Mitigation of Three Types of Stress on Cognitive Performance

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The development of reliable and valid generalizations about real-world behavior, based on laboratory and simulation experiments, continues to be a major challenge in the applied behavioral sciences, particularly cognitive psychology. This challenge, and the tradeoff between reliability and generalizability, is discussed in light of the principal goal of applied science, which is successful generalization, in contrast to basic science, which is the generation of successful theory. Cognitive psychology has been successful in providing useful guidance for the design of performance enhancing techniques to mitigate the effects of stress that can be found in military operations and other applied settings. The manuscripts in this section on Cognitive Foundations of Human Information Processing address three types of stress occurring in the operational environment—sleep deprivation, cognitive load, and physical exertion—and options that may aid in monitoring or counteracting their negative effects. Separately, the manuscripts focus on: the impairing effects of total sleep deprivation on attention versus cognitively demanding tasks, as well as language-based tasks and the utility of short probe tasks to monitor these effects; cognitive load during driving and the ability of supplemental cues to improve performance and subjective questionnaires to assess load status; and the degrading effects of physical exertion on vigilance aspects of cognitive performance and its implications in the military environment. In concluding remarks, based on Tinbergen's four fundamental interrogatives, the need is underscored for the field of cognitive psychology to go beyond descriptive findings of human behavior into the realm of scientific explanatory answers.

Keywords: applied science, cognitive psychology, reliability, generalizability, sleep deprivation, cognitive load, movement, physical exercise.

PERHAPS THE LARGEST and most obvious challenge in the applied behavioral sciences is the formulation of reliable and valid generalizations about real-world behavior based on represented-world experimentation. Science relies of course on experimental methods, which usually encompass the construction of laboratory equipment, instruments, etc., and the requisite focusing of human volunteers on specific behavioral tasks in such ways as to isolate independent variables from each other and from extraneous factors so that variability in measured test performance can be explained by variability in manipulated task conditions. Ideally, of course, one hopes to derive reliable (repeatable) trends among dependent measures so that the relationships among independent and dependent variables can easily be identified and confirmed with appropriate inferential techniques. Moreover, one generally hopes that such findings enable clear generalizability from the laboratory to the real world, or, as psychometricians say, the criterion environment. The issue of validity—in this sense the extensibility of findings to the real world—is importantly linked to the quality of the underlying theory that presumably ties all of the phenomenology together. Unfortunately, reliability—a product of, among other things, control—and validity—a product of, among others, theoretical-contextual verisimilitude—often trade off with one another in the behavioral sciences. Theory is difficult to generate when either is lacking. Let us take an example.

Cognitive psychology cannot manage to explain the so-called Moon illusion. In experiments done in vivo and in vitro, humans perceive the Moon to be larger when it is near the horizon than when it is higher in its orbit, although the body is actually the same size, objectively, in both positions. Hundreds of well-controlled experiments have been conducted in order to understand the Moon illusion, but none offers an explanation. This real-world effect is very reliable, and well described, but not at all explained. That is because it is researched in a purely theoretical way, arguably as is cognitive psychology. Fortunately, this is not such a problem for us presently.

Whereas the ultimate goal of basic science is the generation of successful theory, the principal goal of applied science is successful generalization. In the latter enterprise, theory is nice but unnecessary so long as generalizations work. Nowhere is this more apparent than in the applied science of human behavior in the context of mortal combat. The following four papers, thematically, are pursuits of cognitive foundations of human information processing in laboratory mock ups of aspects of military combat and with nearly 100 volunteer participants. Beyond their specific merits (below), they are useful quite generally in at least three

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ways. First, they provide answers to questions asked analogously at way points along several important research trajectories. Second, they generate as many useful questions as they answer, conveying "research momentum." Third, the manuscripts help underscore the importance of the issue raised above about the trade off between reliability and generalizability.

