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THE EFFECTS OF WEARING A FULL-FACE MOTORCYCLE HELMET ON COGNITIVE PERFORMANCE IN A WARM ENVIRONMENT

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INTRODUCTION

Riders of powered two-wheelers (PTW), such as motorcycles and mopeds, have a higher risk for a fatal traffic accident than for any other mode of transport. It has been estimated that 440 PTW-rider fatalities occur per 100 million person traveling hours, whereas 75 and 25 fatalities for bicyclists and car drivers, respectively, were found over the same period [1]. Notably, cognitive failures on the part of the PTW rider were determined to cause 34% of such accidents [2].
There are indications that full-face motorcycle helmets might deteriorate cognitive performance. The rationale behind this hypothesis is that these helmets are known to i) be excellent thermal insulators [3, 4] with associated warm microclimate temperatures [5], and ii) cause increased levels of carbon dioxide of the order of 2% at low riding velocities [6, 7]. These helmet-mediated effects have been associated with impaired cognitive performance in some studies [8-11], but work on thermal effects also yielded opposite conclusions [12, 13].
The present study aimed at investigating if wearing a full-face motorcycle helmet has a detrimental effect on cognitive performance compared to not wearing headgear in a warm environment, under simulated wind-still conditions.

METHODS

Nineteen healthy male subjects (aged 28.3 ± 4.7 years) completed three familiarization trials, and two experimental trials. All subjects were instructed to refrain from consuming alcohol, drugs and caffeine for 12 hours prior to each trial. In addition, all subjects refrained from panting-inducing exercise between waking and each experimental trial, and were advised to get sufficient sleep. The subjects were comfortably clothed using similar clothing during both experimental trials. All trials were carried out in a climate chamber stabilized at and ambient temperature of 27.2 ± 0.6 ºC, relative humidity of 41 ± 1%, and a wind speed of 1.8 ± 0.2 km/h projected towards the face of the subject. This study was approved by the Cantonal Ethics Committee of St. Gallen (Switzerland).
The subjects sat at the exit of the wind tunnel (Figure 1). A 19' LCD screen was positioned just below base of the wind tunnel, which allowed the subject to see the screen clearly. A conventional keyboard and joystick (Attack 3, Logitech, Fremont, USA) were positioned in front

of the screen. During the trials the subject was the only person occupying the chamber and did not have any contact with the outside. More details on this setup can be found elsewhere [5].

Figure 1*: The first author demonstrating the simultaneous visual vigilance and tracking test (VTT) and auditory vigilance test (AVT); the screen shows the VTT.*

The subjects sat still at the exit of the wind tunnel during the entire trial. The first 30 min of an experimental trial served as acclimation, during which the subjects were reading or carrying out computer work. Cognitive performance was then assessed with a task of simultaneous visual and auditory vigilance, and tracking (VTT+AVT), lasting 30 min. Wearing a full-face motorcycle helmet (HEL) or wearing no headgear (CON) was randomly assigned to the experimental trials. During CON subjects wore clear standard safety goggles in an attempt to match the visual conditions to those when wearing a helmet. During each familiarization trial subjects completed 10 min of VTT+AVT, without acclimation.

VTT has frequently been used to assess cognitive performance, e.g., for the effect of carbon dioxide [14]. It consisted of a tracking task in which a red annulus was presented in the middle of the computer screen, in addition to a blue ball (Figure 1). The ball received random impulses from the software and the goal of the subject was to keep it in the middle of the annulus, using the joystick to control the acceleration direction and amplitude. On the screen, the outer diameters of the annulus and ball were 4.3 cm and 2.6 cm, respectively. The simultaneous visual vigilance task of the VTT was based on continual observation of a black square in the center of the screen which appeared to rotate 45° once per second. At random intervals the square changed into a black circle of similar size (diameter 1.1 cm); upon perceiving this black circle, the subject was to press the 'fire'-button of the joystick as soon as possible. The following parameters were obtained: i) the distance of the center of the ball to the center of the annulus, ii) the reaction time of responding to the circle stimulus, iii) the number of correct responses (response up to 2 s following a stimulus), and iv) the number of incorrect responses (response without a stimulus).

The AVT was an audio examination of vigilance developed for this study, in which the subjects heard a tone every 0.8 s, at either 2.5 kHz or 2.0 kHz. A random sequence was generated in which one three-repetition series was randomly presented per 20 s period, with no series longer than three repetitions. The subjects were instructed to indicate perception of each such triplet as quickly as possible by pressing the spacebar of the keyboard. The following parameters were obtained: i) response time, ii) number of correct responses, and iii) the number of incorrect responses. The tones were presented via earphones (CX300, Sennheiser Electronic, Wedemark, Germany) which were minimally affected by putting on a helmet. The volume with which AVT was presented was chosen by the subject and maintained from trial to trial. A new random sequence was generated each time the program was started. The VTT+AVT show the largest sensitivity to the helmet intervention, among several cognitive tests evaluated in earlier pilot studies.

