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Action slips during whole-body vibration

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ABSTRACT

Helicopter aircrew members engage in highly demanding cognitive tasks in an environment subject to whole-body vibration (WBV). Sometimes their actions may not be according to plan (e.g. action slips and lapses). This study used a Sustained Attention to Response Task (SART) to examine whether action slips were more frequent during exposure to WBV. Nineteen participants performed the SART in two blocks. In the WBV block participants were exposed to 17 Hz vertical WBV, which is typical of larger helicopter working environments. In the No-WBV block there was no WBV. There were more responses to the rare no-go digit 3 (i.e. action slips) in the WBV block, and participants responded faster in the WBV block. These results suggest that WBV influences response inhibition, and can induce impulsive responding. WBV may increase the likelihood of action slips, mainly due to failure of response inhibition.

1. Introduction

We all experience occasions when we suddenly become aware that our minds have been 'absent' from an ongoing task and that we are no longer behaving according to plan, examples from everyday life include swiping an identification card instead of a credit card; throwing away the vegetables instead of the peelings; trying to drive off without releasing the hand brake (Reason, 1990; Reason and Mycielska, 1982). In almost all cases these commonplace slips and lapses cause us little more than momentary embarrassment. In aviation, however, the consequences of similar slips and lapses could be catastrophic. The difference lies not in the nature of the error, but in the extent to which circumstances affect the severity of the consequences.

According to an analysis of all European helicopter accidents between 2000 and 2005, pilot judgement and actions was the most common causative factor, and was involved in almost 70% of the accidents (European Helicopter Safety Team (EHEST), 2010). Undesired Aircraft States (UAS) are flight-crew induced aircraft position or speed deviations, misapplication of flight controls or incorrect system configurations associated with a reduction in margins of safety. An inappropriately managed UAS may lead to an incident/accident (EHEST, 2014).

Reason and Mycielska (1982) summarized information on private aircraft accidents in which an error committed by a pilot was implicated, and concluded that the errors displayed many of the characteristics of absent-minded slips in that they involved apparently unintentional execution of well-established control actions, or omission of such actions. Such errors are important in many working environments. Specialists such as aircraft pilots will easily be able to imagine circumstances in which omitting to execute particular actions in the event of engine failure would have catastrophic consequences. The resemblance between these pilot errors and everyday absent-minded slips does not in itself constitute an explanation for these accidents but the underlying mechanism may be similar; as Reason and Mycielska (1982) put it '*the resemblance between these pilot errors and everyday absent-minded slips does suggest we could learn a good deal more about catastrophic errors from a closer scrutiny of action slips of our daily life*'. In addition, action slips provide important clues about the organization of human performance and the role of conscious attention in the guidance of action especially when sustained attention to action is required to execute a task successfully.

During operations a helicopter pilot has to maintain attention to ongoing tasks. Insufficient attention can result in slips of action when action sequences are triggered automatically, unintentionally and inappropriately. Such action slips tend to happen when attention to task is degraded through such factors as boredom,

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worry or division of attention among several tasks (Robertson et al., 1997). Sustained attention to ongoing tasks is important in preventing action slips; if attention is not sustained then absent-mindedness or mind-wandering is likely. Absent-mindedness or mind wandering in this context is not limited to daydreaming, it encompasses all conscious cognitive activity not focused on the immediate demands of the current task (Cheyne et al., 2011).

For the purposes of this study we have followed Robertson et al. (1997) in defining sustained attention as the ability to sustain mindful, conscious processing of stimuli whose repetitive, non-arousing qualities would otherwise lead to habituation and vulnerability to distraction. Robertson et al. (1997) developed the Sustained Attention to Response Task (SART) which requires a high level of continuous attention to responses and is sensitive to transitory reductions in attention or 'lapses' yet minimizes demands on other cognitive processes such as memory, planning and general intellectual effort. The SART is a go/no-go continuous performance task in which the no-go stimulus appears infrequently and is used as a measure of sustained attention, mind-wandering and the response inhibition element of executive function.

The primary SART measures of interest are errors of commission, errors of omission, and reaction times to frequent go-stimuli (Wilson et al., 2015). Helton and colleagues suggested that commission errors in the SART (i.e. a failure to withhold a response to a rare no-go stimulus) reflected failures of response inhibition while the omission error measure (i.e. a failure to respond to a go-stimulus) could be used as an indicator of sustained attention. Failures of sustained attention and response inhibition measured by the SART have been related to a number of real-world problems and psychological variables, including self-reported everyday failures of attention and attention-related cognitive errors (Cheyne et al., 2006; Manly et al., 1999; Robertson et al., 1997; Smilek et al., 2010; Wilson et al., 2015).

