behaviors subsumed in the AMB factor involve unconditional giving and helping based on generosity and altruistic motivation. AMB thus has the ultimate goal of fostering the well-being of another (cf. Batson, 2014). Because of the association of vagal upregulation with the care-system and altruism, we hypothesized that the ability to activate the vagus would be related to individual differences in AMB, but not other types of prosocial behaviors, which are not based in care-motivation but rather in norm-adherence or self-focused motivation. When it comes to the fourth factor, the self-report factor, an association to HF-HRV upregulation seems unlikely, as self-reports of socio-emotional dispositions had previously been found to be only weakly related to actual behavior (Böckler et al., 2016) and furthermore, no previous study had shown any relationship between increases in HF-HRV and self-reports of socio-emotional dispositions.

2. Methods

2.1. Participants

All measures were provided by participants in the ReSource Project, a large scale study on the effects of meditation and mental training, conducted in Leipzig and Berlin. Detailed descriptions of the overall study design and participant recruitment procedure are available in Singer et al. (in press). Briefly, all participants were selected to be mentally and physically healthy and between 20 and 55 years of age. The present study only utilizes data that were collected before the training began. Of the 332 participants enrolled in the study, 248 (age $M = 39.94$, $SD = 9.32$; 138 female) had complete data on all measures relevant to this paper (see Supplementary