Studying the Influence of Stress on Creativity in a Virtual Reality Scenario

Samory Houzangbe
samory.houzangbe@ensam.eu
Arts et Metiers Institute of Technology, LAMPA, HESAM Université
Change, France

David Antonio Gómez Jáuregui
Univ. Bordeaux, ESTIA Institute of Technology
Bidart, France

Sylvain Fleury
Arts et Metiers Institute of Technology, LAMPA, HESAM Université
Change, France

Loïc Huet
Arts et Metiers Institute of Technology, LAMPA, HESAM Université
Change, France

Léo Berdon
Arts et Metiers Institute of Technology, LAMPA, HESAM Université
Change, France

Baptiste Manusset
Arts et Metiers Institute of Technology, LAMPA, HESAM Université
Change, France

Paul Subert
Arts et Metiers Institute of Technology, LAMPA, HESAM Université
Change, France

Jean-Baptiste Pigrée
Arts et Metiers Institute of Technology, LAMPA, HESAM Université
Change, France

Nadine Couture
Univ. Bordeaux, ESTIA Institute of Technology
Bidart, France

Simon Richir
Arts et Metiers Institute of Technology, LAMPA, HESAM Université
Change, France

ABSTRACT

Whether it is for evolution, competitiveness or problem solving, innovation is necessary to a company's survival. Thus, it is essential to understand these process and what affect them in order to improve innovation. In this paper we focus on the ideation steps (generating ideas and proposing new concepts). We developed an experimental protocol in Virtual Reality, as it has been demonstrated to be a useful medium for creativity. We conducted the experiment following two conditions, one with an induction of stress and one without, to evaluate the effect of stress on the level of creativity. The levels of stress, creativity and physiological signals have been monitored. Our early results did not show significant differences between the two groups, however, as supported by previous studies, we have successfully used the Empatica E4 physiological wearable in our experimental context and observed a general rise in electrodermal activity (EDA) among our participants. We suggest that our experiment was able to elicit an emotional response in our participants that is observable in the physiological data. This preliminary study will help us shape the next steps of our research on the understanding of the creativity experience depending on different parameters.

CCS CONCEPTS

• **Human-centered computing** → **User studies**; **Virtual reality**; • **Computing methodologies** → *Cognitive science*.

KEYWORDS

Creativity, Stress, Virtual Reality

ACM Reference Format:
Samory Houzangbe, David Antonio Gómez Jáuregui, Sylvain Fleury, Loïc Huet, Léo Berdon, Baptiste Manusset, Paul Subert, Jean-Baptiste Pigrée, Nadine Couture, and Simon Richir. 2021. Studying the Influence of Stress on Creativity in a Virtual Reality Scenario. In *Extended Abstracts of the 2021 CHI Conference on Human Factors in Computing Systems, May 09, 2021, Yokohama, Japan.* ACM, New York, NY, USA, 5 pages. https://doi.org/xx.xxxx/xxxxxxxxxxx.xxxxxxx

MEEC '21, May 09, 2021, Yokohama, Japan

ACM ISBN 978-1-4503-XXXX-X/18/06…$15.00
https://doi.org/xx.xxxx/xxxxxxxxxxx.xxxxxxx

1 INTRODUCTION

A company capacity to innovate is crucial for its development and competitiveness. These innovation processes are often complex because they rely on strategic, human, technical and organizational capacities. In this research we are interested in the ideation steps, those that consist in generating ideas and proposing new concepts. These steps rely on the abilities to be creative and creative activities. Creativity is generally defined as the ability to propose new concepts adapted to the context in which they are developed [21]. Even if the temporal, material and human components are important [3], other specific levers can be of use to modulate creativity, influencing, for example, the rationale and problem-solving schemes [2, 22]. It has been demonstrated that numerous elements of the environment can influence creativity [5, 13]. Virtual reality has proven its relevance to stimulate users' creativity during ideation tasks, compared to other sketching tools such as paper and pen [34], Photoshop [20] or computer-assisted conception (CAO) [10]. Mille et al. [23] also demonstrated that sketching idea generation in VR provide a better user experience than CAO and pen and paper. The previously cited studies indicate that virtual reality sketching is appropriate to induce the state of flow, which leads the participants to generate more elaborate ideas.

