

A Naturalistic Neurophysiological Assessment of Photographer Cognitive State in the Vicinity of Mount Everest

John G. Blitch

Abstract A number of cognitive studies support the notion that task focus and mental workload fluctuation in human perceptual activities can be modeled on a dynamic basis in near real time. Few of these studies, however, involve the use of wearable technologies in naturalistic settings. Fewer still do so under conditions of high physiological stress like those encountered on steep slopes at high altitude in foreign environments. This study compares the behavior and cognitive state of photographers climbing to and descending from the vicinity of Everest Base Camp at altitudes approaching 18,000 feet. Ascent and descent activities were compared in terms of overall task engagement, cognitive workload, and behavioral components of the point and shoot decision paradigm involved in adventure photography. Results are discussed in the context of decision-making behavior typically associated with wilderness search and rescue activities carried out at high altitude in environmentally challenging environments.

Keywords Cognitive state • Mental engagement • Workload • Decision-Making • Search and rescue

1 Introduction

There is an old adage in the U.S. Army Ranger handbook that calls for dismounted patrols to avoid returning from an objective by the same route that was used on approach—ostensibly to avoid ambush by enemy forces who may be engaged in tracking activities [1]. There may however, be another more cognitively evolved rationale for this time-tested tactic. It has been established in a number of laboratory experiments that a nearly insatiable penchant for pattern matching makes human beings particularly vulnerable to complacency effects in the form of vigilance decrement [2] and disengagement even in dynamic and demanding tasks like air

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traffic control [3] and semi-autonomous robot supervision [4, 5] where the onset of mere boredom seems to be out of the question. In any case, a reconnaissance patrol that becomes complacent and misses critical environmental cues while on the move will inevitably fail in their mission regardless of whether they ever get ambushed—especially when search and rescue activities are involved. Nothing is more devastating for soldier or adventure athlete, after all, that to leave a comrade behind in the face of danger.

The current study endeavored to examine the issue of complacency in a natural, operationally relevant setting beyond the highly structured laboratory environment where risk and environmental conditions are rigorously controlled in pursuit of crisp quantitative cause-effect correlations. Unfortunately, such correlations can come at a cost in ecological validity by those wishing to extend their findings into the unstructured “real” world. By exploiting recent progress in wearable computing, neurophysiological (brainwave) data was collected on a group of adventure photographers attempting to capture the stunning, awe-inspiring landscape surrounding Mt. Everest and its neighboring peaks in Nepal’s Sagarmatha National Park. This data was used to compare the cognitive state of participant photographers during ascent and descent phases of their activity in order to examine which phase might be more inclined to produce complacency effects.

It is important to note that subjective measures of mental workload, situational awareness, and other aspects of cognitive state that are commonly used elsewhere in human factors research were rejected for this project for a number of reasons, but primarily due to their potentially intrusive nature as described by Parasuraman, Wilson and others [6, 7]. Not only does the injection of Question and Answer (Q&A) protocols into field activities potentially interfere with the task at hand, they may actually disrupt the intuitive and imaginative processes underlying creative and artistic activities such as photographic scene selection.

In any case, the primary hypothesis examined in this study (hereafter referred to as the Ranger hypothesis) predicts that participants returning along the same route used during ascent will show evidence of increased complacency during descent as indicated by EEG indices of brain state and task related behavior (i.e., missing photo-worthy cues). An alternative hypothesis suggests that photographers might actually be less complacent and more active on descent, due to reduced physical exertion and the joyful, positive affect of returning to a more hospitable environment somewhere down the trail.

