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Interpersonal synchrony in electrodermal activity predicts decreased performance in a vigilance task induced by sleep deprivation

Ivo Stuldreher^{1,2}, Jan van Erp^{1,2}, Anne-Marie Brouwer¹

1) Human Factors, TNO, Soesterberg, The Netherlands

2) Human Media Interaction, University of Twente, Enschede, The Netherlands

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Introduction

Safety and security tasks often rely on operators' vigilant attention, the ability to focus for a prolonged period of time while performing a monotonous cognitive task. Sleep deprivation (SD) impairs vigilant attention (Hudson et al., 2020). At the same time, SD is unavoidable in certain professions and under certain circumstances. Continuous information about vigilant attention of sleep deprived individuals would be helpful to monitor whether they are at risk of lapsing and consequently making mistakes. Physiological synchrony may be used for this purpose. Physiological synchrony refers to the degree to which physiological measures such as heart rate (HR) or electrodermal activity (EDA) uniformly change across individuals. When individuals attend to the same events in the world for a few minutes or more, they show physiological synchrony (Stuldreher et al., 2020). The degree of physiological synchrony reflects the amount of attentional engagement, i.e., the more engaged an individual is with the presented event, the higher the physiological synchrony with other individuals. We here investigate whether physiological synchrony as measure of attentional engagement can predict decreased performance in a vigilant attention task during SD.

Methods

This study was approved by the METC Brabant (approval no. NL74961.028.20). 54 Dutch-speaking volunteers (29 female) between 18 to 55 years old ($M = 29.4$, $SD = 11.9$) participated.

Throughout the experiment, participants' HR and EDA were recorded with a Tickr chest-strap (Wahoo Fitness, Atlanta, GA, USA) and EdaMove 4 (Movisens GmbH, Karlsruhe, Germany), respectively. As Figure 1a depicts, over the course of a night, participants were presented with a 10-minute video every hour from 22:00 to 07:00. The movie clips were selected from the Dutch YouTube channels NPO3 and KORT! and featured short, moderately emotionally engaging stories. After each movie clip, participants performed a 10-minute psychomotor vigilance task (PVT), a vigilant attention task in which the participant has to respond as fast as possible to an irregularly occurring stimulus (Hudson et al., 2020). Then they filled out the Stanford sleepiness scale (SSS).

We assessed physiological synchrony across participants during each movie by computing inter-subject correlations (ISC) in HR and EDA following earlier work (Stuldreher et al., 2020; Pérez et al., 2021; Madsen et al., 2022). We also computed the lapse probability performance measure for each

PVT, following (Hudson et al., 2020). We then used hierarchical linear models to investigate whether ISC is predictive of PVT lapse probability.

Results

Figure 1b shows traces of PVT lapse probability, and ISC in HR and EDA over the course of the night. The PVT lapse probability shows a clear pattern over the course of the night, with an increase of the lapse probability up to 04:00 AM, followed by a strong decrease in the early morning. ISC in HR and EDA do not show the reverse pattern. Our hierarchical linear models indeed indicated that ISC in HR did not significantly contribute to the prediction of PVT lapse probability. However, ISC in EDA significantly contributed to the prediction of PVT lapse probability. Follow-up analyses suggest that this is mainly due to the association of very high lapse probability with low ISC. Figure 1c gives an overview of self-reported sleepiness, HR and EDA over the night.

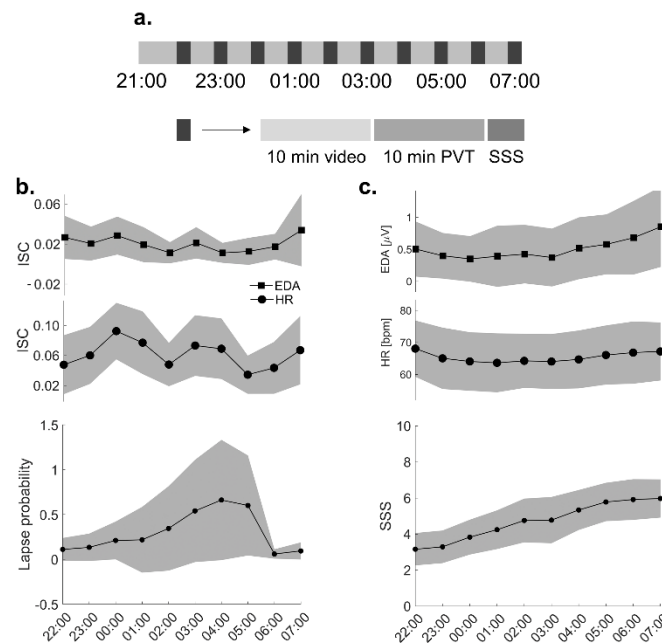


Figure 1. a. The experimental paradigm consisted of a block with a 10 minute video, a 10 minute PVT and the filling out the SSS. b. Traces of PVT lapse probability, and ISC in HR and EDA over the course of the night. c. Traces of SSS, and HR and phasic EDA over the course of the night.

Discussion

We here aimed to predict performance in a vigilant attention task over the course of a sleep deprived night with the use of physiological synchrony. ISC in HR was not predictive of the PVT lapse probability, our metric of vigilant attention performance, but ISC in EDA has a modest predictive value. Note that our movies were not a monotonous cognitive task that require vigilant attention, but were complex stimuli evoking attentional engagement. Participants reported to feel more awake during the movie after which they would feel more tired again during the PVT. For future work, we therefore suggest not to use engaging movies, but continuous background audio such as a radio show. We expect higher predictive value of ISC in such a case. Furthermore, our results showed an increase in EDA over the course of a sleep-deprived night, which as far as we are aware, has not been shown or examined before. The finding that self-reported sleepiness consistently increased over the night while performance showed a profound improvement after 5:00 underscore the notion that self-reports are not always reflective of objective performance.

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