Multiple researchers have studied the relationship between emotional states and creativity. Indeed, in 2008 Dedreu et al. [9] propose a dual pathway to creativity. They present the results of four consecutive experiments. They state that arousal stimulate creativity. Moreover, they specify that positive arousal can enhance performance through higher flexibility and inclusivity, while negative arousal leads to higher creative performance through higher perseverance and persistence. They insist that the effects of emotional states on creativity cannot be only attributed to arousal since the valence of the emotion has to be also taken into account depending on the type of tasks.

Another study by Hao et al. [15] deepened the previous study, they try to find if the compatibility between emotional state and posture lead to better creativity. They conduct two studies, the first one by inducing negative or positive emotions to the participants and making them take an open or close posture. The participants realize an Alternative Uses Task (AUT) [14]. For the second study they use the same protocol as the first one but the participants realize a Realistic Presented Problem (RPP) to test their divergent thinking and creative potential. They conclude that the creative performance is not only linked to the emotion, but rather with the compatibility between the emotion and the posture. They specify that the association of the two could lead to better creativity results.

Back in 1992 Talbot et al. [31] already highlighted a relationship between creativity and stress. In their research they find out that there are strong negative correlations between stress and creative climate, especially arising from relationships with others and organizational structure. However, Byron et al. [8] stated that the relationship between stress and creativity might not be captured by describing the relationship as positive or negative. Somaz and Tulgan [28] suggest that, in a work environment, acute stress induces adrenaline in the body, thereby fueling work performance, intensifying mental focus, and acting as a channel for creativity and innovation. Moreover, some studies [1, 6] found that acute stress seems to facilitate memory in a stressful learning context. In contrast, several studies suggest that repeated, or chronic, stress exposure usually impairs information processing and produces memory deficits in healthy adults [19]. Thus, stress, in these cases, might inhibit creativity [26] and produce a negative impact [25].

The aim of this study is to explore the influence of stress on creativity under a virtual reality scenario. In order to explore this influence, we induce stress before the creativity task, and we will try to detect stress levels using physiological data as well as psychological questionnaires. The results of this study will provide cues towards the adaptation of the creative environment to the user in real time in order to increase the quality of the creative experience and the results produced.

2 APPARATUS

The VR creativity tasks take place in a 3D sketching application. This application allows the user to draw in 3D thanks to the VR 3D tracking capabilities. In the application the user can draw with the handheld controllers. They have the choice between different brush sizes and colors using a color palette. There is also the option to erase parts of the drawing, select and resize or even draw symmetrical forms using a plane that will mirror the lines. The user can save the drawing and create a new scene to start anew.

We decided to use a Vive VR HMD due to its display quality and the tracking offered by the system. It allows the user to freely navigate around their drawing. This VR device is coupled with a VR ready state of the art computer (Intel Core i7 Coffee Lake, 16GB of RAM, NVIDIA GeForce RTX 2070) to ensure that the experience runs as smoothly as possible.

Several studies have showed that physiological data such as heart rate and heart rate variability have been linked with mental stress [30]. In addition, multiple previous studies [16, 18] have showed that electro-dermal activity has been linked with stress levels. In order to record physiological data, we decided to use the Empatica E4 wristband [12]. This smart wearable was designed for research purposes and thus allows to have access to raw data for blood volume pulse (BVP), inter-beat intervals (IBI), skin temperature (SKT), acceleration data and electro-dermal activity (EDA). Multiple studies have focused on the reliability of the E4 for emotion recognition, raw data compared to medical grade tools. Indeed, Ollander et al. [24] compare how the E4 fares against a stationary, medical grade device to detect stress. In their study the authors evaluated the Trier Social Stress Test protocol [7], which consist in a job interview simulation. Van Lier et al. [32] propose a standardized method to validate the reliability of physiological monitoring wearables. The participants realize a stress inducing task to determine if the E4 is able to detect physiological changes reliably. All these authors concluded that the Empatica is a valid sensor device to detect physiological responses to stress factors.

