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EXTENDED ABSTRACT

Introduction

The cognitive overload and emotion experienced by drivers become a primordial issue to study distraction. This is also the case in aviation, where pilots are commonly exposed to different sources of cognitive and emotional stressors and distractors [1]. Therefore, the integration of an online monitoring to assess the cognitive variations into the cockpit would be highly desirable to alert of delicate mental states. To this aim, reliable physiological measures are required. Electrocardiography (ECG) can be considered as one of the most suitable and cost-effective techniques providing powerful and relevant features to study driver distraction and cognitive workload [2, 3]. Heart rate (HR) and heart rate variability (HRV) parameters extracted from ECG signals are employed in aeronautics to determine the impact of different levels of mental overload in performance and decision-making [4, 5]. According to their findings, an increase in HR together with a decrease in HRV will be expected when cognitive workload becomes higher.

Furthermore, the personality is an important factor to take into consideration for drivers and pilots [6, 7]. Several research works have indicated a particular personality profile in pilots, whose neuroticism component is significantly lower than the population norm [8], while they score higher on the conscientiousness facets [9]. Given that physiological responses in general, and the cardiovascular activity in particular, are affected by personality traits [10, 11], it is important to consider this issue in order to better control individual differences and to reach a fine-grained interpretation of the ECG measures linked to the pilot distraction produced by a supplementary task simultaneous to the flight. In this pilot study, the HR modulation susceptibility to arousal level elicited by a social stressor and the cognitive workload is study in 21 private pilots.

Materials and Methods

Twenty pilots (only male; 22.7 ± 3.7 years) participated in the study. ECG signal was recorded (sampling rate = 1 MHz) along the whole experiment by BrainVision Recorder 1.21 (© Brain Products GmbH, Gilching, Germany). The experiment took place in an AL-50 simulator and consisted in two dual-task scenarios which required the simultaneous accomplishment of a pre-established flight plan and a secondary task based on target stimulus discrimination. During the first scenario, pilots were alone to accomplish the task, whereas for the second one, we modulated emotional state similarly to [12] by the filming the participant and involving him in a competition with the other participants.

Both flight scenarios lasted approximately 35 minutes and were analogous in term of difficulty. A strict timing for the flight instructions was specified. Speed (measured in knots), heading (degrees) and altitude (m) parameters were collected during the simulations (sampling rate of 1Hz). The performance was considered as acceptable when the deviations of the expected parameters fell into a margin. Any deviation greater than ±5 units, from the requested flight parameter, was counted as an error. The secondary task consisted of pressing a 7 inches touch-screen as quickly as possible after hearing some isolated numbers integrated among unrelated Air Traffic Control instructions. The task was presented during the cruise and subdivided in two inter-subject counterbalanced phases 12 minutes: Low Cognitive Workload (LCW) phase, where the participant was instructed to press the screen if the heard numbers meet a simple attribute (magnitude or parity); High Cognitive Workload (HCW) phase, where the attribute depended on the color of the numbers displayed on the screen.

All the participants completed the Neuroticism (N) and Conscientiousness (C) subscales of the French version of the Big Five Inventory personality dimensions scale [13]. For each subscale, participants indicated how accurately 9 traits described them on a 5-point scale, ranging from 1 (very inaccurate) to 5 (very accurate). The responses were averaged to obtain the neuroticism and the conscientiousness levels. By combining these dimensions, we were able to identify two different groups into the impulse control personality style [14]. An analysis of variance (ANOVA) of repeated measures was performed: 2 levels of cognitive workload: LCW and HCW, 2 levels of arousal: High and Low and one between-subject factor: personality style (2 levels). Post hoc analysis was based on HSD Tukey's. The cluster analysis to determine the membership of the two personality style (according to neuroticism and conscientiousness simultaneously) groups was based on a simple K-means algorithm (K = 2) with random center value initialization and setting a maximum of 10 iterations.

Results

Globally, a main effect of cognition was found for HR: $F(1,19) = 4.56$, $p = .046$, $\eta_p^2 = .19$, showing a greater value for HCW (M = 86.55 bpm, SD = 15.18) compared to LCW (M = 85.14 bpm, SD = 15.47) condition ($p = .013$). No main effect of arousal and no interaction between cognition and arousal were statistically significant analyzing the whole group.