The data collected during the 30 min VTT+AVT was converted to averages over six 5-min intervals. The majority of the data were not Gaussian distributed, as indicated by a Shapiro-Wilk test. Therefore, non-parametric statistics were used in the analysis. The intervention effect (CON vs. HEL) was evaluated with a Wilcoxon test on the paired results for a given parameter, for all time periods combined. Time effects were analyzed by combining CON and HEL for each time period and subjecting this to a Friedman test; a Wilcoxon test with a Bonferroni-corrected α level was used for post-hoc comparison. The results are reported below as median (25th percentile; 75th percentile). Statistics was carried out with SPSS 16.0 for Windows, and Matlab R2006b for Windows was used for data processing. Significance was defined as $\alpha < 0.05$.

RESULTS

Only tracking as part of the VTT indicated an intervention effect (Figure 2). This tracking performance indicated an increased displacement of 7.2% (-9.9; 23.7) for HEL compared to CON ($p = 0.021$). In more detail, CON and HEL yielded 21.1 pixels (13.5; 30.9), and 21.7 pixels (13.7; 36.2), respectively. Finally, all parameters, with the exception of reaction time for both VTT and AVT, indicated a reduction in performance with increasing time. Figure 2 also indicates the incorrect responses on the VTT. These results are representative for the other incorrect and correct responses for both VTT and AVT, showing a performance decrease towards the end, but no intervention effect.

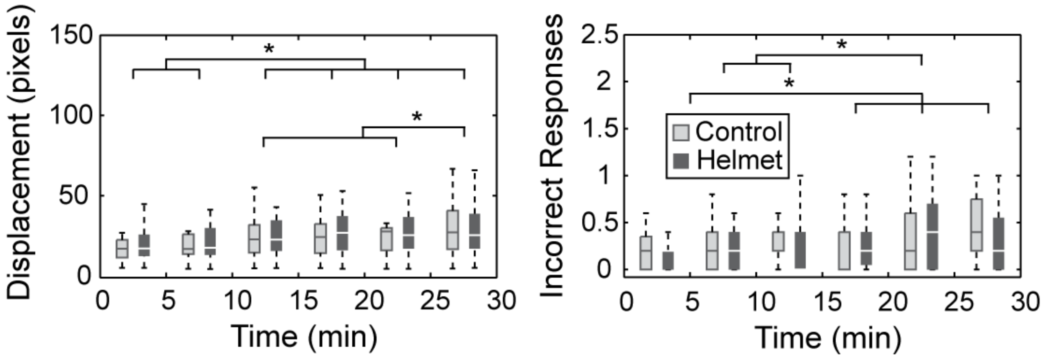

***Figure 2**: Boxplots of the tracking performance and incorrect visual vigilance responses. Significant differences of the time effect are indicated by: * $p < 0.01$.*

DISCUSSION

One of seven parameters showed an intervention effect. This suggests that the effect of wearing a full-face motorcycle helmet on cognitive performance is small, but measurable in the present study. Four other studies have previously evaluated the effect of headgear on cognitive performance of which two found an intervention effect [9, 10], and the other two studies did not [12, 13]. Because these studies differed from the present one in several respects, it is unclear to what the discrepancy among these four studies should be attributed.

Approximately two-thirds of the measured parameters during the VTT+AVT revealed a time effect, and always indicating worse performance toward the end of the examination. Other studies have also reported such time effects [15, 16]. This could be caused by a reduction of the attention capacity [15, 17], suggesting that the cognitive tests and protocol employed in the present study are sensitive to time effects in a manner compatible with those works.

The present study assessed cognitive performance during wind-still conditions. It is expected that if wind were applied in the given climate, effects on cognitive performance due to temperature, humidity or carbon dioxide would be reduced, since greater wind speed increases heat loss from the head [3, 4] and reduces skin and microclimate temperatures [5], as well as reducing microclimate carbon dioxide concentrations [6, 7]. Notably, the subjects reported feeling warm and thermally uncomfortable during HEL. In contrast to the clothing worn by subjects in the present study, in the field riders are likely to wear protective clothing, thereby experiencing a different temperature perception and/or thermal comfort. We assume that heat strain can be expected to occur in the field under the thermal environmental conditions created in the present study. For higher temperatures, microclimate temperature may be even higher than found here, so that a general conclusion on the application of these results to the field is not possible at this time.

CONCLUSIONS

Compared to not wearing headgear, a full-face motorcycle helmet negatively affected one of seven cognitive performance parameters, in the form of tracking performance. In addition, subjects experienced a more unfavorable whole body temperature perception and thermal comfort.

Given the differences between the laboratory and field conditions, it is unclear how the present results relate to traffic safety. Therefore, future studies on this topic could evaluate the effect in under more realistic situations, such as employing a realistic motorcycle simulator, and/or more realistic clothing conditions combined with higher wind speeds. The fact that tracking performance was impaired suggests that manual control of a motorcycle is potentially at risk of degradation when the rider is stressed in a manner similar to that studied here.

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