2 Method

2.1 Apparatus

This experiment was conducted with three primary pieces of equipment: a hand held cell phone camera (Casio C771 Commando with a 5 megapixel camera and



Fig. 1 B-Alert wireless EEG system worn under participants' headgear

480 × 800 pixel display), a Panasonic Toughbook laptop (CF-19 with a standard voltage Intel Core i5 vPro processor) and a wireless EEG (Electro Encephalography) monitoring device called the X-10 B-Alert system manufactured by Advanced Brain Monitoring of Carlsbad CA. This last device acquires 9 channels of EEG collected across the scalp and mastoid leads along with ECG from the clavicle and sternum. The sensor locations for this system comprise: Fz, Cz, POz, F3, F4, C3, C4, P3, and P4. Data are sampled at 256 Hz with a band pass from 0.5 to 65 Hz (at 3 dB attenuation) obtained digitally with Sigma-Delta A/D converters. The RF link is frequency-modulated to transmit at a rate of 57 kBaud in the 915 MHz ISM band. By utilizing a bidirectional mode, the firmware allows the host computer to initiate impedance monitoring of the electrodes, select the transmission channel (so two or more headsets can be used in the same room), and monitor battery power of the headset. Data are acquired across the RF link on a host computer via an RS232 interface. Signal acquisition software then stores the EEG data on the host computer. The proprietary acquisition software used in this process includes artifact decontamination algorithms for eye blink, muscle movement, and environmental/electrical interference such as spikes and saturations.

One important aspect of this device is that the wireless nature of its hardware all but eliminates participants' awareness of its presence within just a few minutes of wear. It is lightweight and compact enough to fit comfortably under a climber's headgear (as indicated in Fig. 1). As such, this system presents a significant contrast to high-density EEG systems common to laboratories and hospitals that are cable intensive and typically require electrodes to be placed on the face and other highly sensitive regions which remain prominent in the perceptual realm of the user.

2.2 *Participants*

Four photographers from the 2014 Himalayan Workshops expedition to Mount Everest basecamp volunteered to participate in this experiment at a monetary incentive rate of \$10 (US) per hour for a maximum of 4 hours. All four participants were experienced photographers with an extensive history of international travel. Two were citizens of Germany, and two others were from Sweden and the United States respectively.

2.3 *Design and Procedure*

Baseline profiles of cognitive state and workload were collected for each participant under nominal (hotel room) conditions. These profiles captured each participant's EEG pattern during the performance of three baseline tasks.

The first baseline task required the participant to remain vigilant while choosing between different symbols presented on a laptop display. The EEG collected during this task is modeled as a state of Hi Engagement that is typical of decision-making activity. This data also contributes to the classification of cognitive workload discussed below. The second task required a simple keyed response to a single stimulus (a red circle appearing on the screen) without any choice or decision-making process involved. The EEG profile established during this task corresponds to a state of Lo Engagement or awareness. The third task requires the participant to respond in a similar fashion to the second task, but with an auditory stimulus presented while their eyes were closed. Data collected during this final task is modeled in conjunction with a large database of typical human sleep profiles to establish states of drowsiness and distraction respectively. The baseline EEG collected during these three tasks is subsequently compared with data collected in the field environment while participants performed "mission" tasks of interest—in this case selecting a photo worthy scene and taking any number of pictures to capture its essence.

Field data was collected on the ascent and descent phases of each participant's approach to Mt. Everest. Although several portions of the ascent and descent routes varied, data was only collected on participants where ascent and descent routes overlapped along the same trail section. It should be noted that weather effects were nearly identical for both the ascent and descent phases for all participants. Bright sunshine dominated throughout the day with only 20–30 % cloud cover. Temperatures ranged between 45–65 °F without any precipitation observed during data collection periods.

2.4 Measures

By comparing EEG collected in the field to the data collected under nominal baseline conditions, the system's proprietary software classified the cognitive state of each participant in terms of their relative task engagement, drowsiness, and mental workload. These data were presented in terms of probability components indicating that the participant was either drowsy (a combination of EEG characteristics indicating distraction and sleep onset), task-engaged at a low (non-choice) level, or task-engaged at a high (choice/decision required) level. These probabilities were all components of engagement and thus added up to a total of 1.000. A separate probability for Hi Workload demand was calculated by the software based on each participant's performance in the choice-required baseline task and a historical data base of EEG collected on thousands of participants during representative performance on forward and backward span tasks. See Berka et al. 2004 for more detail on this classification process [8].