3 EXPERIMENTAL PROTOCOL

First the participants were asked to read and sign a participation consent form and that they accept their physiological data to be monitored and used in the study. They then proceed to fill a pre-experimentation questionnaire to record demographic data. The participant then answer the State-Trait Anxiety Index (STAY-I) [29] in order to measure their level of stress.

Once the participants completed the questionnaires, they were equipped with the E4 and the Vive HMD. They perform a tutorial phase to get accustomed to the sketching application (learning how to draw, erase, change brush size and color, save a drawing

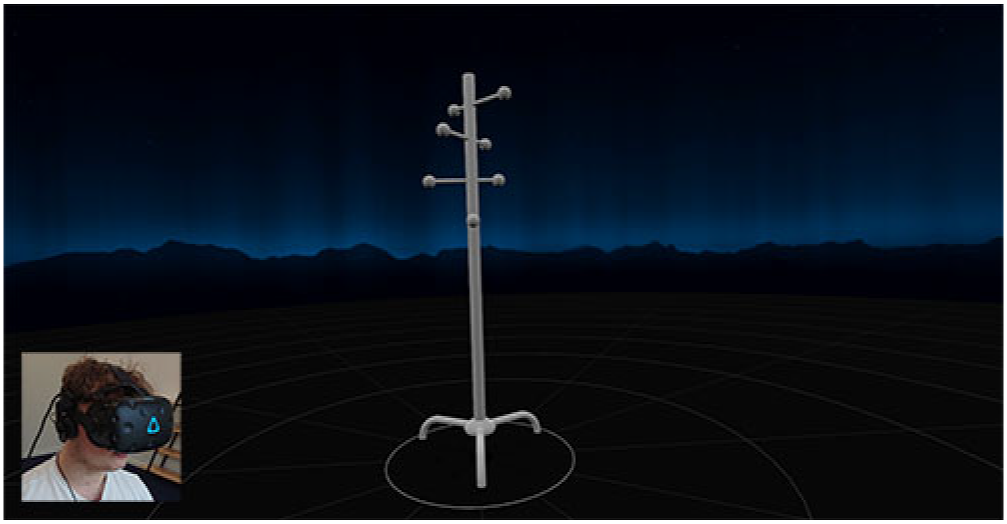


Figure 1: Image of a user with the VR headset and the coat hanger present in the environment.

and create a new scene). The tutorial phase lasts for 3 minutes. Once they complete the tutorial phase, the creativity scenario is described to the participant. The proposed task is to do a divergent creativity exercise, based on Guilford Alternative Uses (GAU) [14]. The creativity scenario consists in a coat hanger company that has produced too many products and the goal of the participant is to imagine as many alternative ways as possible to use them. During these tasks the participant has to draw as many ideas as possible using the 3D sketching tool. The software will present a 3D model of a coat hanger that the participant will use as a basis for the drawing (see Figure 1). Once they complete the drawing, they save it and move to the next idea. The creativity task lasts for 7 minutes.

For this experiment two participants' groups were considered: a stress-induction group and a no-stress induction group. Both groups followed the procedure described previously. However, for the stress group the experimenter introduced to the participant (before the creativity task started) a non-responding jury, physically present in the room. The participants are told that the jury will judge the quality of the ideas produced. The presence of a jury has already been successfully used as a way to elicit stress in different scenarios [17]. The jury was not represented in the virtual world. We decided to conduct a between-subject design to compare the same creativity task. Proposing two different creativity scenario that can be analyzed separately and be compared regarding the level of creativity the participants produce was overly complex for our study.

