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The effect of a helmet on cognitive performance is, at worst, marginal: A controlled laboratory study

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ABSTRACT

The present study looked at the effect of a helmet on cognitive performance under demanding conditions, so that small effects would become more detectible. Nineteen participants underwent 30 min of continuous visual vigilance, tracking, and auditory vigilance (VTT + AVT), while seated in a warm environment (27.2 ($\pm$0.6) °C, humidity 41 ($\pm$1)%, and 0.5 ($\pm$0.1) m s^{-1} wind speed). The participants wore a helmet in one session and no helmet in the other, in random order. Comfort and temperature perception were measured at the end of each session. Helmet-wearing was associated with reduced comfort ($p = 0.001$) and increased temperature perception ($p < 0.001$), compared to not wearing a helmet. Just one out of nine cognitive parameters showed a significant effect of helmet-wearing ($p = .032$), disappearing in a post-hoc comparison. These results resolve previous disparate studies to suggest that, although helmets can be uncomfortable, any effect of wearing a helmet on cognitive performance is at worst marginal.

1. Introduction

The head is one of the most vulnerable parts of the body. Therefore, head protection is recommended, and often mandatory, for many professional and leisure activities. A helmet's main purpose is to protect against mechanical impact, e.g., for bicyclists, soldiers, and firefighters. Consequently, most scientific attention is spent on optimizing helmets to protect against mechanical impact (Aare et al., 2004; Cui et al., 2009; Deck and Willinger, 2006; Mills and Gilchrist, 2008). However, protective headgear is often associated with elevated local skin temperatures, unfavorable temperature perception, and discomfort (De Bruyne et al., 2008; Hsu et al., 2000; Li et al., 2008; Liu et al., 2008; Patel and Mohan, 1993; Skalkidou et al., 1999). This motivated several studies on the ergonomics of helmets, mainly focused on ventilation (Abeysekera et al., 1991; Bogerd and Brühwiler, 2009; Brühwiler et al., 2006; Reischl, 1986; Van Brecht et al., 2008). These studies started to take our understanding beyond the simple mechanics of impact protection to the wider issue of how a helmet affects its wearer.

A helmet is typically worn in situations with a higher likelihood for an accident and/or larger consequences if an accident occurs. Therefore, any tendency for a helmet to distract or otherwise reduce the performance of its wearer is undesirable, and could potentially obviate its protective effect by making potentially injurious incidents more likely to occur. Hancock and Warm (1989) have suggested a relationship between attention performance and stress. The stress in their model can be psychological as well as physiological in nature. This model explains several studies showing negative effects of fabric discomfort (Bell et al., 2003, 2005) and whole-body thermal discomfort on cognitive performance (Gaoua et al., 2012). Since helmets cause disturbances to the wearer, and affect the temperature of the scalp's surface, this raises the question whether a helmet might negatively affect cognitive performance.

Four studies have evaluated the effect of passive headgear on cognitive performance. Three of these studies used the same helmet that covered the scalp and ears but left the face uncovered (Hancock, 1983; Hancock and Dirkin, 1982; Holt and Brainard, 1976). One of these studies found increased reaction times on a dual task while wearing the helmet (Hancock and Dirkin, 1982). A more recent study found a negative effect on cognitive performance of wearing a cricket helmet during cricket practice (Neave et al., 2004). In contrast to these two studies, which showed an effect of headgear, on at least one of the cognitive parameters investigated, the other two found no effect of helmet-wearing (Hancock, 1983; Holt and Brainard, 1976). This discrepancy might indicate that wearing a

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Fig. 1. The setup with a participant carrying out the simultaneous visual vigilance and tracking test (VTT) and auditory vigilance test (AVT). The helmet shown here was not used in the study.

helmet has a minor effect of cognitive performance. In fact, the effect size (r^2) calculated from these publications is 0.02 (±0.02), which is small in magnitude (Cohen, 1988).

The present study revisits the effect of a helmet on cognitive performance with a view to clarifying this contradictory literature. Since the effect of a helmet on cognitive performance is expected to be small, the present study aims at saturating the participants' attention capacity (Hancock and Warm, 1989), so that small effects cannot be buffered, and thus become more likely detectible. In addition, the thermal environment was chosen such that wearing a helmet would cause a substantially higher skin temperature as well as thermal discomfort compared to the no wearing a helmet. The helmet employed was of a full-face type, encapsulating the entire head, thereby causing a realistic by extreme condition. Finally, the study design was aimed at keeping the distraction/discomfort from the body constant and as close as possible to neutral, with the exception of the head as site of the intervention.

