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Effect of examination stress on intraocular pressure in university students

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ABSTRACT

Intraocular pressure (IOP) has been investigated as a possible objective index of mental stressors. Here, we assessed the effect of examination stress on IOP in 33 university students. A repeated-measures design was used with two experimental conditions (examination and control) and two points of measurements (pre- and post-sessions). Also, the cardiovascular response, subjective perceived stress, as well as calculated ocular perfusion pressure and blood-pulse pressure were determined. A Bayesian statistical analysis showed higher IOP values in the examination in comparison to the control condition ($BF_{01} < 0.001$). A similar pattern was found for the cardiovascular indices (diastolic and systolic blood pressure, and heart rate), and these findings were corroborated by subjective reports ($BF_{01} < 0.001$ in all cases). Our data incorporates evidence in relation to the utility of IOP as an objective marker of examination stress, and it may help in the assessment and management of stress in applied scenarios.

1. Introduction

The term “stress” is used to describe experiences that are challenging emotionally and physiologically, and the nervous system regulates and responds to theses systemic processes via the neuroendocrine, autonomic, and immune systems (McEwen, 2007; Tsigos and Chrousos, 2002). It is well known that both chronic and acute mental stressors can have adverse effects on a range of psychological and physiological outcomes (Bibbey et al., 2013; Djuric et al., 2008; Loft et al., 2007) and not only alter the performance of the task (Arora et al., 2010; LeBlanc, 2009) but also have implications for an individual's health (Chida and Steptoe, 2010). These features have been observed in numerous highly stressed populations, such as aircraft pilots, professional drivers, surgeons, and sports professionals (Di Stasi et al., 2017; Heine et al., 2017; Mansikka et al., 2015; Marrelli et al., 2014; Stults-Kolehmainen and Sinha, 2014).

Also, in the field of education, students undergoing academic assessment suffer from both severe acute and chronic stress (Schraml et al., 2012). Especially academic stress related to examinations is considered to be one of the most acute stresses experienced by students which can in turn interfere with academic performance (Park et al., 2012) and even can be detrimental to the student's mental health (LeBlanc, 2009; Maercker et al., 2013). Due to the fact that academic examinations are frequently used in stress research, Bosch et al. (2004) proposed the term examination stress for situations in which a discrete exam is used as a stressor, and following this recommendation, we will use the term examination stress throughout this paper. Although individuals react differently to stress psychosomatically, all the responses to these acute stressful situations are reflected either in subjects' self-perceptions (subjective measures) or in their physiological state (objective measures). In the latter case, the physiological changes due to stress can be evaluated with non-invasive biomarker measurements, focusing on the responses from the autonomous nervous system (ANS) (Castaldo et al., 2015; Kumar et al., 2012; Lambert et al., 2010; Muller et al., 2013) or the hypothalamic-pituitary-adrenal axis (Hewig et al., 2008; LeBlanc, 2009; Loft et al., 2007).

For acute-stress testing, heat-rate variability and salivary cortisol have been the most frequently used markers in the literature, as objective reliable means to indirectly monitor the ANS and hypothalamic-pituitary-adrenal axis, respectively (Castaldo et al., 2015; Marques et al., 2010; Slavish et al., 2015). Also, due to the close relationship between ocular functioning and neurocognitive processes, eye activity, using pupil dilation and blink rate, has been tested in order to correlate stress with physiological measures (Jongkees and Colzato, 2016; Macatee et al., 2017; Pedrotti et al., 2014; Torres-Salomao et al., 2016; van de Groep et al., 2017). The implementation of these indices in large sample sizes represents a cost limitation, and the laborious data processing may limit their utility in ecological scenarios.

In the search for new physiological indexes that reflect changes in the sympathetic-parasympathetic balance, the intraocular pressure (IOP) has recently appeared (Brody et al., 1999; Vera et al., 2017, 2016). Intraocular pressure is defined as the pressure exerted against the outer layers of the eyeball by its contents (Segen, 2006). The role of the ANS in the regulation of IOP is well recognized and the

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sympathetic-adrenal system plays a crucial role in aqueous humour inflow and outflow (Gherghel et al., 2004; Lanigan et al., 1989). In this regard, IOP has been demonstrated to be sensitive to cognitive load or induced-fatigue experimental manipulation (Brody et al., 1999; Vera et al., 2017, 2016). As IOP is not under voluntary control, we hypothesise here that IOP could behave in the same way as in those experiments, and it could provide an accurate and unbiased measure of acute stress by modulating the autonomic nervous system activity.

On the other hand, high levels of IOP are commonly associated with the onset and the progression of glaucoma, an eye disease characterized by loss of retinal ganglion cells and their axons, leading to typical optic-nerve-head damage and visual-field defects (Miglior and Bertuzzi, 2013). In conjunction with IOP, ocular perfusion pressure (OPP), is a key factor that should be evaluated in the management of glaucoma (Cherecheanu et al., 2013). Systolic OPP and diastolic OPP are defined as the difference between systemic systolic or diastolic blood pressure and IOP, respectively, and unstable perfusion with wide fluctuations and repeated ischemic stress lead to optic-nerve-head injury (Costa et al., 2014). OPP decreases when systemic blood pressure (BP) is low or when IOP is high, and 1 mm Hg increase in OPP fluctuation has been associated with a 27.2% greater chance of glaucoma progression (Sung et al., 2009). Therefore, if our starting hypothesis is true, we might conclude that acute stress could exacerbate these fluctuations in OPP and increase glaucoma risk, as speculated in previous works (Kaluza and Maurer, 1997; Shily, 1987). In addition, it would be of primary interest for the control of IOP baseline values in those subjects exposed to high levels of stress, and especially in glaucoma-suspected subjects.

