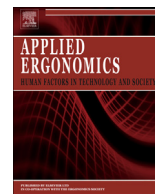




Contents lists available at ScienceDirect

Applied Ergonomics

journal homepage: www.elsevier.com/locate/apergo

Fighter pilots' heart rate, heart rate variation and performance during an instrument flight rules proficiency test

Heikki Mansikka^{a,*}, Kai Virtanen^b, Don Harris^a, Petteri Simola^{c,d}

^a Human Systems Integration Group, Faculty of Engineering and Computing, Coventry University, Priory Street, Coventry CV1 5FB, United Kingdom

^b Systems Analysis Laboratory, Department of Mathematics and Systems Analysis, School of Science, Aalto University, P.O.Box 11100, FIN 00076 Aalto, Helsinki, Finland

^c Finnish Defence Research Agency, Human Performance Division, Rantatie 66, 04401 Järvenpää, Tuusula, Finland

^d Cognitive Brain Research Unit, Cognitive Science, Institute of Behavioral Sciences, University of Helsinki, Helsinki, Finland

ARTICLE INFO

Article history:

Received 22 December 2015

Received in revised form

9 April 2016

Accepted 13 April 2016

Available online xxx

Keywords:

Pilot mental workload

Heart rate

Pilot performance

ABSTRACT

Increased task demand will increase the pilot mental workload (PMWL). When PMWL is increased, mental overload may occur resulting in degraded performance. During pilots' instrument flight rules (IFR) proficiency test, PMWL is typically not measured. Therefore, little is known about workload during the proficiency test and pilots' potential to cope with higher task demands than those experienced during the test. In this study, fighter pilots' performance and PMWL was measured during a real IFR proficiency test in an F/A-18 simulator. PMWL was measured using heart rate (HR) and heart rate variation (HRV). Performance was rated using Finnish Air Force's official rating scales. Results indicated that HR and HRV differentiate varying task demands in situations where variations in performance are insignificant. It was concluded that during a proficiency test, PMWL should be measured together with the task performance measurement.

© 2016 Elsevier Ltd and The Ergonomics Society. All rights reserved.

1. Introduction

Pilots' instrument flight rules (IFR) performance is an essential contributor to an operational effectiveness and a safety of flight. European Aviation Safety Agency requires pilots to pass an annual revalidation flight, or a check ride, in order to maintain their IFR currencies (<https://easa.europa.eu/regulations>). During an IFR check ride, the pilots' performance is assessed against the pre-defined performance criteria with the intent of verifying their proficiency to operate in instrument meteorological conditions (IMC). In military aviation, similar IFR (re-)validation check rides are used (Mavin and Roth, 2014). Modern, high fidelity simulators allow IFR check rides to be flown in a simulated environment, which reduces risk, allows for more precise data logging and performance feedback, and increases aircraft availability (Sarter et al., 2007; Weitzman et al., 1979; Valverde, 1973).

When task demand is increased during an IFR flight, pilots may

compensate it by investing more effort which in turn increases the pilot mental workload (PMWL) (Shaw et al., 2013). Once the mental capacity and/or willingness to invest more effort are exceeded, at some point pilots' performance begins to degrade (Young et al., 2015; O'Donnell, Eggemeier, and Thomas, 1986). There is great potential of compromising flight safety and mission success if these conditions occur during live flying. Measuring PMWL during an IFR check ride can give valuable information about the pilots' ability to maintain the desired performance during events of high task demand. Two pilots with an equal task performance during an IFR check ride may have significantly different cognitive spare capacities, which reflects their potential to cope with subsequent task demand increase (O'Donnell, Eggemeier, and Thomas, 1986; Yerkes and Dodson, 1908). PMWL or spare mental capacity is typically not evaluated during an IFR check ride. To the best of the authors' knowledge, no previous PMWL assessments in the open literature have considered fighter pilots' IFR check rides.

Evaluation of the pilots' spare mental capacity requires measuring of PMWL for which task performance, subjective reports and physiological metrics are typically used (Boff et al., 1994). Subjective measures of PMWL, such as the NASA-Task Load Index (NASA-TLX) and the Modified Cooper Harper (MCH) scale, have been widely used in aviation domain (Hart and Staveland, 1988;

* Corresponding author.

E-mail addresses: mansikkh@uni.coventry.ac.uk (H. Mansikka), kai.virtanen@aalto.fi (K. Virtanen), don.harris@coventry.ac.uk (D. Harris), petteri.simola@mil.fi (P. Simola).

Casali and Wierwille, 1983; Wierwille et al., 1985). While the multidimensional scales, such as the NASA-TLX, have a better reliability, diagnosticity and validity than the uni-dimensional scales, these types of subjective reports are too intrusive to be used during flight or simulated flight. Also, it should be noted that the subjective ratings can become dissociated with performance, especially if the task is resource limited (Yeh and Wickens, 1988). In addition, the data for these measures are typically collected after the trial making them less capable of identifying sudden changes in PMWL. In the aviation domain even sudden, short term PMWL overload conditions may jeopardize flight safety and need to be therefore identified. The instantaneous self-assessment (ISA) technique was considered as a potential real-time subjective measure of PMWL. However, as the PMWL was measured during a real IFR check ride, the use of ISA had to be discarded due to potential primary task intrusion (Tattersall and Foord, 1996). Furthermore, if PMWL is to be used as an additional criterion for an IFR check ride performance, possible pilot biases could compromise the reliability of the subjective measures.

