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Emotional State and Cognitive Workload during a Flight Simulation: Heart Rate Study

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Abstract : Background: The monitoring of the physiological activity related to mental workload (MW) on pilots will be useful to improve aviation safety by anticipating human performance degradation. The electrocardiogram (ECG) can reveal MW fluctuations due to either cognitive workload or/and emotional state since this measure exhibits autonomic nervous system modulations. Arguably, heart rate (HR) is one of its most intuitive and reliable parameters. It would be particularly interesting to analyze the interaction between cognitive requirements and emotion in ecologic sets such as a flight simulator. This study aims to explore by means of HR the relation between cognitive demands and emotional activation. Presumably, the effects of cognition and emotion overloads are not necessarily cumulative. Methodology: Eight healthy volunteers in possession of the Private Pilot License were recruited (male; 20.8±3.2 years). ECG signal was recorded along the whole experiment by placing two electrodes on the clavicle and left pectoral of the participants. The HR was computed within 4 minutes segments. NASA-TLX and Big Five inventories were used to assess subjective workload and to consider the influence of individual personality differences. The experiment consisted in completing two dual-tasks of approximately 30 minutes of duration into a flight simulator AL50. Each dual-task required the simultaneous accomplishment of both a pre-established flight plan and an additional task based on target stimulus discrimination inserted between Air Traffic Control instructions. This secondary task allowed us to vary the cognitive workload from low (LC) to high (HC) levels, by combining auditory and visual numerical stimuli to respond to meeting specific criteria. Regarding emotional condition, the two dual-tasks were designed to assure analogous difficulty in terms of solicited cognitive demands. The former was realized by the pilot alone, i.e. Low Arousal (LA) condition. In contrast, the latter generates a high arousal (HA), since the pilot was supervised by two evaluators, filmed and involved into a mock competition with the rest of the participants. Results: Performance for the secondary task showed significant faster reaction times (RT) for HA compared to LA condition ($p=.003$). Moreover, faster RT was found for LC compared to HC ($p < .001$) condition. No interaction was found. Concerning HR measure, despite the lack of main effects an interaction between emotion and cognition is evidenced ($p=.028$). Post hoc analysis showed smaller HR for HA compared to LA condition only for LC ($p=.049$). Conclusion. The control of an aircraft is a very complex task including strong cognitive demands and depends on the emotional state of pilots. According to the behavioral data, the experimental set has permitted to generate satisfactorily different emotional and cognitive levels. As suggested by the interaction found in HR measure, these two factors do not seem to have a cumulative impact on the sympathetic nervous system. Apparently, low cognitive workload makes pilots more sensitive to emotional variations. These results hint the independency between data processing and emotional regulation. Further physiological data are necessary to confirm and disentangle this relation. This procedure may be useful for monitoring objectively pilot's mental workload.

Keywords : cognitive demands, emotion, flight simulator, heart rate, mental workload
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