Behavioral indicators of complacency were recorded by a hand held cell phone camera and tabulated in terms of photo stops (as opposed to rest stops due to physical exertion) and number of pictures taken. The correlation between both of these metrics and the Ranger hypothesis was assumed to be positive. In other words, a reduced number of stops and fewer pictures taken would suggest a reduction in task focus and complacency onset.

3 Results

Given that data was collected on the same participants across two temporal phases, initial analysis was performed using a paired t-test with a relaxed alpha set at 0.10 to accommodate the inherent variance involved with data collected in dynamic unstructured environments. The EEG data illustrated in Fig. 2 indicate a prominent trend toward decreased engagement, reduced workload, and more drowsiness during descent.

Considering the "Lo" or awareness based metric first, participants recorded a significantly higher probability of engagement on average during the ascent phase ($M = 0.260$, $SD = 0.191$) than the descent phase ($M = 0.178$, $SD = 0.185$), $t(3) = 1.884$, $p < 0.10$ with a relatively large effect size (Cohen's $d = 0.46$). Regarding the "Hi" or vigilant choice metric, participants also recorded a higher probability of engagement during ascent ($M = 0.469$, $SD = 0.320$) than descent ($M = 0.350$, $SD = 0.189$), but at a level that fell short of statistical significance $t(3) = 0.833$, $p > 0.10$. The third engagement metric indicated a higher probability of drowsiness during descent ($M = 0.436$, $SD = 0.219$) than ascent ($M = 0.269$, $SD = 0.183$), but at a statistically insignificant level $t(3) = 1.237$, $p > 0.10$.

The probability of high workload classification associated with ABM's backward/forward span task database demands that it be evaluated separately from

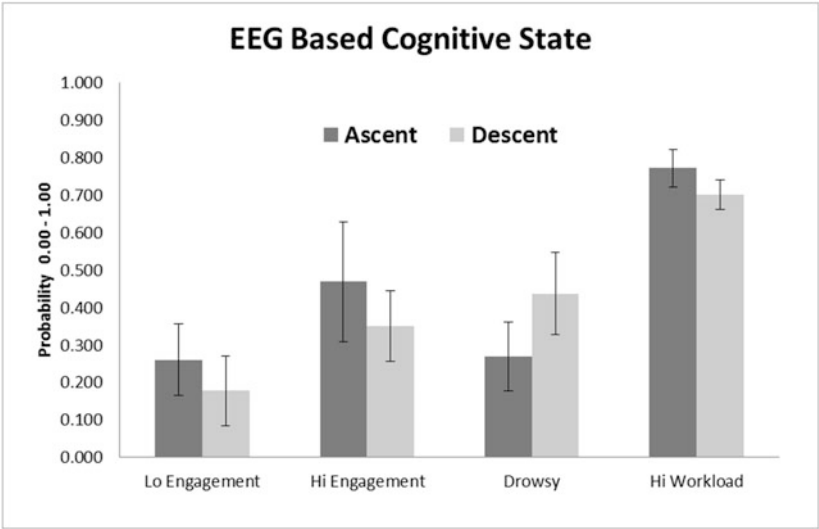


Fig. 2 EEG Based cognitive state probabilities during ascent and descent (with standard error bars)

the engagement data. With that in mind, it was observed that participants were far more likely to be operating under a Hi Workload profile during the ascent phase ($M = 0.771$, $SD = 0.099$), than during the descent phase ($M = 0.699$, $SD = 0.079$), but at a statistically insignificant level $t(3) = 1.104$, $p > 0.10$.