In this study, the foremost goal was to investigate the effect acute stress caused by a discrete exam in university students on IOP in comparison to a classroom lecture. Secondary, we tested the sensitivity of systolic and diastolic blood pressures (SBP and SDP), and heart rate (HR) to examination stress in order to corroborate the effects of acute stress on these cardiovascular indices (Bibbey et al., 2013; Chida and Steptoe, 2010). These measures provide useful insights into the stress states of participants who may not choose to identify clearly themselves as ‘stressed out’ when answering subjective stress questionnaires (Hughes, 2005). In addition, we analysed the effect of acute stress on blood-pulse pressure (BPP) and OPP as possible indicators of cardiovascular and ocular health, respectively.

2. Methods

2.1. Participants

The participant recruitment and experimental procedures for this study complied with the Code of Ethics of the World Medical Association (Declaration of Helsinki), and permission was provided by the university Institutional Review Board (IRB).

An *a priori* power analysis, using the GPower 3.1 software (Faul et al., 2007), was conducted for sample-size estimation. For an assumed power of 0.90, alpha of 0.05, and effect size of 0.25, we had a projected sample size of 30 participants. The present study was carried out with students from second year of a four-year undergraduate degree course in Optics and Optometry (University of Granada, Spain). A total of 36 healthy university student volunteers took part in this study and all subjects gave informed consent prior to participation. Participants were screened according to the following inclusion criteria: (a) being healthy (not suffering any current illness or mental disorder), (b) belonging to the visual asymptomatic group at Conlon survey (≤ 24) (Conlon et al., 1999), (c) not taking any medication (included contraceptives) (Kirschbaum et al., 1999), (d) IOP values $\leq$ 21 mm Hg which is considered as the upper limit for baseline normal intraocular pressure (National Health and Medical Research Council, 2010), and (e) not having a blood-pulse pressure (difference between systolic and diastolic blood pressure) higher than 59 mm Hg prior to both experimental conditions, which is considered an indicator of possible cardiovascular disorders in males and females (Franklin et al., 1999). Additionally, participants were asked to avoid alcohol and caffeine-based drinks 12 h before two experimental sessions (academic examination session and control session), and they had to get at least 7 h of sleep the night prior to both experimental sessions. The participants provided this information by filling in a questionnaire before the commencement of the experimental sessions. The Stanford Sleepiness scale (SSS) (Hoddes et al., 1972) was used to evaluate their subjective levels of arousal and all participants scored 3 or less, which has been used for screening in related experiments (Di Stasi et al., 2015; Vera et al., 2016) (see 2.2 Subjective questionnaires of perceived fatigue and stress level section). We excluded one participant from analysis due to IOP value $\geq$ 21 mm Hg and two participants did not complete the experiment. Thus, data from 33 participants (26 women, 7 men; range age: 19–23 years old; mean age $\pm$ SD: 19.91 $\pm$ 1.21 years old) were considered for further analyses.

2.2. Experimental design

Each participant performed two experimental sessions with different stress levels. The experiments were conducted by two experienced optometrists with a controlled design, including repeated measures in the same group of participants in examination as well as non-examination (control) sessions. We included the same subjects as the control group, both experimental session were scheduled at the same time of day, counterbalanced between participants, and all physiological measurements were taken with the same body position (sitting and neutral neck position) in order to avoid the potential effects of confounding factors such as diurnal variations, re-measurement effect and body position (Malihi and Sit, 2012; Chakraborty et al., 2011; Mancia et al., 1983) on IOP and blood pressure. The level of sleepiness was assessed before each experimental session. The dependent variables for the analysis were: perceived stress level, intraocular pressure, systolic and diastolic blood pressure, heart rate, mean arterial pressure, ocular perfusion pressure and blood-pulse pressure. The sessions lasted ~90 min each. The written examination consisted of 12 questions (maximal duration: 1:30 h) with limited space for response. The examination (first session) started immediately after the students answered the subjective stress questionnaires and physiological measures were taken by two experimenters.

2.3. Subjective questionnaires of perceived fatigue and stress level

We asked participants to fill in the questionnaire Stanford Sleepiness Scale (SSS) before both examination and control sessions in order to evaluate the effectiveness of the fatigue-inducing manipulation. The SSS provides a global measure of how alert a person is feeling, ranging between 0 and 7. It contains seven statements ranging from “Feeling active, vital, alert, or wide awake” (score 1) to “No longer fighting sleep, sleep onset soon, having dream-like thoughts” (score 7).

A second questionnaire to evaluate subjective stress level was passed before and after each session. It consisted of a numerical scale (ranging from 1 to 10) defined as: 0 absolutely not stressed and 10 extremely stressed (Urwyler et al., 2015).

2.4. Instruments and measures

IOP measurements were performed with the Icare Tonometer (TiolatOy, INC. Helsinki, Finland), which has been clinically validated (Davies et al., 2006). Participants were instructed to fixate on a distant target while the probe of the tonometer was held at a distance of 4–8 mm, and perpendicular to the central cornea. Six rapidly consecutive measurements were performed against the central cornea and the mean reading displayed digitally in mm Hg on the LCD screen. The apparatus indicated whether differences between measurements were acceptable, and when the standard deviation was too large a new