Section Papers

1. "Human Performance Under Sustained Operations and Acute Sleep Deprivation Conditions: Toward A Model of Controlled Attention." June Pilcher, David Band, Heather Odle-Dusseau, and Eric Muth (2) examine the effects of sleep deprivation on cognitive and vigilance task performance. Participants were required to remain awake through a night and until nearly noon of the following day. Testing was performed during four sessions, which were 4-h windows. Vigilance performance was found to deteriorate. Interestingly however, cognitive performance was found to be robust to sleep deprivation. The authors speculate on this somewhat surprising finding. Arguing that the nature of the tasks used required the participants to be especially attentive, the suggestion is made that arousal levels remained high or perhaps "rallied" during test times. It would be very interesting to see how the volunteers would perform had they been retained for the remainder of the second day, thus providing perhaps a measure of the effects of sleep loss vs. deprivation (my delineation). The investigators also argue that a controlled attention model might be useful in generalizing these interesting results to sustained operations.
2. "Language Performance Under Sustained Work and Sleep Deprivation Conditions." In a second paper devoted to sleep deprivation, June Pilcher, Laura McClelland, DeWayne Moore, Henk Haarmann, Jaclyn Baron, Thomas Wallsten, and James McCubbin (3) focus on its relationship to language performance. Participants were non-native English-speaking college students whose English, although self-rated, was nearly 90% as proficient as native speakers. Three language tasks were administered during four 4-h windows through a sleepless night. Task selection is interesting. The authors used the verbal component of the Graduate Record Examination, the logical reasoning component of the Law School Admission Test, and an audio task developed in the investigators' laboratory. Generally, the greater the inherent cognitive difficulty, at least in terms of the level of processing required, the more the decrement associated with sleep loss. Several short probe tasks were also derived and administered. These proved to reveal correlation with the primary task decrements. For this reason, as is suggested, some of the probe tasks might be beneficial if applied in real world settings to "diagnose" cognitive decline due perhaps to lack of sleep.
3. "Sensitivity of Subjective Questionnaires to Cognitive Loading While Driving with Navigation Aids: A Pilot Study." In an attempt to understand the effects of task-loading that is organic to vehicle driving tasks, Christopher Smyth (4) reports on the results of 16 participants engaged in a driving simulator. While driving through a map-guided course, participants were provided an experimental mixture of road turning cues, including visual, audio, and combinations of the two or none, and they were intermittently challenged with small problems or puzzles to solve. These probes represented, variously, verbal or spatial-loaded tasks. Importantly, subjective questionnaires were administered after each driving trial. Generally, the provision of supplemental driving guidance proved to be positive. Participants actually drove faster and with more confidence when provided with the navigation supplements as compared to when only the map and no driving cues were provided. The author found that the subjective questionnaires provided significant sensitivity to the effects of cognitive loading. This is of course useful in that, if confirmed, the result generalizes to similar examinations of the effects of workload on real-world tasks. On the other hand, one could argue that the popularity of such rating systems as the Cooper-Harper Handling Quality Scale already represent converging evidence of the reliability of subjective evaluation in this type of context.
4. "The Effects of Movement and Physical Exertion on Soldier Vigilance." Caroline Mahoney, Edward Hirsch, Leif Hasselquist, Larry Lesher, and Harris Lieberman (1) are concerned with the effects of physical exertion on the soldier's ability to sustain focus sufficient to detect signals presented to auditory, visual, and tactile channels. Vigilance, as this type of performance is called, is a venerable subject of study in military contexts. This is because, quite often, long periods of time transpire between significant events. Flagging arousal or loss of attention can lead to disastrous outcomes. This can and does occur in cases of long-duration transit to a target area, during which time, for example, a radar event might go unnoticed. The importance of vigilance is underscored by the fact that the investigators employed a dedicated device known as a vigilance monitor—a very clever device capable of use in many military environments. In this study, while standing or walking in or not in the presence of obstacles, with or without a 40-kg load, participants were presented roughly every minute with a vigilance signal to which they were instructed to respond quickly. After each of six 30-min bouts of treatments, participants were administered (a total of six) 0.5-h cognitive tests. As expected, physical stress was found to be associated with degraded performance. This was indicated by the decrease in the probability of detecting vigilance stimuli as a function of exertion. The authors very wisely argue that these results suggest that behavior pre-context is keenly important

in evaluating cognitive performance. The use of ecologically appropriate tasks and conditions (e.g., using operational components to comprise the 40-kg load) speak well for the generalizability of these important findings and interpretations.

These four studies aimed at the cognitive foundations of human information processing. They hit their target. We can expand the current contemplation, however. I would argue that a psychology that has its roots in what once was called natural philosophy, and now the natural sciences, must address all four of Nikolaas Tinbergen's (5) fundamental interrogatives. If and only if one can adequately satisfy the question of the cause, the development, the evolution, and the (adaptive) function of any particular animal's (A) behavior (B), (neatly, A, B, C, D, E, F), then one can claim to achieve 'theory-based explanation.' Anything less than answering all four renders a research enterprise descriptive rather than explanatory, and thus non-theoretical. Cognitive psychology has provided very useful guidance for the design of performance-enhancing techniques. And the papers prefaced here are certainly no exception—these results and interpretations imply ample advice for engineering design in the realm of reducing the diminution of cognitive functioning in the face of stress (sleep deprivation, workload, and exertion). For the bigger picture, all that is left in order for cognitive psychology to advance to the next level—i.e., to the scientific level of explanation—is for cognitive psychology to understand, embrace, and exploit Tinbergen's simple paradigm. As cited above, cognition's demonstrated inability to understand the Moon illusion is a well-suited reminder and provocation.

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