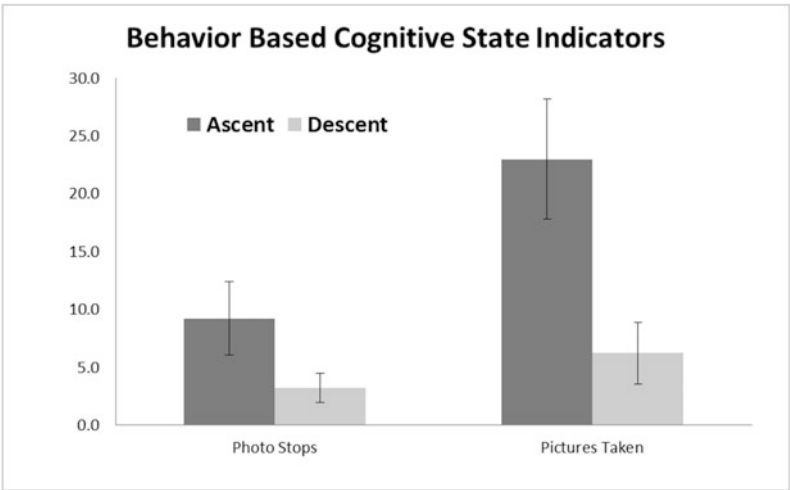


Fig. 3 Estimated number of photo stops and pictures taken (with standard error bars)

Behavioral data was estimated after the fact by video review of each participant's ascent and descent activity captured by hand held cell phone camera, and is presented in Fig. 3. The estimated number of photo stops observed during the ascent phase ($M = 9.3$, $SD = 6.4$), was significantly larger than those observed during descent ($M = 3.3$, $SD = 2.5$), $t(3) = 2.70$, $p < 0.05$, Cohen's $d = 1.1$. The estimated number of pictures taken was also substantially larger during ascent ($M = 23.0$, $SD = 10.4$), than during descent ($M = 6.4$, $SD = 5.3$), $t(3) = 5.04$, $p < 0.01$, Cohen's $d = 1.42$.

4 Discussion

The EEG data presented above are insufficient on their own to make a case for the Ranger hypothesis, especially in light of a relaxed alpha and recognized lack of correction for familywise error. Despite this increased likelihood of Type I error, however, the relatively large effect size associated with the Lo Engagement metric, combined with the strong evidence provided by behavioral data, present a reasonable expectation that these results would be replicated in a manner consistent with Wickens' common sense statistics [9]. This assumes, however, that a larger number of participants willing to endure the hardships associated with this challenging endeavor can be identified and taken through the informed consent process.

It is important to note that while EEG based classification of cognitive state and workload was conducted on a post hoc basis for this investigation, the B-Alert system has the ability to conduct these classifications on the fly in near real time (with display delays running from 1–5 s depending on signal characteristics and features chosen). As such it is a relatively simple process for a patrol leader to monitor the cognitive state of team members wearing the device and observe significant changes within just a few seconds of their occurrence. This data has the potential to detect a task engagement lapse or other complacency issue *before* it actually manifests as an appreciable decline in performance.

5 Conclusion and Future Work

In conclusion, this initial investigation establishes ample evidence of complacency onset during the descent phase of dismounted patrols returning along the same route as their ascent. It is recognized that operational risks (avalanche danger, enemy observation, inclement weather, etc.) may preclude alternate route selection during descent, so leadership may have to invoke other mitigation strategies such as rotating the personnel on point more often or increasing compass/pace checks. Future work should focus on first validating the findings stated above with a substantially increased number of participants, and then exploring which mitigation strategies show the greatest potential in terms of cognitive state observations and

complacency indicators. Subjective measurement methods should also be invoked as well, assuming that an experimental design which more closely emulates a search and rescue paradigm can be established without the concern for disruption of creative or artistic flow.

It is important to note that the potential for confounding variables to threaten naturalistic research of this nature is high. Fatigue, emotional valence, social interaction and a number of other factors undoubtedly contributed to the relatively large variance of data presented here. It is in that context that this effort presents its greatest value—in the promotion ecological validity for those performing difficult tasks in dynamic, unstructured, and risk intensive environments. Conducting human factors research under such conditions presents a wide variety of daunting challenges to overcome—not the least of which is finding a sufficient number of participants and experimenters to accept risk and endure hardship while conducting complicated research in the first place. It is only with continued vigor in pushing beyond the walls of the laboratory into the “real” world, however, that we can truly come to understand the most complicated and adaptive aspects of human cognition.

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