Physiological measures do not have the limitations mentioned above. Many physiological measures, however, are not suitable for a check ride use, mainly because they generate unacceptable pilot intrusion, lack pilot acceptance and disturb simulator and aircraft instruments. Heart rate (HR) and heart rate variation (HRV) measures, although somewhat less sophisticated than some of the more recently developed physiological measures, have been widely employed in real and simulated aircraft environments, enjoy high face validity among the pilot population and generate little, if any, pilot intrusion (Ylönen et al., 1997; Lee and Liu, 2003; Hankins and Wilson, 1998; Dussault et al., 2004). For these reasons, this study used electrocardiogram (ECG) based measures as a method to measure task demand induced activation of the autonomic nervous system (ANS). From an ECG, the normal-to-normal (NN) interval of the heart rhythm was identified. HR and HRV were derived from the NN interval and used as measures of PMWL. Before this study, HR and HRV have not been measured during a real F/A-18 IFR check ride.

Different components of HRV have been used as measures of ANS modulation. HR, although often associated with reactions to variations in the physical task demands, has also been associated with the changes in the piloting task's mental demands. Table 1 summarizes the products of the NN interval used in this study. Also, Table 1 describes how HR and the components of HRV are affected by the increased PMWL.

Several studies have shown HRV and HR to be relatively insensitive to changes in task demand, with HRV and HR being able to differentiate the task demand variations only between the task

and rest conditions (Veltman and Gaillard, 1996; Jorna, 1992; Wilson, 1992; Fallahi et al., 2016; Wei et al., 2014). In a more recent study, Mansikka et al. (2016) successfully used HR and HRV to identify different levels of task demands during simulated fighter missions when the task demand was intentionally and somewhat artificially varied from very modest to extremely high; the temporal demand of the repeated flying task varied from 6 min to 35 s to 2 min 20 s. In this study, the fighter pilots' performance and PMWL were measured during a real instrument check ride without artificial manipulation of task demand. The instrument check ride was carried out in a high fidelity simulator and comprised of clearly identifiable mission segments. Each mission segment consisted of different piloting task and thus generated mission segment specific task demands. The pilots' PMWL measured with HR/HRV and performance variations between different mission segments was studied.

It was hypothesized that HR and the HRV components presented in Table 1 could differentiate the task demand differences between the check ride's mission segments. Also, it was theorized that the PMWL measures could identify differences between the mission segments even when there were no significant performance differences between them. That is, even when the pilots could maintain their performance unchanged from mission segment to mission segment, there would be significant differences in their ANS responses to the changing task demands. Such a finding would support the use of both performance and PMWL measures in future check rides; the differences in the values of the PMWL measures could provide valuable insights about the PMWL's relation to performance and about the differences in the pilots' cognitive spare capacities during events of varying task demands. Ultimately, the level of PMWL could at some later stage be used as an additional IFR check ride criterion where the pilot would have to achieve a minimum performance score without exceeding the given level of PMWL. This study was aimed at evaluating if HR and HRV have potential as such measures of PMWL.

2. Method

2.1. Participants

Data from 26 volunteer Finnish Air Force (FinAF) male F/A-18 pilots with a 1st class IFR qualification were collected. The pilots' average flying experience with the F/A-18 was 781 h (SD = 390). Relevant data concerning the pilots' activities for the 12 h before the check ride were recorded. All pilots had passed an extensive aeromedical examination within the last 12 months and were fit to fly at the time of the study. A written, informed consent was

Table 1
HR and HRV components and their expected change due to increased PMWL.

Measure	Unit	Description	Expected change	References
MEANHR	[1/min]	The mean heart rate.	Increase	Roscoe 1975; Wilson 2002; Roscoe 1993; Vuksanović and Gal, 2007a
MEANRR	[ms]	The mean of NN intervals.	Decrease	Terkelsen et al., 2005; Sun et al., 2012
SDNN	[ms]	The standard deviation of NN intervals.	Decrease	Terkelsen et al., 2005; Tran et al., 2010
RMSSD	[ms]	The square root of the mean squared differences between successive NN intervals.	Increase	Li et al., 2009; Orsila et al., 2008
NN50	[count]	The number of successive NN interval pairs that differ more than 50 ms.	Decrease	Deepak et al., 2014
pNN50	[%]	The NN50 divided by the total number of NN intervals.	Decrease	Taelman et al., 2011
HRVTRI	[-]	The integral of the NN interval density distribution divided by the maximum of the distribution.	Decrease	Cinaz et al., 2013
LFnu	[-]	The normalized low frequency (0.04–0.15 Hz) component of HRV.	Increase	Wu et al., 2011; Miyake et al., 2009
HFnu	[-]	The normalized high frequency (0.15–0.4 Hz) component of HRV.	Decrease	Wilson 2002
LF/HF	[-]	The ratio between the power of low frequency (LF) and high frequency (HF) components of HRV.	Increase	Skibniewski et al., 2015

Download English Version:

<https://daneshyari.com/en/article/6947826>

Download Persian Version:

<https://daneshyari.com/article/6947826>

[Daneshyari.com](https://daneshyari.com)