Whole-body vibration (WBV) is one of the more distinctive features of the helicopter working environment. The frequency and intensity of vibration to which the helicopter aircrew is subjected depend on the aircraft type, weather and flight profile (Kåsin et al., 2011). In every helicopter, peak WBV is related to the blade pass frequency, which varies normally between 15 and 24 Hz according to rotor velocity (3–7 revolutions per second) and number of rotor-blades (Kåsin et al., 2011).

WBV has an impact on performance of various tasks involving vision, motor activity and information processing (Conway et al., 2007; Griffin, 1990; Hopcroft and Skinner, 2005; Mansfield, 2005). The effects of WBV may be attributable to the direct effects of WBV on input processes (such as the collection of information via the various senses, particularly vision) and output processes (such as task-related responses in various modalities, usually manual responses). Indirect effects on motivation, mood and arousal may moderate the direct effects of WBV. The negative impact of WBV can be seen in many work environments but is perhaps most significant in those that require the concomitant use of both transportation and information systems (Conway et al., 2007). Operator performance in aviation or land-based vehicle operations is consistently affected by WBV (Mansfield, 2005).

Conway et al. (2007) conducted a meta-analysis of empirical studies assessing the influence of WBV on human performance; they showed that WBV generally caused a decrement in performance. The disruptive effects of WBV were related to the type of task being performed. The impact was greatest on perceptual tasks such as vigilance or target detection tasks. There was also a negative impact on continuous and discrete fine motor tasks (such as tracking and switching tasks) and on cognitive performance. The impact of WBV was also related to the type of outcome investigated; accuracy of response was degraded more than speed of response.

Newell and Mansfield (2008) investigated effects of WBV and sitting posture on performance of a four-choice reaction time task and perceived workload. They revealed that the task performance was degraded irrespective of sitting postures during 1–20 Hz random WBV with an unweighted magnitude of 1.4 m/s^2 in the x-direction (i.e. fore-and-aft direction) and 1.1 m/s^2 in the z-direction (i.e. vertical direction). Participants' workload measured by the NASA-Task Load Index (NASA-TLX) also increased during the WBV. Interestingly, Newell and Mansfield found that the performance decrements during WBV were associated with increased perceived workload.

Although previous research has examined whether or how performance is degraded, it is not clear why this happens. This paper focuses on the mechanism underlying WBV effects, more specifically on information processing (i.e. perceptual, cognitive and response processes). There has been much less research on the impact of WBV on higher cognitive processes rather than health and discomfort, in spite of its prevalence in certain occupational contexts.

The purpose of this study was to examine how WBV at frequencies likely to be experienced in helicopter working environments influenced sustained attention. We hypothesized that WBV would increase the probability of failure in sustained attention. If failure of sustained attention is more likely during exposure to WBV one would expect a higher frequency of errors of commission (i.e. action slips), errors of omission (i.e. lapses) and faster response times during exposure to WBV than when WBV is absent.

The data presented here is part of a larger study of the effects of WBV and hypoxia on control of goal-directed and stimulus-driven attention. The study was performed in a hypobaric chamber. The results in hypoxic conditions will be reported in a separate paper. The experiments were conducted at the Institute of Aviation Medicine, Oslo, Norway.

2. Material and methods

2.1. Participants

Nineteen healthy volunteers (10 women; 9 men) with a mean age of 22.8 years ($SD = 4.4$) participated in this study. All participants had normal or corrected-to-normal vision. All participants gave written informed consent before taking part and the study was approved by the Regional Committee for Medical and Health Research Ethics, Oslo, Norway.

All participants were elite orienteering runners. In order to reduce the effects of workload, we capitalized on a close cooperation with Norwegian elite athlete organizations and gained access to 19 elite runners in orienteering competing at a national level. The athletes were recruited via the national coaches. Orienteering is a highly cognitive sport and these athletes were highly trained in carrying out information processing tasks under environmental stress and could be expected to adapt readily to environmental changes, similar to helicopter pilots.

2.2. Apparatus

The stimuli were presented on a 27-inch LCD display (Samsung SyncMaster SA350) located at eye level, keeping the distance to the required 64 cm from participants in order to get the correct visual angle of stimuli. The timing of the events, generation of stimuli and recording of reaction times were controlled by a laptop computer connected to the LCD running SuperLab 4.0 software (Cedrus Corporation, San Pedro, California, U.S.).

Vibration was generated using an electrodynamic vibrator (LDS