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Salivary cortisol and cardiovascular reactivity to a public speaking task in a virtual and real-life environment

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A B S T R A C T

Public speaking is a well-known psychosocial stress to occur in social-evaluative situations. This study examined self-reported, autonomic and endocrine stress responses to a 5-min public speaking task. Participants were asked to present either in front of i) a real audience, or ii) a virtual audience or iii) an empty virtual lecture hall. Thus, the main objective of this study was to examine the influence of real or virtual social stimuli on stress reactivity. Additionally, possible sex differences in stress responses were evaluated. Sixty-six women and men (20–33 years) underwent a multidimensional assessment of stress including self-reported state anxiety, heart rate, heart rate variability and saliva cortisol secretion. Results showed comparable increases in all stress responses in both the real and the virtual public speaking group. These findings indicate that the *Self Preservation Theory* is not limited to physically present social entities, but may also be extended to virtual social stimuli; as such this observation is also in line with the so called Media Equation Concept. Implications of the current results for therapy and research are subsequently discussed.

1. Introduction

Psychosocial stress is a widely recognized phenomenon which may occur in diverse social evaluative situations including for instance public speaking. When confronted with a socially threatening stimulus, two complementary mechanisms come into effect and shape the individual's acute response, the autonomic nervous system: the so called Sympatho-Adrenal-Medullary (SAM) axis and neuroendocrine system: the Hypothalamus-Pituitary-Adrenal (HPA) axis. Both axes “are instigated from the hypothalamus, where sensory inputs and serum-based feedback mechanisms monitor the level of environmental demand (i.e., stress) and the ‘internal’ state of the organism” (Bitsika, Sharpley, Sweeney, & McFarlane, 2014, p. 1). In other words, the two mechanisms help the organism adapt to environmental influences by initiating physiological as well as behavioral responses (e.g., the fight-or-flight response; c.f., Taylor et al., 2000).

While the SAM axis acts via the Sympathetic Nervous System (SNS) and is generally known to show a considerably fast reaction, the HPA axis is slower and mainly acts via the endocrine system. As the autonomic stress reaction via the SAM axis includes an increased blood flow and elevated heart rate as well as increased sweating and pupil dilation, SAM axis responses may best be assessed using measures such as heart rate or heart rate variability (HRV; Bitsika et al., 2014). HPA axis reactivity, in turn, is closely linked to the production and release of the stress hormone cortisol, which activates a feedback-loop to regulate stress-related physiological arousal. HPA axis activity may best be assessed using salivary cortisol as a biomarker as it reflects the amount of unbound, biologically active cortisol and may be sampled using non-invasive methods (Kirschbaum, Kudielka, Gaab, Schommer, &

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Hellhammer, 1999; Kudielka, Buske-Kirschbaum, Hellhammer, & Kirschbaum, 2004; Kudielka, Schommer, Hellhammer, & Kirschbaum, 2004; Schommer, Hellhammer, & Kirschbaum, 2003).

1.1. Social Self-Preservation Theory

A meta-analysis (Dickerson & Kemeny, 2004) has shown that if a situation or task includes social-evaluative elements as well as stimuli that are perceived as uncontrollable, cortisol changes are the largest and cortisol recovery rates the lowest. To explain this phenomenon, the authors make use of the so called *Social Self-Preservation Theory* (Dickerson & Kemeny, 2004). According to this theory, the HPA axis supports preservation of the social self by monitoring the environment for threats to the individual's self-esteem and social status; in case of a threat, it triggers self-evaluative cognitions and emotions and increases the release of cortisol in order to cope with the situation. Public speaking tasks, which are perceived as both uncontrollable and a social-evaluative threat because of the fear of failure and of being judged by others, have especially been considered as highly effective in evoking this chain of reactions (c.f. Dickerson & Kemeny, 2004).

The exposure to a social stressor has not only been shown to have a wide-ranging immediate impact on the individual's physiological response (c.f. Dickerson & Kemeny, 2004). It has also been discussed to be associated with cognitive and affective processes that may both directly and indirectly contribute to the development of various diseases and disorders such as depression (McEwen, 2005), cardiovascular diseases (Kemp, Quintana, Felmingham, Matthews, & Jelinek, 2012; McEwen, 1998) and immune dysfunction (Glaser & Kiecolt-Glaser, 2005). Furthermore, psychosocial stress has also been considered to be closely linked to the retention of anxiety disorders, obesity as well as obsessive compulsive disorders, OCD (Dishman et al., 2000; Pittig, Arch, Lam, & Craske, 2013).