At the end of the task the participant is asked to remove the Vive HMD and E4 and asked to complete once again the STAI-Y questionnaire.

4 MEASURES

To measure the level of stress and general anxiety of the participants, we used the STAI-Y questionnaire. In addition, we measured the participants' electro-dermal activity (EDA), as both data have been showed to relate with stress in the literature [16, 18, 30].

The level of creativity is measured for each participants depending on a combined score using the methods of Guilford [14], as described by Fleury [11].The GAU leads to the collection of a set of ideas for each participant. Each set of ideas is then analyzed to be characterized on the basis of four criteria which constitute the scores. These scores are originality (which evaluates whether the participant's ideas were unique when compared to other participants), fluency (the number of ideas generated), flexibility (the number of ideas belonging to different domains or categories) and elaboration (the amount of added detail given for each idea).

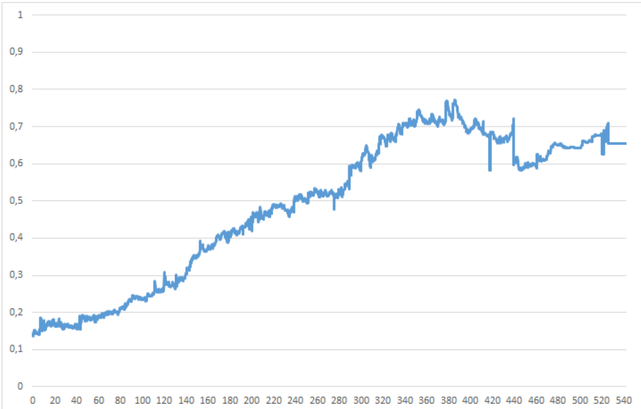
5 PARTICIPANTS

A short experiment has been conducted with 16 Master's students, specialized in VR, thus used to the tools and interaction schemes. There were 10 men and 6 women, aged between 22 and 33 (M=23.56). The participants have been divided in two groups of 8 (one with stress induction and one without). The non-responding jury was done by a member of the lab not well known by the students.

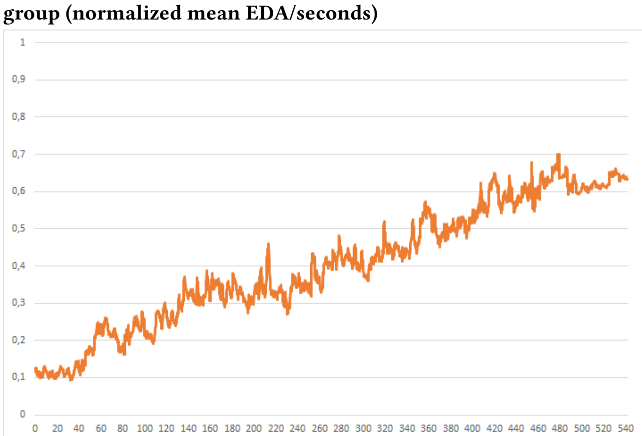
6 PRELIMINARY RESULTS AND FUTURE WORK

To analyze the results of stress we used paired-samples t-test, as the Shapiro-Wilk test of normality was not significant (p=0.141). An early analysis of the result did not show significant differences for the level of stress (before-after) for the non-stress induction group (p=0.320, M-before=33.13, M-After=29.75). The paired-samples t-test did not return any significant differences for the level of stress (before-after) for the stress induction group (p=0.377, M-before=35.63, M-After=33.13). We used an ANOVA analysis to compare the creativity scores between our two groups. The results show no significant differences between the two groups (p=0.442, F=0.627, M-NoStress=14.13, M-Stress=15.50).

Regarding the physiological data (notably EDA) we did not find significant correlations between the average level of EDA and the level of creativity nor the level of stress reported by the participants.



(a) Normalized mean value of EDA for participants in the No-Stress group (normalized mean EDA/seconds)



(b) Normalized mean value of EDA for participants in the Stress group (normalized mean EDA/seconds)

Figure 2: Plots of the mean normalized EDA data.

