THE JOINT EFFECT OF TASK CHARACTERISTICS AND NEUROTICISM ON THE PERFORMANCE, WORKLOAD, AND STRESS OF SIGNAL DETECTION

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The present study tests an extension of the Maximal Adaptability Model of Stress (Hancock & Warm, 1989) that incorporated individual differences into the model (Szalma, 2008). The purpose was to investigate how the task characteristics of information rate (event rate) and information uncertainty (number of displays to be monitored) interact with participant personality (Neuroticism) to affect the performance, workload, and stress associated with a cognitive vigilance task. Results supported claim by Szalma (2008) that the maximal adaptability model should be modified to include person characteristics.

INTRODUCTION

The maximal adaptability model of performance under stress (Hancock & Warm, 1989) has been influential in part because it explicitly identifies the task a person performs as the most proximal source of stress input (see Figure 1). The model defines two task dimensions, information structure (the spatial organization of a task) and information rate (the temporal properties of a task). The model predicts that across a wide range of task demands individuals can maintain a stable adaptive state. However, as demands are increased or decreased to extremes adaptation failures occur (e.g., increased workload and stress; performance decrements). Further, the failures in adaptation are progressive, such that subjective comfort (e.g., perceptions of stress and workload) declines at lower levels of stress/task demand compared to the levels at which performance decrements are observed.

Szalma (2008) recently incorporated individual differences into the model, asserting that because stress results from a transaction between the person and the task (Matthews, 2001) models of stress and performance should incorporate both person and task characteristics to fully account for stress effects. In particular, Szalma (2008) proposed that the level of task demand at which the threshold of adaptation is reached may vary as a function of affective traits. In addition, the slope of the decline in adaptation may also vary as a function of observer traits (see Figure 2). The current study was designed to test these predictions by manipulating the task characteristics of information rate and structure and evaluate whether the effect of task properties on performance, workload, and stress varies as a function of Neuroticism, a trait that has been associated with stress vulnerability (Matthews, Deary, & Whiteman, 2003). The present study was part of another study to test the maximal adaptability model (Szalma & Teo, in press). However, that study examined only task/group differences, with no consideration of person characteristics. The results of that study, and a detailed description of the procedure, are described elsewhere in these proceedings.

METHOD

Participants

Three hundred and nineteen psychology undergraduates (131 males, 188 females) at a large southeastern U.S. university were recruited for the study. Participants received course credit in exchange for participation. Participant ages ranged from 17 to 25 years.

Task

The study used an adaptation of the Bakan (1959) cognitive signal detection task developed by Warm, Howe, Fishbein, Dember, & Sprague (1984). The task consisted of a visual presentation of 2-digit numbers ranging from 01 to 99. Participants were instructed to respond when a critical signal appeared on the screen. Critical signals were 2-digit numbers whose digits differed by 0 or 1 (e.g. 01, 54, 99), and all other numbers were defined as neutral events. Throughout the task, two 2x2 grids appeared side-by-side on the screen where each of the 8 cells was a “display” in which the numbers appeared.

Manipulations

The independent variables were information structure, information rate, and period on watch. Information structure was manipulated by varying the number of the displays (i.e. 1, 2, 4 or all 8) participants had to monitor for the critical signals. The order in which these four levels were presented was balanced via a Latin Square. Before each condition, there was a notification screen, in which a red outline around the display(s) notified participants of the number and location of the displays to be monitored for that condition. The red outline was not present during the task. For the 1, 2 and 4 display conditions, the locations of the monitored displays were randomly selected, with the restriction that in the 2 or 4 display condition the monitored displays were always within the same 2x2 grid.

Information rate was manipulated by varying the speed of presentation of the stimuli (event rate). The four event rates were 8, 12, 16, and 20 events /minute. Each participant was
randomly assigned to one of these four levels. Regardless of the rate of stimulus presentation, all events (stimuli) were presented for 2500msec. The stimulus duration of 2500msec was determined from a pilot study. The number of signal trials was set at 10 signals per 3-minute block of trials across all conditions. The number of non-signal trials varied as a function of event rate.

Measures

Workload. The NASA-Task Load Index (TLX; Hart & Staveland, 1988) served as the measure of workload. It assesses six sources of workload, namely, Mental Demand, Physical Demand, Temporal Demand, Performance, Effort, and Frustration, as well as an aggregate measure of global workload.

Stress. Perceived stress was measured using a short version of the Dundee Subjective State Questionnaire (DSSQ) (Helton, 2004; Matthews et al., 2002) which consisted of the subscales of Task Engagement, Distress, and Worry. Participants rated the 20 items of the short DSSQ on a 5-point rating scale.