1.2. Social stress and virtual reality

In light of its potent role in pathogenetic processes, the prevention or treatment of psychosocial stress has therefore increasingly been integrated in health promotion programs and in the treatment of psychological disorders. Traditionally, therapeutic exposition techniques are used to gradually decrease anxiety. Most commonly, they include confrontation with a feared stimulus in real-life (c.f., Wolpe, 1961). As an alternative to real-life exposure, virtual reality has increasingly come into use over the past decades (c.f., Krijn, Emmelkamp, Olafsson, & Biemond, 2004; Parsons & Rizzo, 2008; Powers & Emmelkamp, 2008). Virtual reality exposure therapy (VRET) provides a valuable intermediate step between imagination and exposure in real-life. Thus, VRET may be especially well-suited to patients who may have problems imagining a fearful stimulus or may not be ready to be exposed *in vivo*. Also, the therapist has maximal control over the stimulus as s/he may stop the simulation as soon as it becomes too overwhelming for the patient. Apart from the apparent gains of reducing therapy costs and time, VRET bears the additional advantage of increasing a patient's compliance and decreasing drop-out during exposure (Garcia-Palacios, Botella, Hoffman, & Fabregat, 2007; Repetto et al., 2011).

Among others, VRET has been developed to treat social anxiety: patients may learn new adaptive strategies in virtual social contexts and may then, in a next step, generalize these behaviors to a real-life social setting (Bordnick, Traylor, Carter, & Graap, 2012). Various studies support the assumption that virtual social scenarios may be used to evoke substantial levels of social anxiety on different levels, including cognitive, physiological or endocrine responses (e.g. Anderson et al., 2013; Garau, Slater, Pertaub, & Razzaque, 2005; Garcia-Lopez et al., 2006; Kampmann et al., 2016; Klinger et al., 2005; Krijn et al., 2004; Morina, Ijntema, Meyerbröker, & Emmelkamp, 2015; Opris et al., 2012; Owens & Beidel, 2015; Sarver, Beidel, & Spitalnick, 2014).

Also, virtual simulations may be used to help the patient train his/her social skills: Among existing programs are online social skills trainings (e.g. Lehenbauer, Kothgassner, Kryspin-Exner, & Stetina, 2013), virtual reality (VR), exposure applications (e.g., Gerardi, Cukor, Difede, Rizzo, & Rothbaum, 2010; Harris, Kemmerling, & North, 2002; Klinger et al., 2005) or even approaches which revert to existing virtual environments such as Massively Multiplayer Online Role-Playing Games (MMORPGs) or Second Life (e.g., Yuen et al., 2013). Their success – similarly to real-life exposure – relies on evoking social stress reactivity. Thus, it is crucial that those virtual cues which are supposed to represent social entities are perceived as such. According to evolutionary perspectives, the human brain is prepared to automatically respond to virtual entities in the same way it would to ‘real’ human beings – an assumption which has comprehensively been described in the *Media Equation* concept (Nass & Moon, 2000; Reeves & Nass, 1996).

Although some studies have already collected data in support of this theory (e.g., Kothgassner et al., 2014; Von der Pütten, Krämer, Gratch, & Kang, 2010), only few have picked up on this notion in the context of social-evaluative stress situations such as public speaking tasks. Previous investigations have examined the stress reaction to either a real audience (e.g., Kirschbaum et al., 1999; Kudielka, Hellhammer, & Wüst, 2009) or a virtual audience (e.g., Felnhofer et al., 2014; Jönsson et al., 2010; Slater, Pertaub, Barker, & Clark, 2006), but not to both. A comprehensive study comparing multiple measures (including self-report anxiety, physiological and endocrine responses) of social stress in a standardized experimental setting using a control group to control for specific influences of the used VR technology is still pending.

Among existing studies, some have shown that virtual audiences in a virtual public speaking task may provoke substantial levels of autonomic stress (as measured by heart rate) and self-reported anxiety (e.g. Felnhofer et al., 2014; Pertaub, Slater, & Barker, 2002; Slater et al. 2006). For instance, Hartanto et al. (2014) used three social scenarios, a neutral situation, a blind date and a job interview to evoke social stress and succeeded in achieving a substantial increase in heart rate (HR) and cognitive appraisal. Also, the authors showed that positive feedback received from virtual social entities leads to a reduction of anxiety and arousal and that negative feedback has a contrary effect. Similarly, Owens and Beidel (2015) found that a virtual environment may provoke significant increases of HR and skin conductance level (SCL) in comparison to a baseline condition and a control group. Yet another study (Villani, Repetto, Cipresso, & Riva, 2012) demonstrated heightened levels of SCL and self-reported anxiety in both a virtual and real-life job interview setting.

In most studies, however, stress indicators are restricted to measures of HR or SCL and subjective reports and do not account for cortisol as a crucial indicator for social-evaluative stress situations (c.f. Dickerson & Kemeny, 2004). Those studies which compare participants’ cortisol levels in similar social evaluative scenarios have produced inconsistent results: Kelly, Matheson, Martinez, Merali, and Anisman (2007) who introduced their participants to simulated job interviews found a significantly lower cortisol stress responses in the virtual group than in the real-life group. In contrast, Kotlyar et al. (2008) reported no change in cortisol concentrations during a speech task within a VR environment; and yet another study using a job interview showed both an increase in SCL and HPA (Montero-López et al., 2015). Finally, a study by Jönsson et al. (2010) which focused on the habituation of