We performed a qualitative analysis of the EDA data. First of all, we reported very few abnormal data records and no disconnection during our experiment. To have a visual representation of the evolution of EDA, we normalized the data (using a min-max algorithm), computed the mean data and then plotted the data (see Figure 2). We can observe for both groups that the EDA is rising throughout the experience. As EDA has been linked with the level of arousal [27], we can assume that the creativity task in VR generated an emotional response in our participants. It is interesting indeed as we have discussed earlier that emotions are keys in the creative process [9].

Even if the results are still not significant, this experiment gives us an interesting perspective in how useful a wearable device, such as the Empatica E4, can be in a VR experience involving movement without inhibiting this experience. This experiment combined with previous literature validate the usage of the E4 as a tool to measure physiological data during a VR creativity task. The increase in EDA levels also is an interesting cue as to how the participants reacted to the experience. If we are able to detect certain physiological response patterns, we might be able to better understand the creative process and adapt the environment to the user's emotional response.

Our next research work will be focused on the analysis of physiological data and its relationship with creativity. We will also study non-verbal behavior (posture) as multiple studies already have showed that there is a relation between different postures and certain types of creative tasks [4, 15, 33]. In addition, different types of physiological data (e.g. skin temperature, hearth rate) will be also considered in order to have additional indicators for stress measurement. Moreover, to correct the limitations of our current protocol we plan on recording the participants personality traits using questionnaires.

ACKNOWLEDGMENTS

We would like to extend our thanks to all the students that participated in the experiment. We would also like to thank the AM Valor engineering team that helped us setup the 3D Sketching environment. Finally we want to thank Olivier Christmann and Geoffrey Gorisse that coordinated the research project and allowed for the development of that research.

REFERENCES

[1] Heather C. Abercrombie, Nicole S. Speck, and Roxanne M. Monticelli. 2006. Endogenous cortisol elevations are related to memory facilitation only in individuals who are emotionally aroused. *Psychoneuroendocrinology* 31, 2 (2006), 187–196. https://doi.org/10.1016/j.psyneuen.2005.06.008

[2] Teresa M Amabile. 1983. The social psychology of creativity: A componential conceptualization. *Journal of personality and social psychology* 45, 2 (1983), 357.

[3] Teresa M. Amabile and Michael G. Pratt. 2016. The dynamic componential model of creativity and innovation in organizations: Making progress, making meaning. *Research in Organizational Behavior* 36 (2016), 157–183. https://doi.org/10.1016/j.riob.2016.10.001

[4] Valentina Rita Andolfi, Chiara Di Nuzzo, and Alessandro Antonietti. 2017. Opening the mind through the body: The effects of posture on creative processes. *Thinking Skills and Creativity* 24 (2017), 20–28. https://doi.org/10.1016/j.tsc.2017.02.012

[5] Benjamin Baird, Jonathan Smallwood, Michael D. Mrazek, Julia W. Y. Kam, Michael S. Franklin, and Jonathan W. Schooler. 2012. Inspired by Distraction: Mind Wandering Facilitates Creative Incubation. *Psychological Science* 23, 10 (2012), 1117–1122. https://doi.org/10.1177/0956797612446024 arXiv:https://doi.org/10.1177/0956797612446024 PMID: 22941876.

[6] Karel J Bemelmans, Jaap G Goekoop, Roel de Rijk, and Godfried M.J van Kempen. 2003. Recall performance, plasma cortisol and plasma norepinephrine in normal human subjects. *Biological Psychology* 62, 1 (2003), 1–15. https://doi.org/10.1016/S0301-0511(02)00089-3

[7] Melissa A Birkett. 2011. The Trier Social Stress Test protocol for inducing psychological stress. *Journal of visualized experiments: JoVE* 56 (2011).