2. Materials and methods

2.1. Participants

Nineteen healthy male participants aged 28.3 (±4.7) years (mean ± standard deviation) completed the study. The participants' head circumferences ranged from 53 cm to 62 cm. The exclusion criteria were the use of medications on a regular basis, or suffering from claustrophobia or an attention disorder. All participants were instructed to refrain from alcohol, drugs and caffeine 12 h prior to each session. During familiarization sessions the participants were instructed to adjust their clothing in order to be thermally comfortable. As a result the participants wore jeans in combination with a long sleeved shirt or a T-shirt. The participants wore the same clothing during both experimental sessions. All participants gave informed consent before participation. This study was approved by the Cantonal Ethics Committee of St. Gallen (Switzerland).

2.2. Setup

The participants sat at the exit of a wind tunnel. A 19″ LCD screen of 1280 × 1024 pixels was positioned just below the exit of the wind tunnel, allowing the participant to see the screen clearly (Fig. 1). A conventional keyboard and joystick (Attack 3, Logitech, Fremont, USA) were positioned in front of the screen. The vertical distance from the participant's head to the top of the wind tunnel was 5 (±1) cm, and the horizontal distance from the end of the housing of the wind tunnel to the forehead was 8 (±6) cm. This resulted in a viewing distance of 53 (±6) cm from the eyes of the participant to the screen. During the sessions the participant was the only person occupying the chamber and did not have contact with the outside, nor had he any reference to time. All measurements were conducted in a climate chamber maintained at an ambient temperature of 27.2 (±0.6) °C, and relative humidity of 41 (±1)%. The wind speed (v_w) was 0.5 (±0.1) m s^{-1} in order to have a minimal, but well-controlled v_w.

2.3. Protocol

Each participant underwent five sessions. The time of day was kept constant to avoid any influences of the circadian rhythm. In order to reduce learning effects on the results, participants carried out three familiarization sessions, this was found sufficient for avoiding a learning effect in a pilot study (available on request). Subsequently, each participant underwent two experimental sessions in a balanced order. The first and last sessions occurred within two weeks, in order to prevent loss of familiarization. Before the start of each session the participant completed a mood questionnaire (Monk, 1989), and indicated the quality and quantity of their sleep during the previous two nights on two visual analogue scales. Finally, each session was finished with the assessment of whole-body temperature perception on a nine-point scale (−4: very cold, to 0: neutral, to 4: very hot) and a five-point thermal comfort scale (0: comfortable, to −4: extremely uncomfortable). Both scales are detailed elsewhere (ISO10551, 2001).

The first 10 min of each experimental session were a familiarization session (Fig. 2). Each participant donned safety goggles (control: CON) or a helmet (intervention: HEL) at the start of this period and kept these on until the session was completed. More details concerning the helmets and goggles are given under Section 2.5. Following the familiarization, a 20 min equilibration phase started, the purpose of which was to achieve a thermal steady state. This period was previously found to be sufficient for this purpose (Bogerd et al., 2011). During this phase the participant read or carried out unrelated computer work. Finally, each participant completed the cognitive test battery. The three separate familiarization sessions, preceding the experimental sessions, consisted of the first 10 min of an experimental session, and did not take place on the same day as an experimental condition.

2.4. Cognitive tests

The following three cognitive performance examinations were employed: i) a simultaneous visual vigilance and tracking test (VTT), ii) an auditory vigilance test (AVT), and iii) a letter cancellation test (LCT). We found the LCT to be sensitive to a motorcycle helmet intervention in pilot studies, and the VTT has been used in previous work (e.g. Van Dorp et al., 2007). The AVT was developed in a pilot study as a secondary load simultaneous to the VTT in an attempt to improve the sensitivity of the method, consistent with the idea of providing an attention capacity load high enough so that the stress caused by the intervention cannot be buffered, as discussed in the Introduction. In what follows these tests are detailed.

2.4.1. Visual vigilance and tracking test (VTT)

The visual vigilance and tracking test (VTT) consisted of a tracking and a vigilance task in parallel. The tracking task involved a red annulus that was presented in the middle of the computer