Neuroticism. The personality trait of Neuroticism (N) was measured with the 20 item version of the N scale from the International Personality Item Pool (IPIP; Goldberg et al., 2006).

Procedure

The data were collected from groups of up to nine participants seated in cubicles that prevented visual contact. Each participant wore noise canceling headphones (Audio-Technica QuietPoint ATH-ANC7) to reduce the impact of any distracting sounds. During the session, if any participant needed to contact the experimenter he/she communicated via a chat window that restricted contact to the experimenter (i.e., participants could not contact one another or anyone outside the laboratory). Participants were asked to surrender their wrist-watches, cell phones, or other portable devices for the duration of the experiment. Participants completed the personality questionnaire followed by the pre-task stress state (DSSQ) questionnaire prior to engaging in the tasks. Each condition was 12 minutes in duration, with the first 3 minutes serving as a practice trial. After each condition participants completed the NASA TLX and post-task version of the DSSQ, the order of which was counterbalanced. The duration of the entire study was approximately 2 hours.

RESULTS

Due to computer-based technical problems some participants did not complete several items on the workload and stress measures and were therefore not included in the analyses for those variables. Hence, the degrees of freedom are not constant across dependent measures.

Data were analyzed via hierarchical regression in which the event rate variable was entered as an effect-coded vector. There were three steps in the regressions for performance and workload: 1) the event rate vectors, 2) Neuroticism, and 3) the event rate by N product vectors. For the stress analyses the entry of the event rate vectors was preceded by entering the corresponding pre-task score. For all dependent measures separate regressions were computed for each display condition.

Performance

Two analyses were done for performance data: overall performance collapsed over the three periods on watch, and the change in performance over time, determined by computing the slope of the function for period on watch for each participant.

For overall detection accuracy N did not significantly predict overall performance ($p>.09$ in each case) or change in performance as a function of time on task ($p>.07$ in each case). A significant event rate by N interaction was observed for response time to correct detections in the 2-display condition, $\Delta F(3,311)=4.22$, $p=.006$, $R^2=.06$, $\Delta R^2=.04$. Separate regressions for each event rate group indicated a significant effect for N in the 12 events/minute, $F(1,77)=7.48$, $p=.008$, $R^2=.09$, $b=-.007$, $t(77)=2.73$, $p=.008$, and 20 events/minute, $F(1,78)=6.16$, $p=.015$, $R^2=.07$, $b=.005$, $t(78)=2.48$, $p=.015$, conditions. Note that at the lower event rate higher N was associated with faster response time, and at the higher event rate higher N was associated with slower response time (see Figure 3).

In the analysis of the slope of response time (RT), an event rate by N interaction was observed for the 1- and 2-display condition separate regressions indicated that higher N was associated with a steeper slope at 20 events/minute, $F(1,78)=11.51$, $p=.001$, $R^2=.13$, $b=.003$, $t(78)=3.39$, $p=.001$. For the 2-display task higher N was associated with a smaller slope at 12 events/minute, $F(1,77)=7.68$, $p=.007$, $R^2=.09$, $b=-.003$, $t(78)=2.77$, $p=.007$, but a steeper slope at 20 events/minute, $F(1,78)=5.47$, $p=.022$, $R^2=.07$, $b=.002$, $t(78)=2.34$, $p=.022$. Hence, the change in RT over time depends on one’s level of N and which event rate is experienced (see Figure 4).

Workload

Higher N was associated with higher global workload in the 1-display condition, $AF(1,301)=9.18$, $p=.003$, $R^2=.05$, $\Delta R^2=.04$, $b=.23$, $t(301)=3.03$, $p=.003$, the 2-display condition, $AF(1,295)=8.87$, $p=.003$, $R^2=.06$, $\Delta R^2=.05$, $b=.22$, $t(295)=2.98$, $p=.003$. Separate regressions for each event rate indicated that higher N was associated with a steeper slope in RT only in the 20 events/minute condition, $F(1,78)=7.48$, $p=.008$, $R^2=.09$, $b=-.007$, $t(78)=2.73$, $p=.008$, and at the lower event rate higher N was associated with a steeper response time (see Figure 3).
Stress

For each scale two analyses were computed, one in which the pre-task state was entered prior to the other variables and one in which it was not. For Task Engagement a significant direct effect of N was observed in the 1-display condition, \( F(1,306)=5.54, p=.05, R^2=.01, b=.04, t(306)=2.00, p=.05 \), the 2-display condition, \( F(1,301)=4.93, p=.03, R^2=.02, b=.04, t(76)=2.22, p=.03 \), and the 8-display condition, \( F(1,301)=5.86, p=.02, R^2=.05, b=.05, t(301)=2.42, p=.02 \). However, none of these effects were significant when the pre-task state was entered first into the model.