[8] K. Byron, Shalini Khazanchi, and Deborah Nazarian. 2010. The relationship between stressors and creativity: a meta-analysis examining competing theoretical models. *The Journal of applied psychology* 95 1 (2010), 201–12.

[9] Carsten KW De Dreu, Matthijs Baas, and Bernard A Nijstad. 2008. Hedonic tone and activation level in the mood-creativity link: toward a dual pathway to creativity model. *Journal of personality and social psychology* 94, 5 (2008), 739.

[10] Seth M. Feeman, Landon B. Wright, and John L. Salmon. 2018. Exploration and evaluation of CAD modeling in virtual reality. *Computer-Aided Design and Applications* 15, 6 (2018), 892–904. https://doi.org/10.1080/16864360.2018.1462570 arXiv:https://doi.org/10.1080/16864360.2018.1462570

[11] Sylvain Fleury, Aurélien Agnès, Rishi Vanukuru, Emma Goumillout, Nicolas Delcombel, and Simon Richir. 2020. Studying the effects of visual movement on creativity. *Thinking Skills and Creativity* 36 (2020), 100661. https://doi.org/10.1016/j.tsc.2020.100661

[12] M. Garbarino, M. Lai, D. Bender, R.W. Picard, and S. Tognetti. 2014. Empatica E3 - A wearable wireless multi-sensor device for real-time computerized biofeedback and data acquisition. In *2014 EAI 4th International Conference on Wireless Mobile Communication and Healthcare (Mobihealth)*. 39–42. https://doi.org/10.1109/MOBIHEALTH.2014.7015904

[13] Gabriela Goldschmidt and Maria Smolkov. 2006. Variances in the impact of visual stimuli on design problem solving performance. *Design Studies* 27, 5 (2006), 549–569. https://doi.org/10.1016/j.destud.2006.01.002

[14] J. P. Guilford. 1966. Measurement and Creativity. *Theory Into Practice* 5, 4 (1966), 185–189. https://doi.org/10.1080/00405846609542023 arXiv:https://doi.org/10.1080/00405846609542023

[15] Ning Hao, Hua Xue, Huan Yuan, Qing Wang, and Mark A. Runco. 2017. Enhancing creativity: Proper body posture meets proper emotion. *Acta Psychologica* 173 (2017), 32–40. https://doi.org/10.1016/j.actpsy.2016.12.005

[16] A. Islam, J. Ma, T. Gedeon, M. Z. Hossain, and Y. H. Liu. 2019. Measuring User Responses to Driving Simulators: A Galvanic Skin Response Based Study. In *2019 IEEE International Conference on Artificial Intelligence and Virtual Reality (AIVR)*. 33–337. https://doi.org/10.1109/AIVR46125.2019.00015

[17] Camille Jeunet, Christian Mühl, and Fabien Lotte. 2013. Conception et validation d'un protocole pour induire du stress et le mesurer dans des signaux physiologiques. 25ème conférence francophone sur l'Interaction Homme-Machine, IHM'13. https://hal.inria.fr/hal-00879588 Poster.

[18] Anurag Joshi, Ravi Kiran, and Ash Narayan Sah. 2017. An experimental analysis to monitor and manage stress among engineering students using Galvanic Skin Response meter. *Work* 56, 3 (2017), 409–420.

[19] Clemens Kirschbaum, O. Wolf, M. May, W. Wippich, and D. Hellhammer. 1996. Stress- and treatment-induced elevations of cortisol levels associated with impaired declarative memory in healthy adults. *Life sciences* 58 17 (1996), 1475–83.

[20] Jee Hyun Lee, Eun Kyoung Yang, and Zhong Yuan Sun. 2019. Design Cognitive Actions Stimulating Creativity in the VR Design Environment. In *Proceedings of the 2019 on Creativity and Cognition* (San Diego, CA, USA) *(C&C '19)*. Association for Computing Machinery, New York, NY, USA, 604–611. https://doi.org/10.1145/3325480.3326575

[21] Todd Lubart, Christophe Mouchiroud, Sylvie Tordjman, and Franck Zenasni. 2015. *Psychologie de la créativité-2e édition*. Armand Colin.