The centers of the personality style clusters are showed in Table 1. The *group 1* (higher level of neuroticism and lower conscientiousness: N+C-) and the *group 2* (lower level of neuroticism and higher conscientiousness: N-C+) are composed of 9 and 11 participants, respectively.

Table 1. Centers of the personality style clusters considering two personality traits

	Neuroticism (N)	Conscience (C)
Group 1	2.20	3.39
Group 2	1.64	4.52

No main effect of personality group was found in HR. However, an interaction linked to cognitive workload was statistically significant: ($F(1,18) = 7.96$, $p = .01$, $\eta_p^2 = .31$). Post hoc analysis confirmed a significant increase between LCW (M = 81.48, SD = 15.10) and HCW (M = 84.64, SD = 16.55) in HR for group 1 only ($p = .007$), while the HR values for group 2 remained stable (see Figure 1). According to the cluster analysis, it seems that HR modulation due to cognitive demands was more remarkable for pilots scoring higher in neuroticism and lower in conscientiousness (N+C-) (Figure 1). No interaction between personality style and arousal level was found.

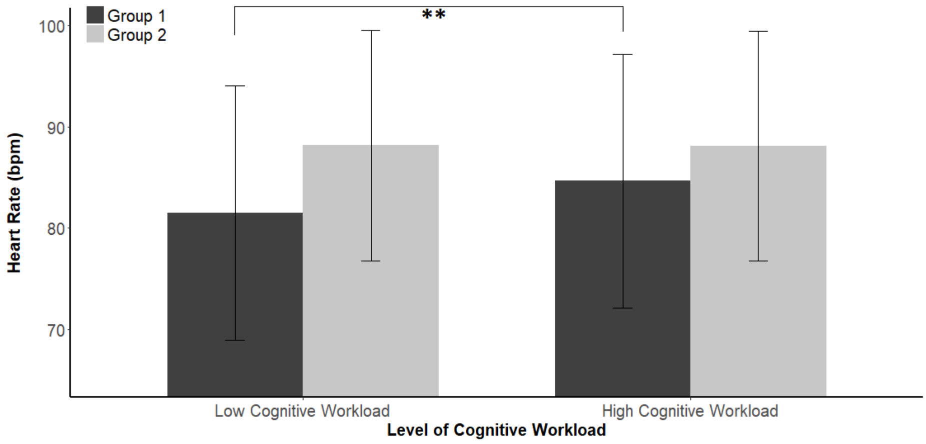

Figure 1. Means ± standard error of HR for Low and High Cognitive Workload for the two groups of participants (Group 1: N+C-; Group 2: N-C+). ** $p \leq .01$.

Discussion

As expected, HR was higher when cognitive workload increased, despite the surprising lack of arousal effect, arguably due to the safe simulated environment where a veritable vital risk did not exist [15].

Although our participants demonstrated moderate scores on neuroticism, in agreement with the results reported by [8], the higher level of this trait together with a lower score of conscientiousness were sufficient to produce quantifiable effects on HR, with increased response to cognitive workload only in the group 1 (N+C-), consistently with previous research works [11]. The group 2 (N-C+), remained unaffected by cognitive workload variations, with globally higher HR values than the group 1.

Most likely, pilots scoring higher in neuroticism and lower in conscientiousness better adapted their effort to the difficulty of the task (lower HR when task was simple, higher HR when task was more complex). Another interpretation of the result would be linked to the conscientiousness, since pilots with higher level of this trait could keep a higher level of vigilance over time, as evidenced by faster HR [16]. Therefore, even if neuroticism is the least dominant personality trait in pilots [17], this result is relevant to implement the interfaces of highly automated aviation system where the operator mental state is crucial to react to certain situations [18].

Interestingly, knowing which personality traits show greater physiological adaptability to cognitive workload variations can be useful to take into consideration in the selection of future pilots as well as in the application in similar contexts like the emerging autonomous vehicles. However, the limitation of the relatively small sample size leads us to be cautious with our conclusions. It would be desirable to complete the study in a larger population and to analyze the HRV parameters to complement HR.

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