For Distress a significant event rate by N interaction was observed for the 1-display condition, \( \Delta F(3,299) = 3.22, p=.02, R^2=.22, \Delta R^2=.03 \), and a direct effect of N in the 2-display condition, \( \Delta F(1,297) = 5.51, p=.02, R^2=.22, \Delta R^2=.01, b=.04, t(297)=2.35, p=.02 \). Separate regressions for each event rate in the 1-display condition indicated that after the pre-task state had been entered into the model, N predicted higher post-task Distress at 8 events/minute, \( \Delta F(1,73) = 5.89, p=.02, R^2=.36, \Delta R^2=.05, b=.07, t(73)=2.43, p=.02 \) (see Figure 5), but not at the other event rates. Note that a significant effect of N on post-task Distress at 20 events/minute in the 1-display condition was statistically significant, \( F(1,72) = 12.51, p=.001, R^2=.15, b=.10, t(72)=3.54, p=.001 \), but was not significant when the pre-task state was entered into the model.

For Worry a main effect for N was observed across all display conditions; 1-display, \( F(1,306)=5.21, p=.02, R^2=.02, b=.06, t(306)=2.28, p=.02; 2-display, F(1,301)=11.13, p=.001, R^2=.04, b=.09, t(301)=3.34, p=.001 \); 4-display, \( F(1,306)=10.64, p=.001, R^2=.03, b=.08, t(306)=3.26, p=.001 \); and 8-display, \( F(1,301)=6.62, p=.01, R^2=.02, b=.07, t(301)=2.57, p=.01 \). However, N predicted greater Worry only in the 2-display condition after the pre-task state was accounted for in the model, \( \Delta F(1,297)=4.01, p=.05, R^2=.20, \Delta R^2=.01, b=.05, t(297)=2.00, p=.05 \).

DISCUSSION

The purpose for the present study was to investigate the extension of the maximal adaptability model to incorporate individual differences (Szalma, 2008), and to specifically examine the effects of the spatial and temporal task demands and participant Neuroticism on performance, workload, and stress. In general the results conformed to the expectations. Accuracy in performance did not vary significantly as a function of N, but workload/stress increased as a function of higher levels on this trait. This represents a performance insensitivity (Hancock, 1996), which occurs when individuals maintain performance only at the cost of greater effort. Hence individuals high in N were able to maintain their accuracy only at the cost of greater effort and strain, exhibiting a ‘hidden cost’ of performance (a ‘latent performance decrement,’ Hocky, 1997).

With respect to response time an interesting finding was that both the overall response time and change in response time over periods was sensitive to different levels of N, but the relationship of N to these variables depended on the combination of display and event rate conditions. With two displays to monitor, a lower event rate was associated with faster responding but smaller changes over time as a function of N. By contrast, at the highest event rate with two displays, response time was slower and increased more rapidly over period on watch for those higher in N.

The original maximal adaptability model of Hancock and Warm (1989) proposed that the spatial and temporal properties of tasks were important inputs for the specification of stress effects. The current study provides evidence in support of this view, but also demonstrates that the tasks (and other environmental variables), by themselves, do not determine stress response. Rather, the characteristics of the person interact with task (and other environmental) parameters to determine operator response to stress. Future research efforts in stress and performance should therefore evaluate both task and person characteristics in order to further elucidate the nature of this interactive relationship.

REFERENCES


Figure 1. The maximal adaptability model of performance under stress (after Hancock & Warm, 1989).

Figure 2. A) The maximal adaptability model incorporating hypothesized adaptive function of individuals high in Neuroticism. The vertical line labeled ‘center point’ illustrates the asymmetry in the model introduced by consideration of traits. B) Representation of the maximal adaptability model shown in (A) focusing on the hyperstress region. Note that the black curves are represent ‘normative’ patterns of adaptation, and the curves in red represent hypothesized adaptive patterns for individuals high in Neuroticism. High levels on this trait would be expected to shift the thresholds of failure (the ‘shoulders’ of the functions) lower, such that for these individuals adaptive failure occurs at lower levels of environmental demand. However, the degree of shift is not equivalent for each level of adaptation. Thus, one might expect that the normative and comfort zones to narrow to a greater degree than the zone of psychological (i.e., performance) adaptation. (after Szalma, 2008).
Figure 3. Response time to correct detections as a function of Neuroticism and event rate.

Figure 4. Slope of the change in response time to correct detections over period on watch as a function of Neuroticism and event rate.

Figure 5. Global workload as a function of Neuroticism and the number of displays to be monitored.