[22] Todd I Lubart and Robert J Sternberg. 1995. An investment approach to creativity: Theory and data. *The creative cognition approach* (1995), 269–302.

[23] Charles Mille, Olivier Christmann, Sylvain Fleury, and Simon Richir. 2020. Effects of digital tools feature on creativity and communicability of ideas for upstream phase of conception. In *Proceedings of the 4th International Conference on Computer-Human Interaction Research and Applications - CHIRA*. INSTICC, SciTePress.

[24] S. Ollander, C. Godin, A. Campagne, and S. Charbonnier. 2016. A comparison of wearable and stationary sensors for stress detection. In *2016 IEEE International Conference on Systems, Man, and Cybernetics (SMC)*. 004362–004366. https://doi.org/10.1109/SMC.2016.7844917

[25] Hans Selye. 1955. Stress and disease. *The Laryngoscope* 65, 7 (1955), 500–514.

[26] James Shanteau and Geri Dino. 1993. *Environmental Stressor Effects on Creativity and Decision Making*. 293–308. https://doi.org/10.1007/978-1-4757-6846-6_19

[27] E. S. Siqueira, T. A. A. Santos, C. D. Castanho, and R. P. Jacobi. 2018. Estimating Player Experience from Arousal and Valence Using Psychophysiological Signals. In *2018 17th Brazilian Symposium on Computer Games and Digital Entertainment (SBGames)*. 107–10709. https://doi.org/10.1109/SBGAMES.2018.00022

[28] H.W. Sormaz and B. Tulgan. 2003. *Performance Under Pressure: Managing Stress in the Workplace*. HRD Press. https://books.google.fr/books?id=guUc3wbP5PIC

[29] Charles D. Spielberger. 2010. *State-Trait Anxiety Inventory*. American Cancer Society, 1–1. https://doi.org/10.1002/9780470479216.corpsy0943 arXiv:https://onlinelibrary.wiley.com/doi/pdf/10.1002/9780470479216.corpsy0943

[30] Joachim Taelman, S. Vandeput, A. Spaepen, and S. Van Huffel. 2009. Influence of Mental Stress on Heart Rate and Heart Rate Variability. In *4th European Conference of the International Federation for Medical and Biological Engineering*, Jos Vander Sloten, Pascal Verdonck, Marc Nyssen, and Jens Haueisen (Eds.). Springer Berlin Heidelberg, Berlin, Heidelberg, 1366–1369.

[31] Reg Talbot, Cary Cooper, and Steve Barrow. 1992. Creativity and Stress. *Creativity and Innovation Management* 1, 4 (1992), 183–193. https://doi.org/10.1111/j.1467-8691.1992.tb00052.x arXiv:https://onlinelibrary.wiley.com/doi/pdf/10.1111/j.1467-8691.1992.tb00052.x

[32] Hendrika G van Lier, Marcel E Pieterse, Ainara Garde, Marloes G Postel, Hein A de Haan, Miriam MR Vollenbroek-Hutten, Jan Maarten Schraagen, and Matthijs L Noordzij. 2019. A standardized validity assessment protocol for physiological signals from wearable technology: Methodological underpinnings and an application to the E4 biosensor. *Behavior research methods* (2019), 1–23.

[33] Andrea Stevenson Won, Jeremy N Bailenson, Suzanne C Stathatos, and Wenqing Dai. 2014. Automatically detected nonverbal behavior predicts creativity in collaborating dyads. *Journal of Nonverbal Behavior* 38, 3 (2014), 389–408.

[34] Xiaozhe Yang, Lin Lin, Pei-Yu Cheng, Xue Yang, Youqun Ren, and Yueh-Min Huang. 2018. Examining creativity through a virtual reality support system. *Educational Technology Research and Development* 66, 5 (2018), 1231–1254.